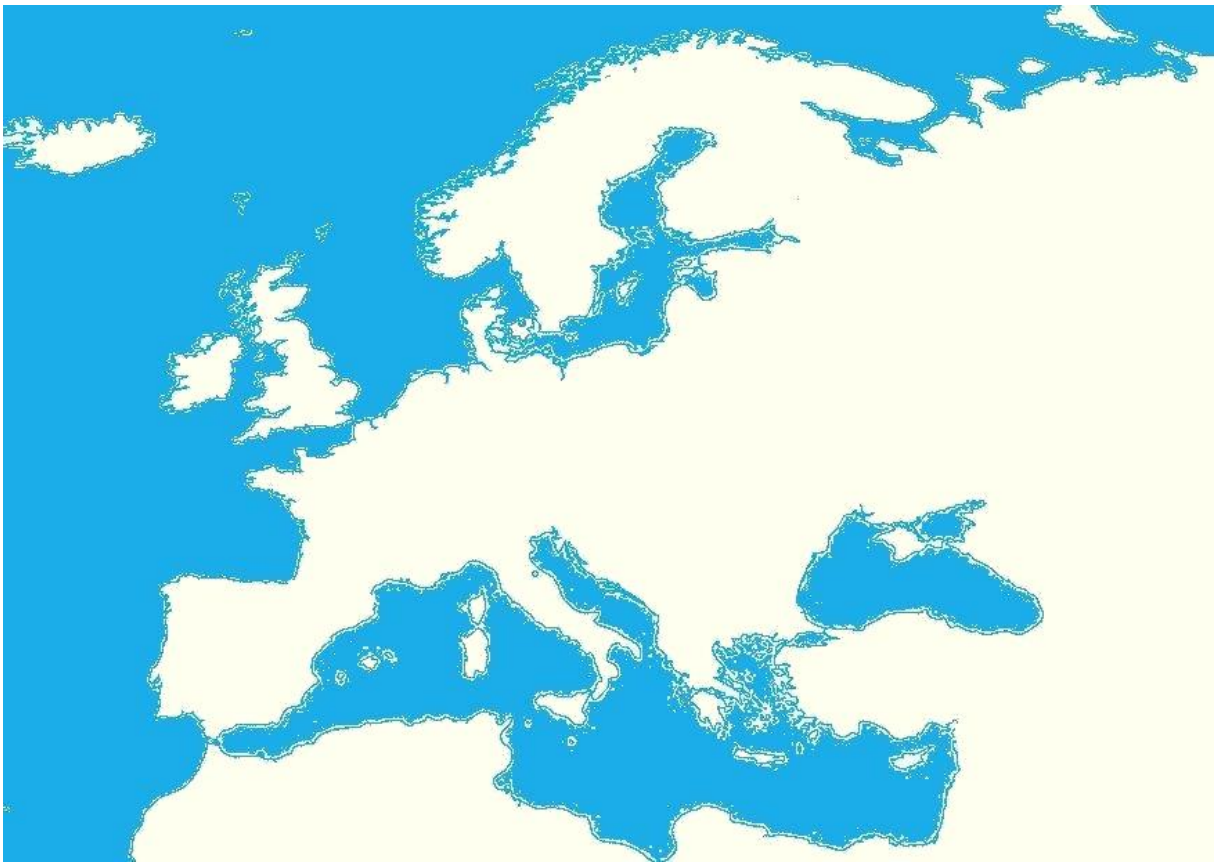

European Conference on Solar UV Monitoring

“UV Monitoring in the European Countries - Personal UV Exposure”

14. - 16. September 2022

Vienna, Austria

ABSTRACTS

(Final Version)

Aim and Scope of the conference:

The conference will provide a forum for presentations on solar UV Monitoring activities of the past, the present and for the future. This conference will also provide a forum for exchange, interrelated support and joint activities to link resources and retrieve additional value. As a significant topic of discussion, a joint visualisation of measured UV-Index values in Europe is aspired. This discussion is an item of the conference agenda.

Scientific committee of the conference:
Dr. Sebastian Lorenz, BfS (Federal Office for Radiation Protection), Germany
Dr. Michael Higlett, PHE/UKHSA (Public Health England/UK Health Security Agency), United Kingdom
Dr. Julian Gröbner, PMOD/WRC (Physikalisch-Meteorologisches Observatorium Davios / World Radiation Center), Switzerland
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University of Veterinary Medicine, Vienna

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ABSTRACTS

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Session: Personal UV Exposure

Exposed body surface area to determine the biologically effective UV radiant energy

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Abstract: Solar ultraviolet (UV) exposure of people and related health risk is mainly examined by estimating the received UV radiant exposure. However, for the estimation of several effects of this exposure like DNA-damage, vitamin D photosynthesis or the probability of developing skin cancer, the total size of exposed skin area is important, and with that UV radiant energy. In this review, methods of calculating the size of exposed body surface area (EBSA) are summarized. The total body surface area (BSA) depends mainly on the height and weight of a person as well as on body shape, gender, and ethnicity and BSA changes during life. There are obvious differences in BSA between different populations. On the South-Pacific-Islands, the BSA of people is in the order of 2.1m² on average, while in Timor-Leste it is 1.5m². Both are located at a similar latitude, so that inhabitants of the South-Pacific-Islands receive 40% higher UV radiant energy. As the EBSA depends on clothing, approaches, which quantify the EBSA by taking into account real garments, are presented. From a recent study on female clothing habits, it is shown that at an air temperature of 36°C, the EBSA of women is 6 times larger than at 18°C.

Solar Ultraviolet Radiation Risk Estimates – A Comparison of Different Action Spectra and Detector Responsivities

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Abstract: Studies assessing the dose-response relationship for human skin cancer induction by solar ultraviolet radiation (UVR) apply a range of methods to quantify relevant UVR doses, but information about the comparability of these datasets is scarce. We compared biologically weighted effectivities applying some of the most relevant UVR action spectra in order to test the ability of certain UVR detectors to mimic these biological effects at different times during the day and year. Our calculations were based on solar spectra measured at Dortmund, Germany (51.5° N). Convolutions with the CIE action spectra for erythema and non-melanoma skin cancer (NMSC) as well as with ICNIRP's weighting function showed comparable solar zenith angle (SZA) dependences with little influence of season or latitude. Calculations for a number of UVR detector responsivities gave widely discrepant absolute irradiances and doses, which were nevertheless related to those calculated with both CIE spectra by correction factors largely SZA independent. Commonly used detectors can thus provide quite accurate estimates of erythema and NMSC induction by solar UVR. [Zölzer F. and Bauer S. 2021. Solar Ultraviolet Radiation Risk Estimates – A Comparison of Different Action Spectra and Detector Responsivities. IJERPH 18(9), 4887. doi: 10.3390/ijerph18094887]

Functionalized Printable Strips for Solar UV Dosimetry as Active Part of a Device for Personal Monitoring of Cutaneous Vitamin D_3 Production

Maier-Queiroz R.(1), Vaz E.C.R.(1), Domingues T.A.L.(2), Henriques D.(2), Moura L.A.(2), Tavares T.(2), Melo L.F.M.(2), Melo S.B.(2), Santa-Cruz P.A.(1)

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Abstract: Sun exposure allows the skin to generate over 90% of the vitamin D needed by the human body, and after the current COVID-19 pandemic scenario, in which populations need to avoid exposure to reduce contamination, it will be necessary to restore levels of this vitamin, which also plays an important role in the immune system. Cutaneous production of vitamin D may be better than oral intake and can be monitored by dosimetry of solar UV radiation. In this work, we present a promising solution for personal monitoring of vitamin D production using printable UV dosimeter targets whose photonic signal is used as an input data to be converted into vitamin D personal production via software embedded in smartphones. The personal UV dosimeter is a molecular nanodevice developed by our group 20 years ago and its printable version was presented five years ago [1] with the patent issued this year [2]. In the molecular nanodosimeter, $Eu(btfa)_3 \cdot bipy$ is a photonic complex printed as a functional ink by a Drop-on-Demand materials printer to produce functional paper strips. The btfa ligands act as a UV antenna, and the bipy ligand shields the Eu^{3+} ions that produce a red luminescence at 612 nm, inversely proportional to the accumulated UV dose, by a photocleavage mechanism that mimics skin damage, with a memory effect that allows dosimetry. Here, thanks to a project approved in the Brazilian SibratecNano Program, we present the first results of a solution to use this molecular dosimeter as the active part of a device to monitor the personal cutaneous vitamin D production status through a correlation with the received ultraviolet dose. The only part of the solar spectrum that causes vitamin D formation is the UVB (280–315 nm). Reaching the skin, it photoisomerizes 7-dehydrocholesterol (7-DHC) to form pre-cholecalciferol, which is isomerized into cholecalciferol (vitamin D_3). To monitor the UVB dose for correlation with vitamin D_3 production, the photonic molecular device presented here is used to produce an input signal for calculations in a software we designed to run on a smartphone [3]. The photonic signal generated is used as input in the app to estimate the amount of vitamin D produced by the user, combining this signal with user inputs (such as clothing coverage, age, etc.), allowing a correlation between UVB dose and vitamin D_3 production through a correlation curve. We observed a wide range, up to 1000 times the MED-UVB, for~70% of luminescence quenching, showing a high resolution around MED values to monitor at the same time skin cancer risks.

[1] Sousa F.L.N. et al. Mater. Res. Express 3 045701 (2016)
[2] Santa-Cruz P.A. Patent PI1003026-3, 06 Aug. 2010, issued 21 Sept. 2021.
[3] Vaz E.C.R et al. Braz. J. Rad. Sci. 10-02A (2022), 1-16. DOI: 10.15392/bjrs.v10i2A.2032

Distribution of the solar UV exposure in the head/neck region – requirements for headgears and supplemental topical sunscreen application for skin cancer prevention

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Abstract: Introduction: The localization of 80 % of the SCCs and 90 % of the BCCs are concentrated in the head/neck region – skin areas of increased solar UV exposure. The tumour incidence differ between the skin areas of this region and furthermore between the both skin cancer entities [1]. UV exposure is a main skin cancer risk factor. The UV level should not reached one minimal erythema dose MED (for person of the skin type II-III: 1 MED means in standard erythema doses 2,5-3,5 SED). The UV exposure level of the several skin areas depends on the direction of incidence of the solar radiation to the skin.
Objectives: To compare the efficiency of skin cancer protective measures (7 headgears) in the head/neck region it is necessary to carry out detailed distribution measurements of the biological effective solar UV-exposure (in SED) vs. the uncovered, unprotected head. The results are important for recommendations to the general population (as well as for outdoor workplaces).Further questions in this connection were: Is it necessary to improve the skin protection of headgears by an additional application of topical sunscreens? In which skin areas of the head/neck region the sunscreen application is recommendable?
Materials & methods: For the skin a cosine-like angular response is assumed. Therefore the polysulfone film (PSF) as actinic UV-sensor with a good cosine response is an appropriate sensor, especially to

investigate the so-called solar terraces – the skin areas of increased skin cancer incidence. To simulate 8 hours moving under clear sky conditions 8 dummy heads were mounted on a carousel placed on top of a roof. Each dummy head was prepared with PSF-dosimeters at 14 positions – vertex of the head as reference. The 8h-exposures (9-17 MESZ) were carried out repeatedly at 3 days (for averaging) in Jul. 2018 (solar noon elevation $\square_S$ = 60° (60°-day), UVI 7) and at 3 days in Sep. 2018 ($\square_S$ = 42° (42°-day), UVI 5). To investigate the skin protective effect against the solar UV-exposure 7 heads with caps/brimmed hats in comparison to an unprotected head were exposed.
Results: Even by the use of headgears, independent on the type, the lower skin areas as chin, upper lip, cheek or the neck (front and sides) are low protected. UV-exposure levels per 8h between 7-24 SED at 60°-days or 4-12 SED at 42°-days (vs. 10-28 SED or 7-10 SED respectively for the unprotected head in this skin areas) mean multiples of the MED. In result, a given colour-coded overview compare the UV-protective efficiency at 14 positions of the several headgear models at 60°- or 42°-days.
Conclusion: Even if UV-protective headgears will be used, an additional topical skin protection has to be applied, at least below the eye line.
Acknowledgement: *)supported by the German Social Accident Insurance Institution for the building trade

[1] Lobeck et al. 2017 Hautarzt 68: 377-384

Reduction of UV exposition by wearing a hat: measurements of 5 different hat types and (their) comparison with modelling

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Solar ultraviolet radiation (UVR) can cause acute and chronic skin damage in humans as well as increase the risk of other adverse health effects. Several protective measures can be taken to reduce the skin's exposure to UVR such as wearing clothing, sunglasses, hats, or sunscreen. In the present study, the UV protective effect of five hat types was measured using UVR dosimeters attached to 15 different body parts in the head and chest area of a mannequin on a rotating platform. Measurements were taken on a clear sky day with one measurement cycle being performed for each of the five hat types, including an additional measurement cycle without a hat. The measurements were carried out at 1s intervals throughout the day, so they allow the exact determination of the received UVR dose at the different parts of the body depending on the sun azimuth and zenith angle and orientation of the mannequin. The data analysis shows, as expected, that wide-brimmed hats made of dark, tightly woven material offer the best protection against erythemal UV radiation. For the lower parts of the body, shoulders, chin and chest, UV protection is rather low with most hat types. At the end, we compare simulations performed with a simple geometric model with the measurements performed. The agreement between model results and measurements is analyzed as a function of hat type, mannequin orientation, and sun azimuth and zenith angle.

Patterns of teenagers' outdoor exposure in Spring-Autumn period during and after the first COVID-19 lockdown in 2020, Poland

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Abstract: During Erasmus ++ project, BRITEC (Bringing the Research Into the Classroom), we proposed a research "Ultraviolet radiation and vitamin D". The initial aim of this research was to assess teenagers' behavior during outdoor school trips to estimate ultraviolet personal doses, using the Citizen Science. The question was, if during such trip, children can gain the recommended dose of vitamin D and what was the risk of overexposure. The COVID-19 pandemic forced the change of our objectives. Schools were closed and from March to April 2020 the first lockdown was performed. Nevertheless, from May 2020 children were allowed to spend time outdoors. Thus, we asked participants to fill online surveys from May to September about their free time during individual outdoor activities, instead of school trips. In the surveys participants were asked about age, weight, height, skin phototype, type of activity, SPF use, but also cloudiness, time outdoors and geographical location. Surveys were

anonymous, thus we did not gather any sensitive or personal data. We managed to gather 146 surveys, from which we estimated erythemal and vitaminal doses using UV modelling, cloudiness, and other data from surveys. In 48% of surveys children exceeded 1 MED during their outdoor activities. The dose of sun-synthesized vitamin D of 1000 IU (or 2000 IU) was estimated for 77% (or 66%) of surveys. Only 13% declared to use sunscreen. Also, overexposure increases with age, i.e. from our estimates for those in the age 17-18, 72% exceeded 1 MED, while in the group of teenagers with the age 12-14, only 26%. It seems that children after their restriction to stay home during COVID-19 lockdown in 2020, tried to compensate the lack of sunlight in the following May-September period. Despite of the fact, that most of them could gain the recommended dose of vitamin D from the skin synthesis, they also had a tendency to pose a threat of overexposure on themselves.

UV-Exposure from Every Day's Live Caused by Clothing in Dependence Temperature, Gender and Age

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Clothing is one of the most important factors for solar ultraviolet (UV) exposure of people. However, there is only little information on clothing habits available. Therefore, we investigated clothing of young females in dependence of meteorological parameters during every day live. Afterwards, we applied meteorological measurements and measurements of UV radiation to calculate the relative UV exposure of different body parts. We developed a body chart, which divides the body into six sections, together with a coding scheme that describes the worn garments. Clothing of around 10000 adults were observed in the urban region of Vienna and meteorological conditions were recorded. People were divided by gender and grouped into young adults, mature adults and elderly people. Our study shows that air temperature is the most important factor, while wind speed and humidity did not show any significant influence. Therefore, we have generated frequency distributions for wearing certain garments in dependence of air temperature. Additionally, in temperatures from 10°C to 30°C, frequency of people was almost constant, but in higher temperatures, it decreased significantly. We will show the changing UV exposure of different body parts throughout one year. Clear differences in the UV exposure in dependence of age and gender will become obvious.

S e s s i o n : Q A / Q C

Calibration of the Austrian UV-Monitoring Network detectors

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Abstract: Broad band filter radiometers with a response function similar as the CIE erythemal response function are in use in national and regional monitoring networks. Experience within the Austrian UV Monitoring network, which is operational since 1998 shows the sensitivity of the broadband detectors to environmental conditions. Significant short time variations up to 10% in the absolute response may be affected by environmental temperature variations especially in case of high internal humidity, although the instruments have an internal temperature regulation. Changes in the internal relative humidity affect the spectral response up to more than 10%. Long time variations of the absolute response of up to ±20% affect the data quality in the routine operation. These variations are quite individual for each detector. The high frequency of recalibrations each year turned out to be necessary because the sensitivity of some detectors changed irregularly during operation. The applied method of absolute calibration is a combination of a laboratory characterisation of the relative spectral response function and a field characterisation of the solar erythemal irradiance. To characterise the relative spectral response a

tuneable light source, developed by CMS at the Medical University of Innsbruck is in use. The actual system consists of a 150W Xenon high pressure lamp and a DM150 Bentham double monochromator. To characterise the angular response regarding DIN5032, a specially developed cosinemeasurement facility is in use. The absolute sensitivity is calibrated in relation to a DTM300 Bentham double monochromator traceable to the Physikalisch-Technische Bundesanstalt in Germany. By applying these carefully and regular method of calibration, high quality measurement data are guaranteed. With this data investigation of short.

Towards a traceable global solar UV monitoring network

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Abstract: In view of improving the status of the solar UV measurements within the UV monitoring community, the World Calibration Center for UV (WCCUV) organised in 2017 the 2nd solar ultraviolet broadband radiometer campaign UVC-II [1,2]. After an up to three month calibration period all devices were returned to their owners including a certificate demonstrating traceability to the international system of units (SI). The calibration uncertainty of this certificate was less than 6 % for the majority of the radiometers. The deviation to the original calibration factors was analysed. From this data one can extract three components affecting the overall measurement uncertainty of solar UV measurements using broadband radiometers on different time scales: Usage of additional correction factors next to the absolute calibration factor, control of the humidity inside the device and recalibration frequency. The WMO Scientific Advisory Group for UV (WMO SAG UV) reviewed the results of the campaign and was pleased to see the large number of participants across all WMO regions. However, it also noted that the calibration factors and measurement equations used by the participating institutes not always follow the recommendations of the WMO [3] as well the sometimes scarce to non-existent recalibration frequency of the solar UV radiometers. After the campaign a questionnaire was sent to the participants of the UVC-II, in order to better capture and understand the needs of the solar UV community. The returned questionnaires were analysed and resulted in the conclusion that a follow-up solar UV broadband filter radiometer campaign (UVC-III) under the auspices of the WMO will be organised in 2022. Furthermore, a training course for the post processing of the data would help to encourage the users to use additional correction algorithm and finally that an operational measurement uncertainty estimate would help to reveal minimum achievable uncertainties of UV measurements using broadband radiometer under various conditions.

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How well do we need to measure solar UV irradiance to still be useful?

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Abstract: Solar UV irradiance measurements from broadband filter radiometers have improved considerably over the last years, as exemplified in the most recent UV intercomparison (UVC-II) in 2017 at PMOD/WRC. Currently, broadband UV radiometers can be calibrated at state of the art calibration laboratories with expanded uncertainties as small as 3% (95% coverage probability). Simultaneously, models incorporating satellite measurements are now providing high spatial resolution (0.05°) maps of solar UV irradiance from radiative transfer calculations over Europe and other areas. The solar UV

irradiance obtained from these models have improved considerably because of the much better availability of input data to the models (e.g. total column ozone, cloud information, aerosols, …). Comparisons between solar UV irradiance measurements and values from these models have shown that models have become very good at estimating clear sky values, while comparisons under overcast or broken cloud conditions remain challenging. We will discuss the limitations facing these comparisons. In this context, we will discuss the current challenges facing surface measurements of solar UV irradiance in the context of these new developments based on near realtime satellite based solar UV retrievals.

Quality assurance and Quality control of the Austrian UV monitoring network

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Abstract: Since over 20 years data of erythemally weighted UV radiation is gathered in the framework of the Austrian UV monitoring network. The sheer amount of data from 13 measurement sites distributed over Austria is valuable for scientific analysis but even more so if thoroughly checked in respect of quality. In order to assure a high quality of the data proper maintenance of the detectors is required as well as elaborated data processing followed by quality control measures. Some key points of the whole process are coordinated maintenance and annually calibration of the detectors, comparison of the gathered data to a clear sky model to eliminate outliers and analysis of timelines of the measured data as well as the calibration data to see current problems early and also to improve data quality retrospectively.

UV-monitoring network of Masaryk University, Czech Republic: data processing and evaluation

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Abstract: The UV-monitoring network of Masaryk University is operational since 2012 and consists of 3 measurement sites located in the Czech Republic (Brno, Jeseniky Mountains) and Antarctica (Mendel station). The sites are equipped with broadband UV radiometers to measure UVA and UVB irradiances, and erythemally weighted ultraviolet (EUV) irradiance that are recorded continuously at 10-minute intervals. EUV monitoring is made with UV Biometer 501A version 3 manufactured by Solar Light (USA) and UV-S-E-T radiometer from Kipp & Zonen, the Netherlands. In addition, the GUVis-3511 multi-channel filter radiometer from Biospherical Instruments (USA) is operated in Brno, allowing total ozone content and column water vapor calculation. The total ozone content is estimated using the libRadtran radiative transfer model with the GUVis-3511 radiometric data and compared with the Ozone Monitoring Instrument (OMI) satellite observations retrieved for geographical coordinates of Brno station. The daily and seasonal variation of UV irradiances as well as differences in the transmittance characteristics of the atmosphere and clouds are evaluated using cloud modification factor, nonlinear regression and radiative transfer models.

S e s s i o n : U V M o n i t o r i n g

UV radiation in Novi Sad (Serbia): UV Index monitoring and variability of high erythemal UV radiation doses

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Abstract: The UV monitoring in Novi Sad has been in operation by broadband Yankee UVB-1 biometer at the campus of the University of Novi Sad (45.33° N, 19.85° E, 84 m above sea level) since 2003. Data of UV index are taken every 30 s, averaged over 10 min intervals, and automatically saved in the database. The time series were reconstructed using an improved reconstruction technique that is based on parametric numerical model NEOPLANTA calculations of erythemal radiation and the empirical relationship between the erythemal doses and sunshine duration. In this study, we presented the maximum daily UV index values over the period 2003-2018 and the variability of reconstructed high erythemal UV doses ($_{h}UV_{ery}$) over the period 1971-2018. Additionally, the influence of low total ozone column (TOC), low cloud cover conditions, and high surface albedo on $_{h}UV_{ery}$ was analyzed on a seasonal basis. Analyzing the measurements we concluded that maximum daily values are almost the same in the period of sixteen years, in the summer months maximum values are about 9. Based on the 90th percentile of each month we assessed a set of 1691 days with $_{h}UV_{ery}$ (10.65 %). The fraction of $_{h}UV_{ery}$ days in the last two decades was considerably larger (12.29%) than in the period before (6.97%) and during (8.68%) TOC depletion. We observed a statistically significant increase in the annual number of days with $_{h}UV_{ery}$ of +6.26 days/decade ($p<0.01$). The increase was statistically significant in all seasons, except winter, while it was the most pronounced in summer (+2.44 days/decade, $p<0.01$). However, the increase was not uniform over the entire observation period. Over the period of TOC depletion (1971-1980), the number of days with $_{h}UV_{ery}$ decreased, followed by a steep significant increase over the period of TOC depletion (1981-1996) of +16.75 days per decade ($p<0.05$). After 1996 $_{h}UV_{ery}$ increased slowly (+3.19 days/decade), but the trend was not statistically significant. Considering the influence of each UV affecting factor separately, the analysis showed that low cloud cover had slightly more influence on the occurrence of $_{h}UV_{ery}$ days than TOC in all seasons except winter. Of the total number of $_{h}UV_{ery}$ days, 89.47% were recorded when the cloud cover was low, while 80.65% of $_{h}UV_{ery}$ were recorded when the TOC was low. However, the most frequent reason for $_{h}UV_{ery}$ is the combination of these two factors (75% of all $_{h}UV_{ery}$ days). In the winter season-high surface albedo influenced the appearance of 18.26% of $_{h}UV_{ery}$ days. It is important to emphasize that we analyzed the reconstructed erythemal doses, not the measured data. Reconstructed data (implying the quality of the reconstruction) provide valuable resources for insight into UV variability in the past although cannot replace measurements. The results indicate even if the TOC recovers in the 21st century as expected, the appearance of days with high erythemal doses will still be significantly affected by future changes in the cloud cover.

Monitoring of spectral UV radiation at Marambio Base, Antarctic Peninsula Region

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Abstract: UV radiation is an important component of the environment, which has both beneficial and harmful effects on organisms. Due to the recent changes in ozone layer and weather patterns, its monitoring continues to be an important task. One of the main advantages of spectral UV observations lies in the fact that they can be fitted with any action spectral curve, whether it focuses on the erythema creation, DNA damage, or vitamin D synthesis. Also, UV spectra, unlike broadband measurements, enable detailed analyses of individual parts of the spectrum, and therefore a better understanding of the solar UV radiation variability. The Czech Hydrometeorological Institute, in cooperation with the National Meteorological Service of Argentina, contributed by spectral UV radiation measurements at Marambio Base. In the period between February 2010 and January 2020, over 45 000 UV radiation spectra were collected by the B199 double monochromator Brewer spectrophotometer. More than 23 000 observations could be paired with explanatory variables, i.e. with total ozone column measured independently by the B199, cloudiness from the ERA5 reanalysis, and surface albedo at 360 nm from OMI/Aura satellite instrument. The ten years long time series allowed for assessing UV radiation variability in the individual years and months. We also studied the effects of selected explanatory variables on UV radiation at different wavelengths, and an analysis of trends was also performed. Over the 10-years period, statistically significant trends were only found in March. They could likely be explained mainly by the changes in surface albedo.

Long-term changes in erythemal UV irradiance and UV 300-380 nm in Moscow since 1968: main tendencies and their causes

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Abstract: Ozone depletion and current climate change significantly influence the solar UV radiation levels at the Earth's surface relevant for human health. There is a wide program of UV measurements at the Meteorological Observatory of Moscow State University since 1968 till nowadays. The UV measurements in the spectral range of 300-380 nm started in 1968 by a self-constructed instrument and continued by broadband UV-A YES-1 and Kipp & Zonen UV radiometers. Biologically active erythemal irradiance have been in operation since 1999 by broadband UV-B YES-1 and Kipp & Zonen UV radiometers. To maintain high quality of measurements, checking of calibration coefficients were regularly carried out against reference instruments, which, in turn, were calibrated against European standards. Measurements were also validated against the results of UV transfer model. We present the results of intercomparison between different broadband instruments. In addition, long-term interannual UV variability is studied using both measurements and reconstruction model over the period of 1968-2020. We revealed trends and temporal peculiarities of UV radiation variability; the effects of ozone, aerosol and cloudiness are discussed. Effect of cloudiness changes on UV radiation is also assessed using UV measurements in the spectral range of 300-380 nm.
This study is partially supported by grant number 075-15-2021-574.

25 years of solar UV monitoring in Dortmund, Germany – data processing and trend analysis of UV index values and daily erythemal UV dose

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Abstract: In Germany, the Federal Office for Radiation Protection operates a nationwide network for solar ultraviolet (UV) radiation monitoring in cooperation with the Federal Environment Agency, Germany's National Meteorological Service and other associated institutions such as the Federal Institute for Occupational Safety and Health with a UV measuring station in Dortmund. This UV measuring station has been providing spectrally resolved data on the solar UV irradiance from sunrise to sunset for more than 25 years. The station is equipped with a double monochromator system which is calibrated against the national standard at least once a year. For evaluation, the measured data (individual spectra from 1996 until 2021) were undergoing a strict quality assessment which includes scientific quality control and correction of the data (based on calibration and measurement system data, Fraunhofer lines comparison, etc.). If a correction of incorrect data was not possible data were masked and not used. The UV index and daily erythemal dose were calculated from the remaining data. For a trend analysis of UV Index and erythemal dose the occurring gaps in the Dortmund data set are challenging. Thus, the missing values of the daily UV index and the daily erythemal UV dose are replaced by estimated values (see talk "Imputation methods for UV monitoring data gaps" presented by F. Heinzl). In a further step monthly averages are calculated on the basis of daily values of the UV index and the erythemal UV dose. For the trend analysis we use linear models to investigate the influence of time on the monthly means of the UV index and the erythemal UV dose. Both, the trend component and the seasonal component are estimated. The covariances of the individual regression parameters are estimated flexible in order to counter the problem of correlated measurements and the problem of different levels of variance. The results of the trend analysis of UV index and daily erythemal UV dose and the statistical significances will be presented and discussed in this task.

UV Index monitoring: locally by FMI's ground-based radiometers and globally by TROPOMI and GOME-2 satellite instruments

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Abstract: We present UV index monitoring activities by the Finnish Meteorological Institute (FMI) based on ground-based measurements and satellite retrievals. FMI's operational UV monitoring network includes 7 sites where UV indices are measured with broadband SL501A radiometers. In addition, UV indices are determined by two spectroradiometers. FMI is responsible for three satellite-derived UV products that include UV index as a parameter: 1) The EUMETSAT Offline UV dataset, which is generated in the framework of the Satellite Application Facility on Atmospheric Composition Monitoring (AC SAF) (acsaf.org); 2) the OMI UV product, which uses the measurements of the Ozone Monitoring Instrument aboard the NASA EOS-Aura satellite launched in 2004 (sampo.fmi.fi and avdc.gsfc.nasa.gov); and 3) the TROPOMI UV product, which uses measurements of the Tropospheric Ozone Monitoring Instrument (TROPOMI) aboard the Copernicus Sentinel-5 precursor (S5P) satellite launched in 2017 (nsdc.fmi.fi/data/data_s5puv.php). FMI also measures the UV index at Marambio, Antarctica, in collaboration with Servicio Meteorológico Nacional Argentina (fmiarc.fmi.fi/sub_sites/GUVant/). We show recent results of FMI's UV index measurements in Sodankylä, 67°N, and Marambio, 64°S. The year 2020 was exceptional at the two sites in terms of the effect of polar ozone loss on surface UV radiation. Unusually large relative anomalies in UV radiation were observed at Sodankylä on 6 April 2020 and at Marambio in the beginning of December 2020. We further summarize results of the validation of the satellite-derived UV products 1 and 3. In total, the TROPOMI surface UV radiation product includes 36 UV parameters and quality information. Ground-based data from 25 sites located in Arctic, subarctic, temperate, equatorial and Antarctic regions were used for validation. For most sites, 60%–80% of TROPOMI data are within ±20% of the ground-based data for snow-free surface conditions. The relative differences between daily UV doses measured by instruments on the ground and TROPOMI were within ±10 % and ±5 % at two-thirds and at half of the sites, respectively. The AC SAF UV Data Record R1 products (OUV RECO) were compared with ground-based measurements from 30 sites for the period 2007–2017. The OUV RECO datasets include daily doses and maximum dose rates of UV-B and UV-A radiation, UV data for several biological weightings, plus the UV index at solar noon, error estimates, and quality control flags. For daily UV doses, the relative differences to ground-based measurements is less than or equal to 10% at 23 of the 30 sites. The average of the medians of all stations, excluding two Antarctic sites, was –1.20%. At high latitudes where non-homogeneous topography and albedo or snow conditions occurs, challenges in discriminating snow and clouds still exist in satellite-derived UV data.

The Solar UV-VIS Spectral Irradiance Measurements. Overview of Recent Space and Ground-based Activities from Belgium

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Abstract: BIRA-IASB contributes since the 90's to the monitoring of UV-VIS Solar Spectral Irradiance (SSI) using instrumentation for ground-based as well as Top-Of-Atmosphere (TOA) measurements. The 90's were characterized by the first impulses for an accurate climatology of global UV-VIS irradiance measurements and BIRA-IASB participated deeply in these campaigns. It was followed by the development of a Belgian monitoring network performing spectral and broadband measurements, namely to measure the UV index (UVi). UV instruments are installed in Antarctica at the Princess Elisabeth Antarctica station to monitor the typically high UVi due to ozone layer depletion. BIRA-IASB aims to contribute to new EU project (EURAMET) involving solar UV measurements, in parallel with a new impulse for the Belgian network (for acquisition and data processing). The UVi network instruments for both spectral and broadband solar measurements are characterized and calibrated at BIRA-IASB whose radiometric laboratory (B.RCLab) is being developed to become a reference for radiometry in Belgium, in close collaboration with metrology federal services. Concerning space activities, BIRA-IASB was deeply involved in the 9-year SOLAR/SOLSPEC mission on the International Space Station that delivered reference solar spectra in the UV-VIS and NIR. The outcome of the heritage of this French

and Belgian collaboration is the involvement for radiometric characterization and calibration of a new 2-Unit CubeSat designed for Earth Energy balance and solar UV irradiance studies.

UV erythemal and vitamin D retrieval from surface-based and satellite measurements and UVIOS nowcasting model simulations for Athens, Greece

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Abstract: Important biological processes (e.g. Erythema and Vitamin D production) depend on solar spectral UV radiation. Commonly used Indices that quantify those process are UV Index (UVI) and Vitamin D effective dose (VitD) that depend on the attenuation of spectral UV irradiance at specific spectral bands. For now casting and forecasting purposes they are commonly estimated by radiative transfer modelling which includes assumptions of the atmospheric transmittance. The use of spectral measurements in complex atmospheric conditions provide an opportunity to assess the validity of the assumptions and the accuracy of the estimations. We focus on an 12 month period (2020-2021) of measurements in Athens, Greece. Quality Assured Surface spectral measurements from Brewer spectrophotometer and a Precision Spectral Radiometer (PSR) are used to retrieve both indices. PSR measures Global Horizontal spectral Irradiance at 1020 spectral channels in the region 300-1020nm. The instruments are installed in the center of Athens. In addition, UVI from the Ozone Monitoring Instrument (OMI) on board of Aura satellite and for both UVI and VitD multi-satellite based products derived from the Tropospheric Emission Monitoring Internet Service (TEMIS) are assessed. These datasets provide one value per day, either on the satellite overpass or the daily maximum, hence the comparison with the ground based measurements is performed accordingly. Finally, UVIOS (UV-Index Operating System) is a novel nowcasting UV retrieval model that exploits the synergy of radiative transfer models with high-performance computing, cloud information from satellites and other atmospheric parameters from the Copernicus Atmospheric Monitoring Service. The UVIOS output is the UVI at high spatial and temporal resolution (5 km and 15 min, respectively)) in real time. For the present study the output for the grid point of interest, is linearly interpolated at the moments of PSR and Brewer measurements in order to make a valid comparison. Especially focusing on the effects of ozone and cloud and aerosol optical properties in the retrieval of UVI and VitD.

S e s s i o n : F i l l t h e g a p

Imputation methods for UV monitoring data gaps

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Abstract: One of the challenges that the German solar UV monitoring network faces in measuring ground-level solar UV radiation is the permanent and gap-free data collection over a long time period. Over this long measurement period, data gaps can occur due to incorrect and therefore discarded measurements, maintenance or longer downtimes of the measurement systems. These data gaps can lead to incorrect conclusions in the further data evaluation and trend analysis of UV data. To close the gaps of UV data (UV index and the erythema dose), we have developed three imputation methods that enable us to close these data gaps in a practical way, which are briefly mentioned here:
1. Average-based imputation: The missing daily values are statistically estimated via averaging of UV data. The averaging was performed for each day of the gap with available UV data from all other years on the similar date and with available UV data from the days directly before and after the day. The considered number of days before and after the gap was optimized.

2. Model-based imputation: An additive model is estimated to explain the impact of global solar radiation and TOC (total ozone column) on UV data. For this purpose, the days on which information on these variables is available are used. The model is then used to estimate missing daily values of UV data.
3. Mixed imputation: Here we use the method *model-based imputation.* If this is not possible for individual days due to missing information on global solar radiation or TOC we use *average-based imputation*.
The three imputation methods are developed and validated using selected data sets from the UV station of the Federal Institute for Occupational Safety and Health (BAuA) in Dortmund, Germany, and another data set from a Belgian station in Uccle. A comparison of the three methods will be presented and the advantages and disadvantages will be discussed in the talk. An application of the method for an improved trend analysis will be presented in the talk "25 years of solar UV monitoring in Dortmund, Germany – data processing and trend analysis of UV index values and daily erythemal UV dose" by S. Lorenz.

A near real-time UV-Index map for Europe

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Abstract: The website www.uv-index.at provides near real-time maps of UV Index covering the area between 12.5°W and 42.5°E longitude as well as 33°N and 72°N latitude. The spatial resolution of the grid before projection is less than 1 km. The maps are updated every 15 Minutes with a delay of 30 Minutes. A time lapse of the maps of the current day is also available. In order to be able to calculate the underlying clear sky map in a reasonable time a big interpolation table was calculated using libRadtran. The input parameters for the clear sky map are taken from the latest available run of the NOAA GFS forecast for noon. The clear sky maps calculated in this way are modified by a cloud attenuation factor derived from Meteosat Second Generation data yielding the maps shown at www.uv-index.at. In the talk, the technical challenges of the operational generation of these maps will be discussed.

Session: Models, Forecast and Input

Improving albedo in UV forecasts

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Abstract: In the Austrian UV network, we not only measure UV radiation, but also provide a clear sky model calculation for the current day, as well as a UV "nowcast" in the form of maps of Austria and Europe which take current cloud conditions into account. From comparing several years of measurements to the clear sky model, discrepancies seem to be more pronounced in winter, which indicates snowfall and corresponding changes in surface albedo as a source of error. In the Alpine region additional complications arise from the complex surface as the effective albedo is influenced by the surrounding topography. We therefore attempt to retrieve albedo information from UV measurements and satellite data in order to get a more accurate input value for the clear sky model.

All-sky radiative transfer modelling in the Aosta Valley region in the frame of the SOUVENIR project

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Abstract: The SOUVENIR (SOlar UV Extensive Network for Information and Reporting) project, funded by Fondazione CRT, aims at a better dissemination of the global solar ultraviolet (UV) Index in the Aosta Valley region, in the north-western Italian Alps. UV radiation has been monitored there since 2004, with high-quality traceable measurements starting in 2006. With the purpose of identifying the best strategy to raise public awareness on this topic, a network of experts has been created involving researchers in the technical-scientific (atmospheric physics, meteorology), medical (dermatology) and socio-psychological (risk communication) disciplines. One of the milestones of the project on a technical/scientific level is the refinement of the current radiative transfer modelling chain used to forecast the UV index for the next days. In particular, the new approach is based on an improved daily climatology of surface albedo and aerosol amount and properties, obtained from both direct and ancillary measurements, and then given as input to the radiative transfer model (libRadtran). We first validate this method in clear-sky conditions, by comparing simulations and measurements at the three monitoring sites (Saint-Christophe, semi-urban site, 570 m a.s.l.; La Thuile, mountain site, 1640 m a.s.l.; Plateau Rosa, glacier, 3500 m a.s.l.). About 50 cloudless cases are appropriately chosen in the period 2017-2021, based on sky-camera pictures, vertical profiles from a ceilometer, and short-wave/long-wave downward irradiances. In the selected days, the new modelling chain provides estimates within ±1 UV index at every station compared to the measurements, even on a complex topography such as the one in the Alps. Once the algorithm is validated in the clear-sky case, the effect of the cloud fields from numerical weather prediction models is introduced. Several strategies to account for clouds in the UV Index forecast are discussed and evaluated. The output from the chosen method, consistent with the weather predictions from the local bureau of meteorology, is then disseminated to the public, together with the respective clear-sky estimate (according to the WMO/WHO guidelines).

S e s s i o n : I n s t r u m e n t s

Self-sustaining UV Index sensor node

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Abstract: We present a self-sustaining UV Index sensor node. It is based on the well-proven UV-Index probe „sglux ERYCA“ which is embedded into a solar powered cellular network infrastructure.
The system contains of:

- A calibrated sglux ERYCA probe with a measurement range of UVI 0 to 30 and an output voltage range of 0 to 10 volts. This sensor shows a spectral response with excellent reproduction of the erythema action spectrum according to ISO 17166:2019.
- An IoT module with data acquisition, energy management and data transmission unit. This module digitises the measurement signal and transmits it to a server via the mobile phone network when there is a change or at regular intervals. The MQTT protocol is used here, which means that almost any IoT infrastructure can be used on the receiving side. In addition, the energy generation from the solar cell is controlled and used to charge the integrated battery, which is able to maintain operation for several days of insufficient solar radiation.
- A 10 W solar panel for autonomous energy supply. Thus the system can provide UVI monitoring in areas were no infrastructure is available except mobile radio coverage.
- Adjustable clamps to attach the UVI-Transmitter to various posts or railings.

In the first part of the contribution we focus on the data collection and transmission via the MQTT protocol to a user cloud service and finally to a database as well as the methods to minimize the data transmission volume and the power consumption.
In the second part we discuss the UVI monitoring data obtained within the last 2 years.
1. Data collection and transmission
sglux UVI-transmitter is equipped with a GSM/LTE modem and comes with 10 years data plan by a service provider offering nearly worldwide mobile data coverage. The IoT-module acquires data from the UVI probe using a smart algorithm which activates the sensor only during a measurement. In case of an interrupted mobile data connection the measured values are buffered in the IoT module and are re-send after reconnection. In addition, the energy harvesting from the solar panel is controlled by the IoT module. The data is transmitted via TLS-secured connection to a MQTT-server. The measurement

data as well as multiple status information are transmitted as JSON-encoded strings. Transmission intervals are independent for measurements and status data to reduce the number of transmissions. Finally all data can be accumulated in any conventional database or sophisticated cloud platforms at will.

2. UVI monitoring data Berlin 2020 – 2021

On the roof of sglux headquarters in Berlin, Germany a UVI-Transmitter acquires data since February 2020 without any major interruptions. Comparing the UVI maximum from satellite data and the UVI-Transmitter on a day-by-day basis yield in a good agreement and shows the main advantage of a local measurement as clouds are detected correctly. The accuracy of the system was evaluated by comparing data to spectroradiometer measurements between 11:00 and 15:00 during a typical sunny day resulting in a very good agreement

Session: UV Index for the Public

The Austrian UV measurement and research project: New developments, insights and future plans

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Abstract: Even 20 years after the establishment and continuous development of the Austrian UV monitoring Network, technological advancements and the growing time series of UV index data allow ongoing structural improvements and new insights. I will give an overview of recent developments in data infrastructure, processing and visualization tools, and show how these can lead to e.g. improved understanding of detector characteristics and support data quality control as well as assessing radiative transfer model performance. I will also introduce the prototype of the new project webpage, including the new UV index map of Europe, and discuss general principles and issues regarding the visualization and communication of the UV index. Finally, I will give a rough sketch of the project's future road map.

A Satellite-Derived High-Resolution UV Climatology for Public Health

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Abstract: Ground UV irradiance is used as a proxy for estimating the potential risk of health outcomes, such as skin cancer, particularly due to the lack of dosimetric data at population level. Related public health or epidemiological studies require country-scale and long-term datasets realistically representing the UV irradiance variability, as different outcomes (vitamin D, non-melanoma skin cancer, melanoma…) are usually associated with different temporal exposure patterns. Available UV irradiance datasets should thus include a high spatial resolution adequately resolving topographic effects and a high temporal resolution establishing the irradiance variation during the day. Additionally, their accuracy needs to be determined via validation with ground measurements. We present such a UV climatology established for Switzerland with a dedicated algorithm [1]. This algorithm uses large-scale datasets as input, typically from the ECMWF, EUMETSAT or CAMS, to infer surface irradiance. This allows for the influence of the most important parameters to be accounted for, such as total ozone column, cloud and aerosol optical properties and surface albedo. We calculated the global UV erythemal irradiance at a spatial resolution of 1-2km and an hourly temporal resolution over the period 2004-2020. Ground UV measurements from three meteorological stations were used to validate the climatology over the whole period. For clear-sky data, an accuracy of the order of ±10% is obtained, while for all-sky data the expanded uncertainty varies between about ±0.5 UVI for low UVI (~1) and about 20% for high UVI (>6). This climatology is a versatile data source for public health whose value was enhanced with mapping

and analysis tools made publicly available (https://meteoswiss.github.io/python-TAMER). Beyond the computation of historic distributions of UV irradiance for any spatiotemporal aggregations within data bounds, the temporal resolution of the data allows for the incorporation of hourly exposure schedules in the estimation of UV doses. Additionally, exposure ratio information can increase the specificity of UV dose estimations by considering different postures and body parts. The data and the accompanying toolset can be easily used, for example, to estimate the statistical distributions of daily UV doses for school children across Switzerland, the probability of sunburn during the ski season, or the cumulative UV dose of outdoor workers over a multi-year period. These are just a fraction of the many potential research avenues this dataset presents [2].

[1] Vuilleumier et al., 2021, doi:10.1016/j.envint.2020.106177

[2] Harris et al., 2021, doi: 10.3390/atmos12020268

Subverting the UV index to balance public health messaging across the globe

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Abstract: The UV index was designed to inform the public about the solar UV irradiance, specifically the erythema-effective radiation. Its colour-coded warnings of sunburn are predicated on a white-skinned person. However, the risk to some communities is not too much solar UV exposure but too little, raising the risk of vitamin D deficiency and associated health impacts. The erythema-effective and vitamin D-effective UV are not identical, and the relationship between the two is non-linear, so spectral measurements provide the most robust conversion from one biologically weighted measure to another. Nonetheless, a conversion matrix can provide a good approximation to the full biological weighting conversion, and then the hard-won public understanding of the UV index could be used for much broader health messaging. The measure of vitamin D status is serum 25-hydroxyvitamin D (25OHD). A dose response for UV-25OHD has been developed based on short, frequent exposures to UV radiation. Translating this into public health guidance requires knowledge of the local UV climatology, as well as other climate factors, local culture and dress, and a skin-type dependent adjustment. Here we provide examples of how the UVI could be used to help apply our understanding of balancing UV risks and benefits, illustrating the steps required to finesse the message for different climates and populations.

2. POSTER PRESENTATIONS

A) ENVIRONMENTAL UV RADIATION

Instruments

Stray-light characterization of a StellarNet CCD Array Spectrometer using filters

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Abstract: CCD array spectroradiometers measure radiation over a wide range of wavelengths covering the complete solar spectrum. Recently, these instruments have experienced a notable development and their applications in meteorology research have specially increased. In fact, they are becoming more and more popular as a reliable alternative for the highly demanding scanning spectroradiometers. However, these new instruments present some drawbacks which must be addressed before being used as standard instruments. For instance, the measurements of the solar ultraviolet (UV) spectra is limited by the stray light coming from other wavelengths. Additionally, they present a dark current which varies with the temperature changes of the instrument. The latter can be sorted out in two ways: by stabilizing the temperature of the spectrometer or by measuring its dark current just before or after each measurement. Different solutions have been proposed to overcome this drawback. In this study, a 400 nm long pass filter has been used as a first approach to estimate the stray-light of a StellarNet Black-Comet CXR-50, which has been recently installed at INTA – "El Arenosillo" Sounding Station in Huelva (Spain). The filter has been placed after the spectroradiometer entrance slit in a filter wheel designed specifically for this purpose. This filter wheel is moved with a servo motor to allow three different positions: open, closed and filter. The open position allows light to enter undisturbed, the closed position blocks the entrance to measure dark signal, and the filter position interposes a low-pass filter that blocks UV light, allowing the estimation of stray light in the UV region.
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Preliminary comparison of UV AvaSpec-2048 CCD Array Spectroradiometers with Brewer #150

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Abstract: The Brewer spectrophotometer has been the World Meteorological Organisation (WMO) Global Atmosphere Watch (GAW) standard for Stratospheric Ozone Measurement since 1988. This scanning spectrometer also measures UV spectral irradiance. Since it is very expensive and labor-intensive, the use of more affordable spectrometers has increased in the last decades. An interesting alternative is to use CCD array based spectroradiometers, which can offer high-quality spectral measurements. To guarantee this quality, a previous characterization and calibration must be performed. The radiometric station deployed in Badajoz by the research group AIRE of the Universidad de Extremadura (Spain) has been equipped with two UV Avantes AvaSpec-2048 CCD arrays spectroradiometers. In order to address their performance, a preliminary comparison between each UV Avantes and the double monochromator Brewer #150 has been conducted at the El Arenosillo Atmospheric Sounding Station, located in Mazagón, Huelva (Spain). Spectral solar UV irradiance has been measured with a temporal resolution of 30 minutes with the Brewer #150 and a temporal resolution of 1 minute with each Avantes. These measurements have been taken within two campaigns: autumn 2021 (October 2021) and spring 2022 (May 2022). Avantes spectra have been calibrated against a POMD-WRC-calibrated 1000W lamp. The Avantes/Brewer ratio has been calculated for specific zenith angles between 20° and 80°, and 5 nm-wide wavelength bands centred at 310, 320, 340 and 350 nm. Results for each campaign and each Avantes show a ratio greater than 1, being approximately constant for zenith angles below 65° and wavelengths between 300 nm and 360 nm. This ratio increases abruptly with the zenith angle over 65° and for wavelengths shorter than 300 nm. These results indicate a clear overestimation for Avantes, which should be corrected. For future comparisons, a longer period of time will be used and the Avantes calibration will be improved.
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Experimental characterisation of the linearity in UV-VIS AvaSpec-2048 CCD Array Spectroradiometers

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Abstract: Solar ultraviolet (UV) radiation has notably increased at Earth's surface due to ozone depletion. This radiation affects many biological and photochemical processes of living beings, so its study is of great importance for a variety of fields. Long-term exposure of humans to UV radiation may be detrimental, inducing skin cancer, cataracts and weakening of the immune system. As it is located in mid latitudes, Extremadura is a region with very high UV levels, mainly around the summer solstice, so it is an interesting place for UV studies. Therefore, the radiometric station of the Universidad de Extremadura in Badajoz has been equipped with two UV Avantes AvaSpec-2048 CCD arrays spectroradiometers, hereinafter identified as UV13 and UV14, which will provide spectral information. These instruments provide measurements from 280 nm to 440 nm by steps of around 0.08 nm. In order to meet the required quality, CCD array spectrometers must be thoroughly characterised. One of the most important aspects to be measured is the linearity with respect to integration time and irradiance. Deviations from a linear behaviour may result in UV irradiance underestimation or overestimation, which can lead to significant uncertainties as the UV radiation has a low intensity. To conduct the linearity characterization of the Avantes, some experiments were performed in the INTA/ESAt radiometric laboratory at El Arenosillo (Huelva, Spain) in November 2021 and May 2022. To that aim, the irradiance emitted by an ultra-stabilized 1000 W lamp was measured using integration times ranging from 1 s to 14 s at several distances between 25 cm and 60 cm. Dark signal was subtracted from the spectra and linear regression analyses were performed to check the linear response to the integration time and irradiance. These regression analyses yielded R-squared values higher than 0.95 and relative MAE below 3%. According to these results, both spectroradiometers showed a linear behaviour with integration time and irradiance within their whole counts range.
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Calibration of Erythemal Weighted Broadband Meters for Other Photobiological Endpoints – The UV-Biometer

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Abstract: Erythemal weighted broadband meters (EBM) are widely used to monitor erythemally effective irradiance. We picked up the idea to make use of different EBMs as "UV-Biometer", to gain measured values for other photobiological effects based on calibration and conversion factors. With the availability of the action spectra for the complete ultraviolet (UV) wavelength range as precondition, we decided to calculate these factors for following effects: non-melanoma skin cancer, DNA-damage, clearing for psoriasis, ICNIRP's workers protection, persistent pigmentation and skin aging. Additionally the effect of missing values within the UV-A range is estimated using the action spectrum for vitamin D photosynthesis. Altogether nine different types of broadband meters were analyzed, and calibration factors were calculated in dependence of total ozone (100 DU to 600 DU) and solar elevation (0°to 90°). Calibration for all effects was applied to a broadband meter within the Austrian UV-Index network. As most of these action spectra have threshold limit values or minimum dose equivalents, irradiance was converted into threshold exposure times. Uncertainties from total ozone during routine operation are estimated. Furthermore, we derived factors to convert erythemally effective irradiance to the respective effects, which establishes an easy way to obtain data without taking a closer look on the instrument, when it is proper calibrated for erythemally effective irradiance. The calibration and conversion factors

can deliver consistent values effects, but should not be applied to all of the EBMs and effects listed above.

M e a s u r e m e n t s

Time series intercomparison of total column ozone and aerosol optical depth data as measured by a SolarSIM-D2 multi-filter radiometer, Brewer spectrophotometer, SP02 sunphotometer and LI-1800 spectroradiometer

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Abstract: Spectral instruments can be used to monitor critical atmospheric constituents, such as the aerosol optical depth (AOD), total column ozone, and precipitable water vapour content. For example, SolarSIM-D2 is a multi-channel radiometer that samples spectral irradiance in several wavelengths bands then uses radiative transfer models to determine the aforementioned atmospheric transmittances and the resulting spectral irradiance distribution of direct normal irradiance. Because it is a relatively newly developed radiometer, no long instrument history is available, so each study of its behaviour can provide additional information to the present knowledge. Therefore, in this study we investigate the accuracy of SolarSIM's measurands, namely the AOD and total column ozone retrieval, as compared to co-located reference instrumentation at the Budapest observatory of the Hungarian Meteorological Service. In this poster, results of a comparison of total column ozone values as measured by a SolarSIM-D2 and the Brewer double monochrometer spectrophotometer No. 152 are presented and discussed for the 2017-2021 period. We investigate the relative errors between the instruments for various atmospheric conditions. Furthermore, a comparison of AOD data is also studied for three instruments (a SolarSIM-D2, a SP02 sunphotometer and an old LI-1800 monochrometer spectroradiometer). The latter study was done for a short period due to a malfunction of reference instrumentation. The results demonstrate that the SolarSIM-D2 performs at the accuracy level specified by the manufacturer.

Total ozone column estimation from global UV spectral irradiance measurements of a BTS array spectroradiometer

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Abstract: The discovery of the stratospheric ozone depletion in the 1980s led to renewed interest in its measure. To monitor long-term trends, as well as to determine the complete ozone layer recovery, satellite and reference ground-based instruments (Dobson and Brewers spectrophotometers) were developed. Nevertheless, these ground-based references are both expensive and high-maintenance, hindering the growth of global ground-based measuring networks. As an alternative to Brewer and Dobson spectrophotometers, array spectroradiometers, based on CCDs, could be used to complement the actual ozone data sets. Total ozone column (TOC) values can be derived from global ultraviolet (UV) spectral measurements by comparing the ratio of two nearby wavelengths, which are differently absorbed by ozone, against ratios simulated with a radiative transfer model. However, to carry out the above-mentioned procedure, there is no consensus about which pair of wavelengths should be chosen. Additionally, in the case of spectroradiometers, there is available information on several wavelengths. Therefore, in this study, different wavelengths have been essayed to derive the TOC estimations obtained from the BTS-2048-UV-S-WP array spectroradiometer, developed by Gigahertz-Optik. Likewise, these values have been compared against reference ones, obtained from direct solar measurements, provided by the Brewer MK-III doublemonochromator spectrophotometer No. 150. The

two instruments were compared at INTA/El Arenosillo site (Latitude 37.10 N, Longitude 6.73 W) from 5 July to 15 July 2021.
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Total ozone and aerosol influence on local UV index variability

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Abstract: Clear-sky UV index (UVI) is mainly influenced by total ozone and aerosol variability at particular place. The UVI forecast model used in the Slovak Hydrometeorological Institute does not reflect the aerosol impact on the clear-sky UVI. The study provides analysis of relations between measured total ozone, aerosol optical depth in visible and UV range of the spectrum and the clear-sky UVI data. Improvement of the UVI forecast quality after AOD addition to predictive parameters of the simple modified Canadian model of the UVI is investigated. Five years (2015 - 2020) of global UV irradiance and total ozone measurements by the Brewer spectrophotometer and the AOD determined by the sun photometer involved in the AERONET project are used for the analysis performed for the Poprad-Gánovce station data (49.03N; 20.32E; 706 m).
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Preliminary results of total ozone and UV radiation measurements in Brno, Czech Republic

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Abstract: Ultraviolet (UV) radiation is a relatively small portion of the total solar radiation reaching the Earth's surface. Even so, UV radiation has some beneficial but also harmful effects on living organisms including humans. Nowadays, in the context of unprecedently large Arctic ozone depletion in March/April 2020, UV radiation monitoring is crucial for both research teams and the general public. The aim of this study is to analyse the total ozone column (TOC) and the erythemal ultraviolet (EUV) radiation measurements, which have been performed in Brno in 2020. Solar UV radiation monitoring was carried out by two instruments: the 501A version 3 broadband UV Biometer manufactured by Solar Light (USA), and the GUVis-3511 multi-channel filter radiometer from Biospherical Instruments (USA). The second one is in a parallel operation since July 2019. EUV data from the 501A UV Biometer were measured every 5 s and recorded as 1-min averaged values, while the GUVis-3511 radiometer was operating at 10 Hz sampling interval and data were processed through the 1-min intervals. The ozone content was estimated using the libRadtran radiative transfer model with the GUVis-3511 radiometer data. For the TOC calculation, the ratios of spectral intensities at ozone-absorbing (313 nm) and non-absorbing (340 nm) wavelengths were used. The ground-based TOC, obtained this way, was further compared with satellite retrievals from the Ozone Monitoring Instrument (OMI) satellite data for the geographical coordinates of the Brno station. We also analysed daily and seasonal variation of EUV radiation and TOC from the available data sources, and we studied the differences in transmittance characteristics of the atmosphere and clouds during the year.

Comparison of erythemal UV radiation and total ozone column during spring 2019 and 2020 in central Svalbard, Arctic

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Abstract: Solar ultraviolet (UV) radiation is a form of electromagnetic flux reaching the Earth's surface, which can have both beneficial and harmful effect on living organism. Variations in erythemal UV radiation and ozone over the Arctic has already been discussed, but as 2020 shows, the recent decrease of the Arctic ozone is becoming a very important research task. The intensity of erythemal UV radiation depends on the ozone content, clouds and aerosol amount. The variability of total ozone column over the Arctic is caused by specific stratospheric circulation, referred to as the polar vortex, which differs from year to year. During strong stratospheric circulation, a large-scale depletion of ozone can occur. The aim of this contributions is to compare and evaluate relationship between total ozone column and erythemal UV radiation in the two consecutive years, 2019 and 2020. The satellite and ground-based measurements available for the Longyearbyen station (78°13′N 15°38′E) were used to assess total ozone and erythemal UV radiation in the Svalbard archipelago. Ground-based observations were carried out using the UVS-E-T Kipp&Zonen radiometer at the 1-min storing interval. The NCEP/NCAR reanalysis data were used to assess the atmospheric circulation at the 50 and 10 hPa pressure levels over the Arctic region. We have found that total ozone column suddenly dropped below 220 DU over the Western Canada during unusually strong and persistent polar vortex. The ozone depletion has also been observed in central Svalbard in the period of 30 March to 18 April 2020. In spring 2020 at Longyearbyen, the ozone amount decreased by almost a half compared to 2019. In this context, we have detected a twice as high increase in erythemal UV doses in spring 2020 than in 2019.

Monitoring of solar spectral and broadband ultraviolet irradiance in Aosta, Italy: recent advances

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Abstract: Spectral and broadband measurements of solar ultraviolet (UV) radiation in the Aosta Valley, a pristine Italian mountain region in the north-western Alps (mean altitude >2000 m a.s.l.), were launched in 2004, and the traceability chain and QA-QC procedures became fully operational since 2006. The network, managed by the local Environmental Protection Agency, is based on a double-monochromator spectroradiometer (Bentham DTMc300), located in Saint-Christophe (45.742°N, 7.357°E, 570 m a.s.l., WIGOS ID 0-380-5-1, semi-urban site) and routinely monitoring solar global irradiance in the range 290-500 nm every 15'. Three UV broadband radiometers (two Kipp&Zonen UV-S-AE-T and one Yankee Environmental System UVB-1) are also deployed at Saint-Christophe, La Thuile (1640 m a.s.l, mountain station) and Plateau Rosa (3500 m a.s.l., glacier). Recently, the spectral UV dataset of Aosta–Saint-Christophe has been re-evaluated and homogenised to account for the effect of temperature of the diffuser and for calibration problems and changes in the calibration scale. The final spectra (“level 2”) constitute one of the most accurate datasets globally. For the present contribution, we additionally re-evaluate the series from the three broadband stations on the basis of past comparisons regularly performed (every year) with the reference spectroradiometer, and consistently with the new “level 2” data now available from this instrument. The outcomes of such comparisons are shown and some considerations are made about the degree of agreement among all instruments, the stability of the broadband radiometers, and the sensitivity of the calibration matrix to the environmental characteristics of the site of calibration/operation. The performances of the new SUV-E digital radiometers, included in the network lately in view of a progressive replacement, and increasingly used at many sites all over Europe, are discussed. The resulting broadband datasets, together with their corresponding uncertainties, are presented and are employed to illustrate the altitude effect, the seasonal cycle of UV irradiance and its main influencing factors in the investigated area.

Variability and trends of the surface solar spectral ultraviolet irradiance in Italy

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Abstract: Ozone depletion in the 1980s and 1990s raised public awareness in the detrimental consequences of very low stratospheric ozone concentrations and the high levels of surface solar UV radiation potentially reaching the surface. Since the mid -1990s the ozone depletion has been decelerated and the first signs of recovery are encouraging sign. However, according to the results of several studies, in the last two decades changes in climate and air quality were even more decisive for changes in the levels of surface UV irradiance over many regions worldwide. High quality measurements of the surface solar spectral UV irradiance as well as other atmospheric parameters affecting it are of key significance for the accurate detection, quantification and attribution of such changes. Long series of high-quality continuous measurements of the surface solar spectral UV irradiance are available at three different sites in Italy covering the whole latitudinal extent of the Italian territory: Aosta (45.7° N, 7.4° E, 570 m a.s.l.), Rome (41.9° N, 12.5° E, 75 m a.s.l.), and Lampedusa (35.5° N, 12.6° E, 50 m a.s.l.). The spectral UV and total ozone series are analysed for all three sites for the period 2006 – 2020. For Rome the series are also analysed for the period 1996 – 2020. Series of the Geopotential Height (GPH) at 250 HPa are analysed for the same periods. Significant anticorrelation between monthly anomalies of GPH at 250 hPa and total ozone, and significant correlation between the 250 hPa GPH and the UV irradiance at 307.5 nm was found for all sites. The correlation among the GPH monthly anomalies at the three sites was statistically significant, as well as the correlation among the corresponding total ozone monthly anomalies. Positive trends of the monthly average UV irradiance were in 2006 – 2020 were detected for specific months at all sites, which were attributed to changes in cloudiness and/or aerosols. In 1996 – 2020 the 307.5 nm irradiance increased over Rome, mainly due to decreasing lower stratospheric ozone. The significance of dynamical processes which take place in the troposphere for the variability of total ozone and surface solar UV irradiance is highlighted in the study.

Time series analysis of UV measurements at Uccle (Belgium) and Utsteinen (Antarctica)

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Abstract: The Royal Meteorological Institute of Belgium performs spectral UV measurements with Brewer spectrophotometers at two stations: Uccle, Belgium (50.8°N, 4.35°E, 100m a.s.l.) and Utsteinen, Antarctica (Belgian research station Princess Elisabeth, 71.95°S, 23.35°E, 1380m a.s.l.). The UV time series at Uccle started with measurements of the single monochromator Brewer#016 in 1990 and are complemented by measurements of the double monochromator Brewer#178 since 2002. At Utsteinen, Brewer#100 (double monochromator) started measuring in 2011. In this contribution we analyse the UV index (UVI) time series for both stations. For Uccle, the analysis is done on a daily and monthly basis and the differences between Brewer#016 and Brewer#178 are investigated. For Brewer#016, a significant positive trend of 5.8 ± 0.4 % per decade is found in the anomalies time series for the maximum daily UVI value for the period 1991 – 2020 (maximum daily UVI value minus long-term mean daily maximum UVI value). Similar positive trends are found for the analyses on a monthly basis, and also for the period of Brewer#178 (2002 – 2020). The 75 % percentile of the difference of UVI values between Brewer#016 and Brewer#178 is ± 0.05. Likewise, time series of the erythemal UV dose are analysed and significant positive trends per decade are found, for both Brewers and both on a daily and monthly time scale. Further, previous analyses on the relationship of time series of daily average ozone, daily average AOD, total daily global radiation and total daily erythemal UV dose are re-analysed with now longer time series. The measurements of Brewer#100 in Antarctica do only cover the periods of austral summer (November – February). The other months, Princess Elisabeth station (PES) is not inhabited and Brewer#100 not operational. UVI values, in particular in November and December, are strongly influenced by the variation of the total ozone column amount. For example, in December 2020, when the Antarctic ozone hole lasted very long, maximum UVI values between 13 and 14 were measured.

Furthermore, auxiliary data such as global radiation, surface albedo and cloud cover are available for PES. The relationship of these observations to the measured erythemal UV dose is investigated.

UV Index for the Public

A student's view of the public awareness of UV Index

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Abstract: In August 2021 the Laser and Optical Radiation Dosimetry (LORD) Group hosted a three-week summer student through the Nuffield Research Placement (NRP) programme. During the placement the student was tasked with completing a small research project on public awareness of the UV Index, outlined in this poster. The NRP student's research is the sole work of the student and outlines their findings. Public Awareness of the UV index should be more widespread so that the correct protection measures are taken to prevent eye and skin damage. A small population is aware of the risks of UV exposure and a smaller population has a good understanding on how to use the UV index. The aim of this project is to analyse Public Health England's (PHE) UV Index web page views and to consider how the UV index is currently communicated and how this may be improved. Data analysis of the PHE webpage is presented along with research on how other UK organisations and other countries communicate the UV index. From these findings proposals have been made to find a better way of communicating the UV index.

Investigation into the public's awareness of the UV Index, a student's view.

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Abstract: In August 2021 the Laser and Optical Radiation Dosimetry (LORD) Group hosted a three-week summer student through the Nuffield Research Placement (NRP) programme. During the placement the student was tasked with completing a small research project on public awareness of the UV Index, outlined in this poster. The NRP student's research is the sole work of the student and outlines their findings. Public awareness of UV index is not as prevalent as it should be. Despite the tool informing of the risks behind UV exposure, a small population is aware of it and an even smaller sample understands it. Solar UV radiation is something we are exposed to every time we are outside in the sun and overexposure can cause negative health effects such as erythema (sunburn), eye cataracts and, in the long term, skin cancer. This poster summaries two areas investigated, firstly looking into how Public Health England (PHE) currently communicates the UV index including analysis of the website views. Secondly to collate methods of communication currently undertaken in the UK and internationally with the aim to propose a better way of communicating the UV index.

The UVEX App: Raising public awareness of the risks of solar UV radiation

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Abstract: It is known that overexposure of humans to solar ultraviolet (UV) radiation is harmful and entails severe risks. While short-term overexposure may produce skin burns, long-term exposure may be related with the development of skin cancer, cataracts and weakening of the immune system. For this reason, it is of the utmost importance to raise public awareness of the risks of overexposure to UV

radiation and of the need to adopt effective protective measures in those situations with high radiation levels. Within this framework, the AIRE research group of the Universidad de Extremadura has been informing the public about the risks of overexposure to solar UV radiation for more than fifteen years. In order to improve this awareness activity, the UVEX Android App is being developed aimed to report the UV level and recommendations for protection to the public, taking advantage of the fact that most people own a smartphone. The application makes use of the mobile's GPS to geolocate the user so as to provide the UVI level on that location. The UV Index (UVI) was jointly defined by WHO, WMO and ICNIRP to become an understandable and useful vehicle to inform the public about the risks of solar UV radiation. The UVEX App provides forecasted values of UVI on a 15- minute basis for the actual day and day after, with special attention to the maximum daily values. Additionally, the UVEX App recommends adopting protective measures in accordance with the actual UV radiation and the phototype of the user, which classifies a person by its reaction to exposure to UV radiation. The phototype of the user is obtained by a simple test included in the App. Finally, the UVEX App features a "solar calculator" which provides the user with an estimation of the time to reach the MED (minimal erythema dose) according to the time when solar exposure begins, the forecasted UV levels for each 15 minutes, and the particular phototype of the user. This calculator provides a more understandable quantification of the risks of solar exposure and about the need for protection measures. The application is meant to be operative in Spain and Portugal (islands included), which are two of the countries in Europe with the highest levels of solar radiation. Furthermore, the large influx of national and foreign tourists emphasizes the interest of this application and similar awareness activities.
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A comparative study among different empirical approaches for the short-term prediction of the UV Index

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Abstract: Several numerical models can be used to predict UV index or the daily dose, both on short- and long-term. Radiative transfer models (RTMs) are sophisticated codes which solve the radiative transfer equation in a multi-layered atmosphere, given the amount and optical properties of its components. Hence, the reliability of the radiation field calculated/predicted by such physical models depends on the accuracy of the data provided as input, which is not always available. In this study, we explore the effectiveness of alternative approaches to deterministic methods, in order to predict the UV index for the following day with less detailed input and less computational resources: 1) using the climatological value for the corresponding day of the year as a projection; 2) using the measurement from the previous day (persistence hypothesis); 3) statistical-empirical relationship linking the UV index to a set of predictors (e.g., solar zenith angle, ozone, clouds, etc.) and 4) the method of analogues. The first, the second and the last approach do not need predictors and rely on the quantity and quality of the available data. For this study, we use the long series of high-quality UV and ozone data from the Italian stations of Rome (41.9° N, 12.5° E, 75 m a.s.l., urban environment), and Aosta (45.7° N, 7.4° E, 570 m a.s.l., mountain valley station) over the period 2006 -2020, during which both observatories have been operating. These two grounds-based stations, located at quite different latitude, altitude, and environmental context, are chosen since they regularly underwent quality control/quality data assurance and are traceable to the SI through international reference standards. Furthermore, the sensitivity to additional input parameters, such as the OMI products of UV aerosol index, radiative cloud fraction and effective surface reflectivity, is assessed. Pros and cons of the considered approaches are discussed in order to assess their application as an alternative to the physical ones.

Additional UV 'D-index': the relevance of introduction and related problems

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Abstract: Solar UV exposure has various health effects, and the UV-index has been introduced to prevent negative consequences of overdose. At the same time, considering the critical role of vitamin D for human health and the global pandemic of vitamin D deficiency, there is a clear need for an additional UV 'D-index' that reflects the ability of sunlight to initiate vitamin D synthesis in human skin.
It is important to emphasize that standard UV-index is not suitable for this purpose in view of significant difference between the CIE erythema and 'Vitamin D synthesis' action spectra. As a result, UV monitoring based on using erythemic UV dose will not provide adequate quantification of synthesized vitamin D. It is proposed that global UV mapping and yearly and daily forecasts should take into account both erythemic and "anti-rachitic" solar UV-indices especially in view of the expected health effects of low UV-B levels on Earth due to air pollution. As is known, Vitamin D3 is a fat-soluble prohormone that is synthesized in skin in two stages. First provitamin D3 (7-Dehydrocholesterol) upon solar UV-B irradiation is converted into Previtamin D3 which is further transformed to vitamin D3 at body temperature. Therefore, the amount of accumulated previtamin D3 is a measure of biological 'anti-rachitic' UV dose obtained during an exposure.
However, since an express method for such direct measurement has not yet been developed, the radiative quantity for the dosage unit for vitamin D3 synthesis in vivo is not established yet, and it is determined based on the physiological response to an equivalent oral dose of 1000 IU of vitamin D3 per day. It should also be noted that the standard CIE action spectrum for the production of previtamin D3 in human skin has not yet been validated [1].
Therefore, to measure the anti-rachitic UV dose, it is most appropriate to use the same photoreaction in vitro that underlies the natural synthesis of vitamin D3, given the previously identified linear correlation between the accumulation of previtamin D3 in vitro and an increase in the level of 25-hydroxyvitamin D in vivo [2]. To follow the photoreaction course in real time three operation modes of varying complexity have been developed [3].

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B) PERSONAL UV EXPOSURE

Protection of outdoor workers from solar ultraviolet radiation: some results on shade and clothes for beach lifeguards in Tuscany (Italy)

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Abstract: The UV radiation risk is still little known and underestimated by outdoor workers and employers, as highlighted for example by the Plan of the Tuscany Region (Italy) "Risk from Solar UV Radiation in Outdoor Workers" which investigated several working sectors. Among these the seaside sector, well represented in Tuscany and mainly characterized by “outdoor” activities during the annual peak of UV radiation. Several studies have pointed out as occupational solar exposure increased eyes and skin diseases among which the non-melanoma skin cancer, with an excess risk up to three-fold increase in outdoor workers. Only recently the seaside sector in Tuscany is beginning to be aware of the use of protective measures such as shady areas and clothing (in addition to sunscreens, sunglasses, etc.) in order to reduce the professional risk due to solar UV exposure. In this work the UV protection properties offered by some shading structures were analysed during a summer clear sky day by means of two erythemally weighted broadband radiometers. Concerning clothes, were described some recent experiences of LaMMA/CNR-IBE on the UV protection offered by natural fabrics, while the ultraviolet protection factors of some T-shirts, used in the coastal area by beach lifeguards, were assessed. The shading structures blocked the direct component of the sun radiation, while the diffuse one, albeit also significantly reduced, continued to be not always negligible (due to environment reflection) especially considering a stay for several hours for the whole summer, therefore suggesting as good practice the maintaining of further protective measures (T-shirt, sunglasses, sunscreen, etc.) also in the shade. Results are shown both as instantaneous and cumulated doses for different time intervals along the day. The protective role of fabrics was emphasized and in particular, the tested T-shirts showed a very good-excellent protection (only one good protection) according to the New Zealand standard. The results show that also in the seaside context the dissemination of good practices, including those tested, could be particularly effective as primary prevention for workers who are subjected to very high levels of radiation for very long periods empowering employers and at the same time instil in workers an adequate awareness of the risk.

Personal UV exposure measurements in Kenya and Tanzania – Preliminary results

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Abstract: During the past 40 years, a variety of studies have been undertaken to measure the personal UV exposure of people. Almost all studies focused on light skinned populations in Europe, Australia and North America. Until today, no measurements have been made at the Equator, where UV radiation is highest.For this study, personal UV exposure measurements were made at two different locations in Kenya: Malindi, located at the coast and Nairobi, located at an altitude of 1660 m asl. A variety of volunteers with different professions have been equipped with wrist-watch-like electronic devices, which measure the erythemally effective UV irradiation at the wrist. These devices have been calibrated to solar radiation prior to the study and calibration was checked after the study. As one of the interesting results, the differences in personal UV exposure between the left and the right hand of a taxi driver due to the open car window could be quantified. We will show that the open car window has s significant influence on UV exposure. Most exposed are guards during their inspection gallery and gardeners, while street vendors could choose shaded places and therefore are less exposed. Beside others, we will show that the “Exposure ratio to ambient UV” for gardeners in Kenya is similar to that for gardeners in Europe and that the median personal UV exposure is close to 1 MED for skin type VI in Kenya.

3D body model calculations of UV-exposure during beach holiday

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Abstract: Vacational UV exposure frequently results in acute skin damage, presenting as erythema or sunburn, and contributes significantly to an individual's annual UV exposure. Previously, UV exposure measurements made at only a few body parts were available. These are hard to generalize to other body sites, other geographic locations, or other dates. In this presented work, we use a radiative transfer model in conjunction with 3d-body models to calculate the body distribution of UV exposure during a beach vacation. Behavior and clothing habits of people during a week at a beach resort (Tampa, FL, 28°N) were considered. The results show that the most exposed body sites are parts of the head, hands, forearms, shins/calves, feet and the neck. Parts of the head receive 52 SED and 210 SED during a day at the beach and over the course of a full week at a beach resort including other whereabouts than the beach, respectively. Such vacational UV exposure may double the annual UV exposure of people and contribute significantly to skin aging and corresponding alterations of the skin. This clearly indicates the need of appropriate sun protection during beach holidays.

Skin color and pigmentation of Austrian farming families during the year and during life

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Abstract: The objective of this study was to examine pigmentation and skin color changes on different body parts over a period of one year, using objective tri-stimulus measurements. Our results show a difference of winter skin color and pigmentation on the forehead between females (lighter) and males (darker). With adults (darker) and children (lighter), a difference on temporary, as well as on continuously exposed body parts was observable. It could be proven that farmers experience a darkening of the skin throughout a lifespan, whereas no such effect was found in spouses, suggesting that the change in spouses' skin color is more related to personal behavior than age. Winter skin colors showed a difference in facultative and constitutive skin color already in children, where an accumulation of facultative pigmentation is present, indicated by correlation of age and skin color on the forehead. On the other hand, skin color changes on temporary exposed body parts seem to be determined by behavior instead of being related to age. Additionally they undergo a seasonal change of pigmentation in all three groups and further a similar but noticeable weaker effect is also present on the forehead. The skin color of the inner upper arm, a body part often referred to as non-exposed, changes with season in children and farmers. Lastly, we found, that exposure to a Standard Erythema Dose (SED) of 1.4 per day on average results in an increase of pigmentation, while a lower exposure leads to fading.