Meeting report

Annual Meeting of the Nordic Ozone and UV group, 2019

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DOI: 10.19232/uv4pb.2019.1.14

Introduction

The Nordic Ozone and UV group is a working group within the network of Nordic National Meteorological Services (NORDMET). The annual meeting 2019 was organized by Public Health England (PHE) in Chilton, U.K., 26–27 March.

The meeting provided opportunities to discuss the following areas: Ground based ozone measurements; Modelled ozone events and scenarios; Space-based ozone and UV products; Ground-based UV measurements; UV radiation and its effects on biosphere and on materials; Solar radiation and human health. The meeting is a good forum to share research ideas and results connecting UV/ozone studies and time series with research into the effect of UV.

Multidisciplinary research is much appreciated and the members of UV4Plants are invited to participate in the next meeting, to be held in Oslo, Norway, in April 2020. To give you an idea of the themes of the latest meeting, summaries of five presentations are presented here below. As before, colleagues from outside the Nordic countries are very welcome in the NOG meetings. In case you are interested to hear more about the next meeting or to be part of our mailing list, please send a message to `mailto:kaisa.lakkala@fmi.fi`.

Is exposure to UV radiation a viable choice for vitamin D production in the modern world?

Ann R. Webb, Richard C. Kift, Mark Farrar and Lesley E. Rhodes

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The measurement of UV radiation is often, at least partially, justified on the grounds of public health issues. Traditionally this was sunburn and skin cancer (risk), more recently vitamin D synthesis (benefit) has also gained support. Ability to balance UV benefit and risk depends on location (climate), skin type and behaviour, the latter determined by culture, employment and personal choice. Alternatively, vitamin D can be acquired by ingestion though modern diets are generally low in vitamin D and regular supplementation would be the most reliable way to achieve this. We showed how the risk/benefit balance for UV exposure can be achieved in the UK climate, whether different sections of the population come close to finding that balance, and how supplement use can be encouraged based on the climatology (Figure 12.1).

Daylight photodynamic therapy

Luke McLellan[1,3], Paul O'Mahoney[1,3], Stephanie Logan[1,2], Susan Yule[1,2], Carol Goodman[1,2], Andrea Lesar[2], Lynn Fullerton[2], Marina Khazova[4], Michael Higlett[4], Sally H.

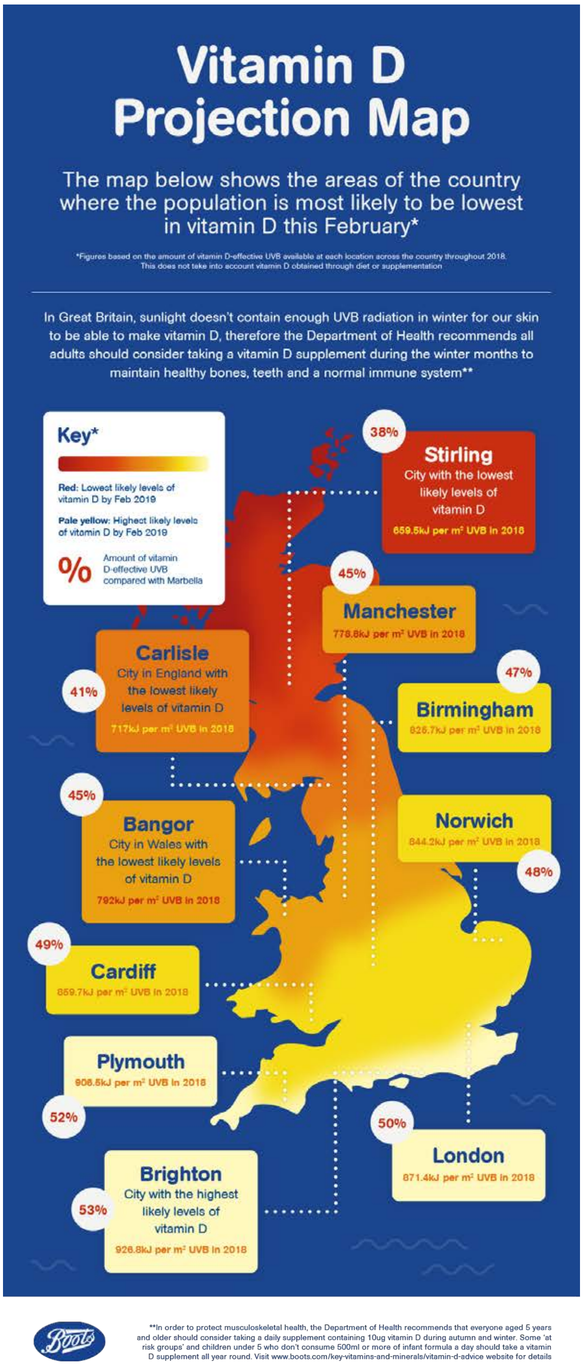

Figure 12.1: The vitamin D projection map shows the regions where the population are most at risk of wintertime vitamin D deficiency due to lack of solar vitamin D-effective UV radiation. The colour coded map is based on the total annual vitamin D-effective UV for 2018, calculated from satellite data input and verified against ground-based measurements.

Ibbotson[1,3] and Ewan Eadie[1,2]

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Daylight photodynamic therapy (dPDT) is an effective treatment for type I and moderate type II actinic keratosis (AK). In combination with a light sensitising cream and molecular oxygen, it uses visible solar radiation to treat AK that are caused by over exposure to solar ultraviolet (UV) radiation. It is also a patient preferred treatment due to its high rates of clearance, convenience and low pain scores. This is important as AK is a chronic disease where treatment management and patient happiness is of high importance. An in-house patient survey was conducted at the Scottish Photodynamic Therapy Centre validating patient willingness to carry out home-based dPDT for their disease.

For a successful treatment, it is though that a minimum protoporphyrin-IX (PpIX)-weighted dose of 40 $\mathrm{kJ\,m^{-2}}$ is required. Lux meters are an inexpensive method of monitoring daylight exposure, and a conversion model was derived in order to convert illuminance (measured on a lux meter) into the clinically relevant PpIX-weighted dose. Applying this conversion model to historical data provided by Public Health England (PHE) gives an estimate for the expected PpIX dose year-round in the UK which may act as guidelines for clinicians and dPDT practitioners validated the model and demonstrated that successful dPDT can be applied year-round.

PHE also provided data on erythemally weighted UV and UV-A irradiance. As dPDT is a consequence of chronic UV exposure, historical trends in UV data help indicate, to an extent, prior patient exposure. This also depicts safer treatment times where UV dose is low whilst retaining a sufficient dPDT dose and omitting periods that fall below this. Similar trends for UV-A radiation were also shown.

This data highlights the need for photoprotection during dPDT particularly during the summer months around solar noon especially as patients have already accumulated chronic UV damage. However, approximately 40% of the dPDT dose absorption spectra lies within the UV-A, a region that is highly attenuated by modern day sunscreens. In our in vitro study, we demonstrated a reduction in the received PpIX-weighted dose of between 38% and 92% for a variety of sunscreens, highlighting the importance of sunscreen choice in dPDT.

Record-breaking 2018 and the increasing surface solar radiation over Sweden since the 1980s

Thomas Carlund

Swedish Meteorological & Hydrological Institute

During the period 1983–2018, for which good quality and homogenous radiation data has been recorded in Sweden, some clear features in the surface radiation climate show up (Figure 12.2). Significant positive linear trends in global radiation are found at all stations. Averaged over all stations, the trend until 2005 was about $+4\,\mathrm{W\,m^{-2}}$ per decade. From 2005 the increase is weaker but still positive. A major reason for the continued positive trend is the record sunny summer half year of 2018. The main reason for the increased surface solar radiation is a decrease in cloudiness leading to increased sunshine duration. Also UV irradiation was high in 2018. However, at the (single) measurement station in Norrköping record-breaking amounts were not experienced in 2018, despite normal to slightly lower total ozone amounts during the summer. One reason for the discrepancy in record years between global and UV irradiation measurements could be the relatively high uncertainty in the UV measurements.

Long-term Ozone Observation at the Swedish Institute of Space Physics in Kiruna

Uwe Raffalski

Institute of Space Physics, Kiruna, Sweden

The Institute of Space Physics (Institutet för rymdfysik, IRF) is a governmental research institute established in 1957 in order to conduct long-term observation of geophysical parameters in the first place. As Observatory it has started ozone monitoring in 2001, making use of its unique location north of the polar circle and, during wintertime, well inside the polar vortex most of the time. The Kiruna Millimeter wave Radiometer KIMRA measures the emission from the ozone line at 230 GHz ($\lambda \approx 1.3$ mm). Comparing our continuous measurements with satellite observations both data sets show very good agreement. The simultaneous observation of a CO emission line at ca. 231 GHz, close to the ozone line, enables to take dynamical processes into consideration when estimating the winter/spring ozone loss. Dynamical effects like down transport of relatively ozone rich air masses from the mesosphere where ozone is formed can mask the ongoing chemical ozone depletion further down in the atmosphere. Therefore it is important to eliminate dynamical effects by using CO as a tracer. A comparison between CO data from KIMRA and Aura/MLS satellite data shows very good agreement and provides confidence in such ground-based measurements of the upper stratosphere and mesosphere, a region of the atmosphere which is hard to probe in any other way than with the means of remote sensing.

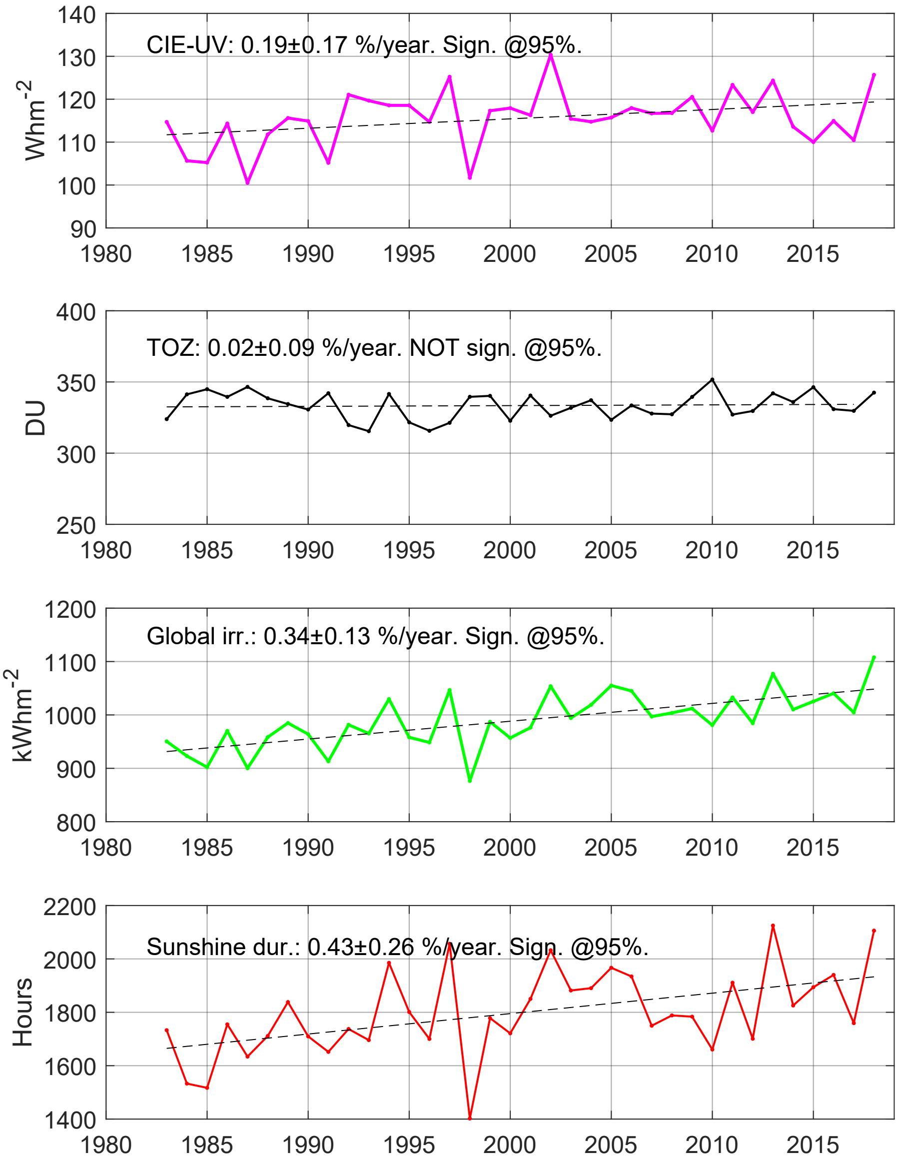

Figure 12.2: Time series of some solar radiation monitoring variables measured at the Swedish Meteorological and Hydrological Institute's station in Norrköping, Sweden. From top to bottom: Annual erythema-weighted UV irradiation, annual mean total ozone, annual global irradiation and annual sunshine duration.

Validation of AC SAF UV record product

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The EUMETSAT Satellite Application Facility on Atmospheric Composition Monitoring (AC SAF) UV Data Record R1 products (OUV RECO) were compared with ground based measurements from 30 sites for the period 2007–2017 (Figure 12.3) (Lakkala et al. 2019). The OUV RECO includes daily doses and maximum dose rates of UV-B and UV-A radiation together with values obtained by different biological weighting functions, solar noon UV index and quality control flags. The OUV RECO time series is processed using uniform algorithm throughout the 10-year period. For UV daily doses, the median of relative differences from ground based measurements was less or equal to 10% at 23 sites. The average of the medians of all stations, excluding two Antarctic sites, was -1.20%. For daily maximum dose rates, the relative difference was less or equal to 10% at 18 sites. The average of the medians was -5.4%, when excluding two Antarctic sites from the analysis. The stations of Syowa and McMurdo are located at the coast of the Antarctic, where high reflectivity from snow and ice together with changing sea ice conditions increase uncertainties in satellite retrievals. There still exist challenges in discrimination of snow and clouds for extreme conditions, like in spring at the high latitude site of Barrow.

Acknowledgement: The AC SAF team and operators of ground-based measurements are acknowledged.

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UV-dose data from an arctic station (Ny-Ålesund) applied to the study of UVB and UVA radiation effects on early life stages of zebrafish

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The Arctic sea-ice has undergone significant changes in recent years: decline in extent of summer ice, reduced ice thickness and younger ice pack (Wang et al. 2014). These changes have contributed to decreased surface albedo and increased transmission to the upper ocean, resulting in more energy deposited to the Arctic sea. Temperature increase and different exposure to visible light and UV have strong implications for the primary production of marine biomass, particularly photosynthesizing ice-algae and phytoplankton, serving as nutrient store for zooplankton (eg. *Calanus finmarchicus*), amphipodes, krill, fish larvae, etc. (Figure 12.4).

As part of the Norwegian UV-monitoring program, a GUV multiband filter radiometer

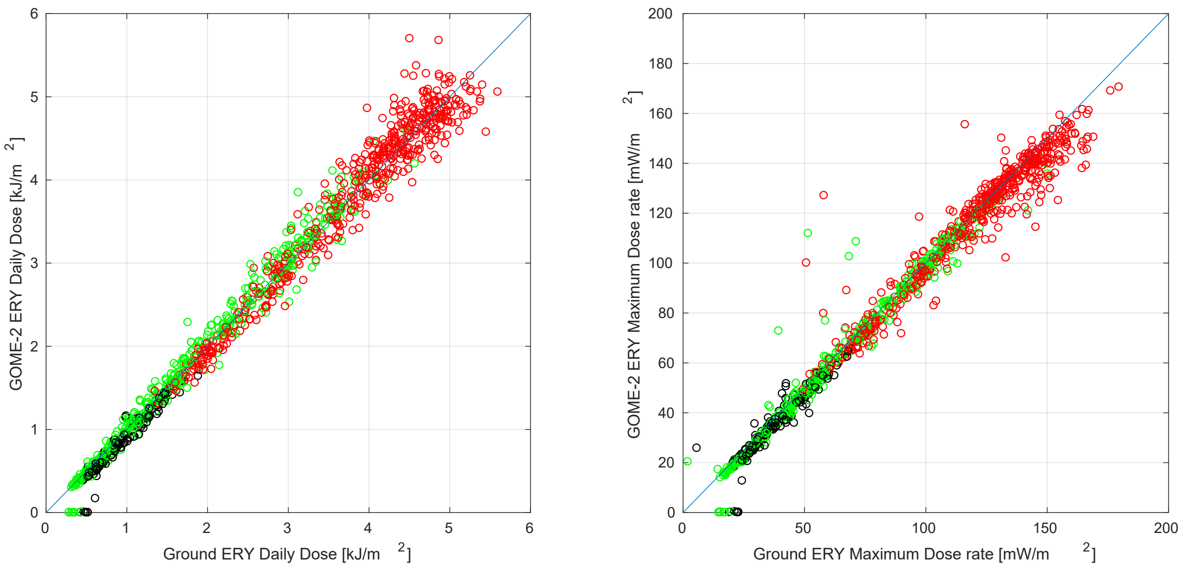

Figure 12.3: A) Erythemally weighted UV daily dose and b) erythemally weighted maximum UV dose rates measured by a spectroradiometer (Ground ERY) and the corresponding satellite product (GOME 2 ERY) at Summit 72°N. Data sets were divided into four seasons (December–February, blue), (March–May, green), (June–August, red) and (September–December, black). (Figure from Lakkala et al. 2019).

Table 12.1: Environmental doses at the surface or under an ice cover expressed as LD50 for zebrafish in UVA and UVB.

Conditions Surface, total regular mean dose	UVA Daily dose/ LD50: 2	UVB Daily dose/ LD50: 17
Number of extra LD50 going from:		
Normal to low Ozone	0.0	3.5
Clear to thick clouds (reduced dose)	-1.4	-11
High to low albedo	0.1	1.0
Thick to thin ice	0.28	1.9

located in Ny-Ålesund (78°N) has been operating since 1995, providing 23 year time series of UVB and UVA surface irradiances, as well as sky transmittance and surface albedo in the UVA part of the spectrum. The surface albedo represents the combined backscatter of open, and ice- and snow covered Kongsfjord area, land and ice caps, providing an indirect measure of inter-annual variations in snow and ice extent, and indicates the onset of snow melting. The melting period, starting in early May, ending in mid-July, occurs at a time of maximum solar elevation and natural variability in stratospheric ozone, where a shift in snowmelt period may result in significant variations in UV doses in the biologically active surface layer of the ocean. Combining high and low ozone values based on AURA-OMI overpass data, late and early onset of ice melt from long term GUV measurements, and clear sky and overcast conditions, we have estimated daily variations in surface UVB and UVA irradiances at the top of an ice layer. Furthermore, using ice transmittance data based on Belzile et al. (2000), daily variations in UVB and UVA irradiances in the ocean surface layer were estimated.

It is well known that waters around

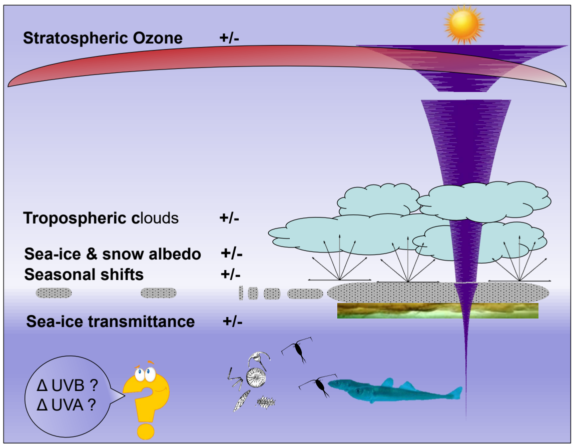

Figure 12.4: Schematic presentation of the main processes that contribute to climate related changes in UV-doses in an arctic marine environment.

Svalbard, Norway, are important spawning grounds for marine fish, which are of great economic importance for several countries. We have used an established fish model system to estimate to what degree the climate-induced changes in UV irradiance can influence survival, physiological factors and behaviour of fish larvae.

We exposed zebrafish (*Danio rerio*) embryos (4.5-–5.5 hpf, hours post fertilization) to sub-lethal and environmentally relevant doses of UVA (94, 187, 377 $kJ\,m^{-2}$) and UVB radiation (0.13, 0.25, 0.76 $kJ\,m^{-2}$) from broad band fluorescent tubes for studies of behavioural and physiological effects. LD50, the dose killing 50% of the embryos, was estimated, and environmental exposures and experimental doses were expressed in terms of LD50. The doses used for studies of physiological and behavioural effects were all below the LD50 (range 0.13–0.68 times LD50) and caused no significant difference in survival, deformities, or hatching between exposed and control groups. Compared to controls, there were transient UVA and UVB exposure effects on heart rate. UVA exposure led to significant reductions in larval movement following exposure to the two highest doses of UVA, i.e. reduction in the time spent active and the total distance moved compared to control at 100 hpf, while no effect on the swimming speed was observed. The lowest dose of UVA had no effect on behaviour. In contrast, the highest dose of UVB led to a possible increase in the time spent active and a slower average swimming speed although these effects were not significant ($p = 0.07$). UV exposures also caused effects on ROS formation and lipid peroxidation. These results show that UV doses below LD50 levels are able to cause changes in the behaviour and physiological parameters of zebrafish larvae, as well as oxidative stress in the form of ROS formation and LPO. The changes in activity and swimming speed may be assumed to influence important functions as ability to migrate, search for food or avoid predators. Further testing is necessary to assess how this type of radiation and the effects observed could affect fish population dynamics.

We have presented climate related dose changes in Table 12.1. It can be assumed from the results obtained in zebrafish, that biological effects on naturally occurring fish embryos in the arctic sea may be induced by doses within the range of climate-driven variation.

Acknowledgement: This project was supported by Research Council of Norway through its Centres of Excellence funding scheme, CERAD project number 223268/F50.

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Editorial-board-reviewed article.
Published on-line on 2020-01-13.
Edited by: T. Matthew Robson and Pedro J. Aphalo.

Figure 12.5: Group photo: Michael Higlett