Global Atmosphere Watch radiation measurements

Laurent Vuilleumier[1], Gilles Durieux[1], Stephan Nyeki[2], David Vernez[3]

[1]Federal Office of Meteorology and Climatology MeteoSwiss, Payerne, Switzerland
[2]Physikalisch-Meteorologisches Observatorium/World Radiation Center, Davos, Switzerland
[3]Center for public health and primary care medicine (Unisanté), University of Lausanne, Switzerland

laurent.vuilleumier@meteoswiss.ch

Part of this programme: GAW

Keywords: solar irradiance; ultraviolet, visible, infrared and spectral irradiance; precision filter radiometer (PFR); pyranometer; pyrheliometer; UV biometer; aerosol optical depth (AOD); integrated water vapour (IWV)

1. Project description

The goal of the Global Atmosphere Watch Radiation Measurement program at Jungfraujoch is providing long-term monitoring of surface downward radiation fluxes. It is conducted in the framework of the GAW Swiss Alpine Climate Radiation Monitoring program (SACRaM), which applies operational guidelines similar to those of the international Baseline Surface Radiation Network, except for the daily maintenance requirements due to the remote nature of the site. In 2019, a good degree of data availability was achieved, especially considering the challenging conditions at Jungfraujoch. On average, the data availability for radiation parameters reached 97%. Achieving this level of data availability for continuous automatic monitoring at Jungfraujoch implies a constant effort to sustain the highest achievable accuracy, stability and continuity in the measurements.

The measurement program includes shortwave (solar spectrum) and longwave (infrared thermal) broadband measurements as well as UV broadband measurements. Short- and longwave measurement series are important for climate research, while UV measurements are of interest for both public health and exploring the relationship between the evolution of the ozone layer and radiation. Broadband radiation is measured both as global downward hemispheric irradiance and as direct sun irradiance.

In addition, direct spectral irradiance is also measured, which allows aerosol optical depth (AOD) and integrated water vapour (IWV) column to be determined. In association with the WMO GAW Precision Filter Radiometer (PFR) network, MeteoSwiss operates such sun photometers at the four SACRaM stations measuring the direct irradiance in 16 narrow spectral bands within the range 305-1024 nm since 1998. One of the four sites is Jungfraujoch, characterized by an alpine environment and partial free tropospheric conditions. At nine wavelengths, aerosol optical depth (AOD) is computed at times when no clouds are in the path of the direct solar beam.

Nyeki et al. (2019) studied trends in 20-years long time series of longwave downward irradiance (LWD, infrared thermal) measured at four Swiss stations. An increase in LWD is one of the main indicators of climate change. Positive LWD trends were detected at all four stations. Clear-sky trends are significant at all stations (90% confidence level), while all-sky trends are significant at all but one station. At the Locarno and Payerne lowland stations (367 m a.s.l. and 491 m a.s.l., respectively), clear-sky decadal trends are 2.9 (±1.8) Wm^{-2} and 2.4 (±1.9) Wm^{-2}, respectively, while at the Davos and Jungfraujoch mountain stations (1594 and 3580 m a.s.l.) they are 4.8 (±1.7) Wm^{-2} and 5.4 (±1.9) Wm^{-2} (see Fig. 1).

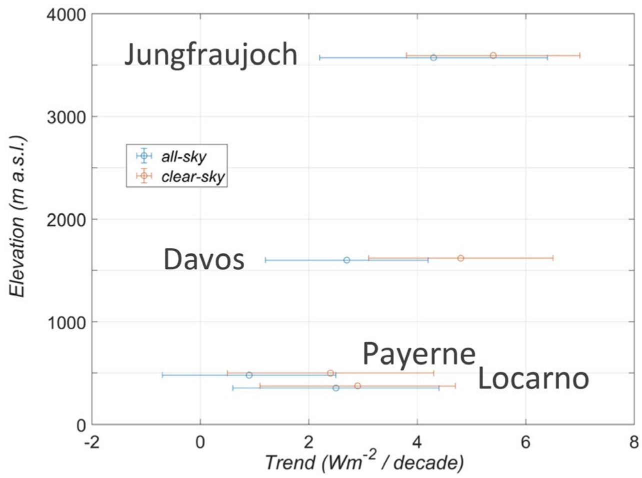

Figure 1. LWD irradiance trends (Wm^{-2} per decade) for clear-sky (red) and all-sky (blue) data at four Swiss sites.

This suggests an elevation dependence of the LWD trends, and a possible elevation dependence of climate change in Switzerland. This would be in agreement with Pepin et al. (2015), who claim that climate warming is stronger at higher elevations. Having four stations at various elevations and in relatively close proximity allows investigating how the LWD trends correlate to other trends.

Analysis of corresponding trends of temperature and integrated water vapor (IWV) column also reveals positive trends in these quantities; however, the temperature trends do not show a similar elevation dependence. IWV trends also do not show such an elevation dependence when their absolute magnitude is considered, but IWV above mountain stations is on average lower than above the lowland stations. The effect of changes in IWV on LWD may thus be more influential at mountain station than at lowland stations. Using an empirical parameterization of clear-sky LWD as a function of temperature and IWV did not allow LWD trends at mountain stations as strong as those observed to be reproduced. This may indicate that other factors contribute to the clear-sky LWD mountain trends. However, preliminary RTM (radiative transfer model) calculations from an ongoing further study suggest the empirical parameterization does not correctly represent the clear-sky LWD dependence on IWV at low IWV.

Religi et al. (2019) conducted a study for determining how to achieve a balance for benefiting from positive health effects of UV exposure (vitamin D) without being exposed to the risk of excessive exposure (increased skin cancer risk). It is challenging since overexposure to solar UV radiation is responsible for cutaneous melanoma and epithelial skin cancer, but natural production of vitamin D triggered by skin exposure to UV allows achieving vitamin D levels essential for skeletal health.

This study aimed to quantify solar UV doses needed to trigger 1000 International Units (IU) vitamin D doses and, at the same time, which was the limit dose producing sunburn. Solar UV irradiance measured at four meteorological stations in Switzerland for the period 2005–2017 were used to evaluate these doses. Solar UV exposure durations needed to produce vitamin D with limited sunburn risk were estimated while considering mean vitamin D food intake of the Swiss population and seasonal skin coverage.

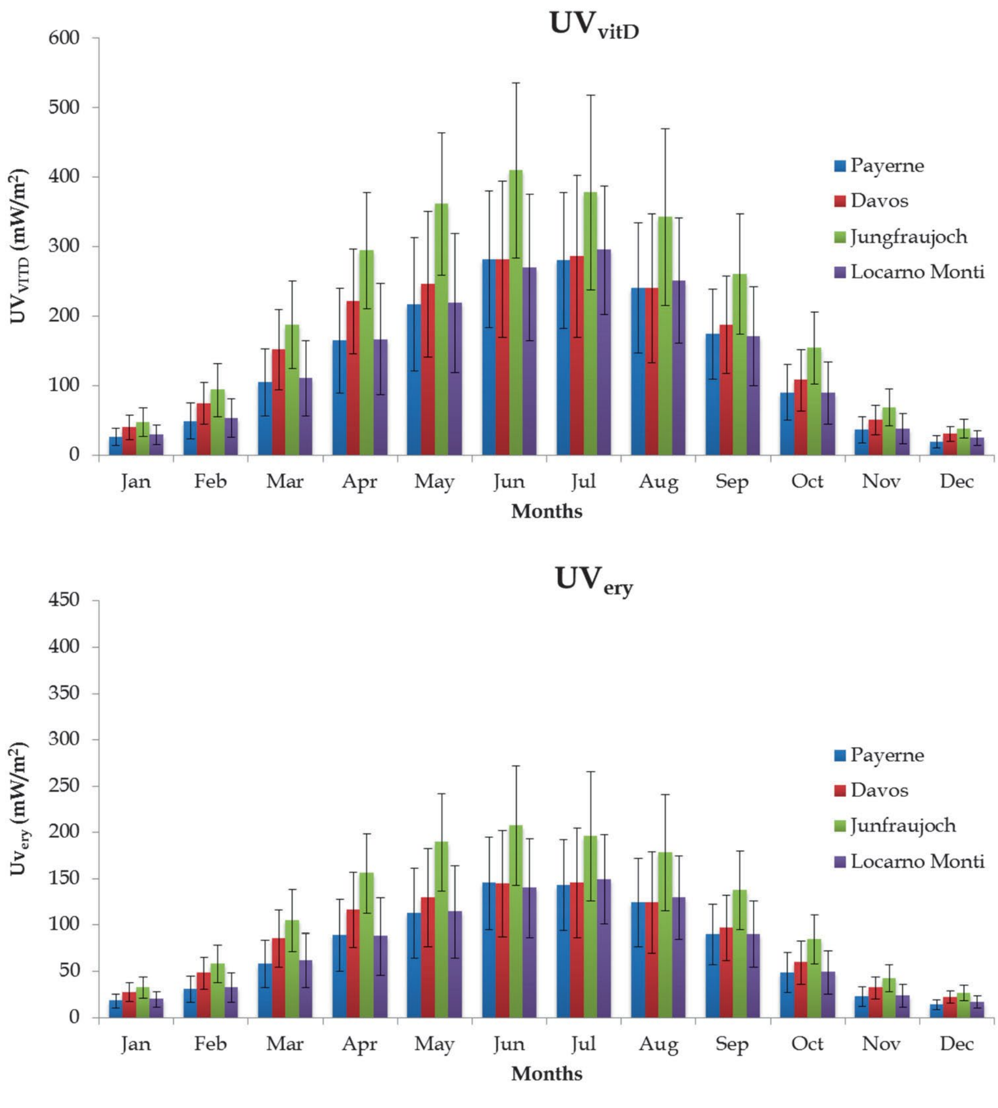

Figure 2. Monthly means of the 11:30-to-12:30 CET mean hourly values of UV_{vitD} and UV_{ery} at four Swiss stations (Jungfraujoch, Davos, Payerne and Locarno-Monti).

The UV broadband irradiances measured at Jungfraujoch, Davos, Payerne and Locarno-Monti with instruments equipped with a filter reproducing the erythema sensitivity function (UV_{ery}) were used to compute a UV irradiance weighted with an action spectrum for vitamin D production (UV_{vitD}). For this computation, we used a ratio depending on the total ozone column determined by McKenzie et al (2009). Fig. 2 shows the mean monthly values of the noon (11:30 – 12:30 CET) hourly irradiances of UV_{vitD} and UV_{ery}. These mean hourly irradiances of UV_{vitD} were used to determine the time necessary to produce 1000 IU vitamin D using a formula adapted from McKenzie et al. (2009) considering skin phototype, the fractional area of skin surface exposed and an age factor reflecting the ability of an adult to produce vitamin D. The mean hourly irradiances of UV_{ery} were then used to determine whether the time necessary to produce 1000 IU vitamin D would result in an UV dose inducing an erythema (sunburn).

In summer and spring, with 22% of uncovered skin, 1000 IU vitamin D doses are synthesized in 10–15 min of sun exposure for adults. Exposure durations between erythema risk and 1000 IU vitamin D production vary between 9 and 46 min. In winter and autumn, the recommended vitamin D production without sunburn risks is often unachievable, since up to 6.5 h of sun exposure might be necessary considering 8–10% of uncovered skin surface. The vitamin D food intake only represented 10% of the recommended vitamin D production and remained unchanged throughout the year.

These findings might clarify why vitamin D deficiency is common in Switzerland. Moreover, exposure durations between recommended vitamin D and increased sunburn risk might only differ by a few minutes. Without additional oral vitamin D supplements, daily doses of vitamin D (1000 IU) are not achievable in autumn and winter months in Switzerland.

References

Nyeki, S., Wacker, S., Aebi, C., Gröbner, J., Martucci, G., and Vuilleumier, L. Trends in surface radiation and cloud radiative effect at four Swiss sites for the 1996–2015 period. *Atmos. Chem. Phys.*, **19**, 13227–13241, doi:10.5194/acp-19-13227-2019, 2019.

McKenzie R, Liley J, Bjorn L. UV radiation: balancing risks and benefits. *Photochem. Photobiol.* **85**, 88–98, 2009.

Pepin, N., Bradley, R. S., Diaz, H. F., Baraër, M., Caceres, E. B., Forsythe, N., Fowler, H., Greenwood, G., Hashmi, M. Z., Liu, X. D. and Miller, J. R. Elevation-dependent warming in mountain regions of the world. *Nature Climate Change*, **5**, 424, doi: 10.1038/nclimate2563, 2015.

Religi, A., Backes, C., Chatelan, A., Bulliard, J-L., Vuilleumier, L., Moccozet, L., Bochud, M., Vernez, D. Estimation of exposure durations for vitamin D production and sunburn risk in Switzerland. *J. Expo. Sci. Environ. Epidemiol.*, **29**, 742–752, doi:10.1038/s41370-019-0137-2, 2019.

Internet data bases

http://www.meteoswiss.admin.ch/home/measurement-and-forecasting-systems/atmosphere/strahlungsmessnetz.html
http://wrdc.mgo.rssi.ru/

Collaborating partners / networks

Dr. S. Nyeki, Dr. J. Gröbner, "Physikalisch-Meteorologisches Observatorium Davos" (PMOD) World Radiation Center (WRC).
Dr. D. Vernez, Dr. J.-L. Bulliard, "Centre universitaire de médecine générale et santé publique, Unisanté, Lausanne"

Scientific publications and public outreach 2019

Refereed journal articles and their internet access

Nyeki, S., S. Wacker, C. Aebi, J. Gröbner, G. Martucci, and L. Vuilleumier, Trends in surface radiation and cloud radiative effect at four Swiss sites for the 1996–2015 period, Atmos. Chem. Phys., **19**, 13227–13241, doi: 10.5194/acp-19-13227-2019, 2019.
https://doi.org/10.5194/acp-19-13227-2019

Religi, A., C. Backes, A. Chatelan, J.-L. Bulliard, L. Vuilleumier, L. Moccozet, M. Bochud, D. Vernez, Estimation of exposure durations for vitamin D production and sunburn risk in Switzerland, J. Expo. Sci. Environ. Epidemiol., **29**, 742–752, doi: 10.1038/s41370-019-0137-2, 2019.
https://www.nature.com/articles/s41370-019-0137-2

Address

Office fédéral de météorologie et de climatologie MétéoSuisse
Station Aérologique
Ch. de l'Aérologie 1
CH-1530 Payerne
Switzerland

Contacts

Dr. Laurent Vuilleumier
Tel.: +41 58 460 9541
e-mail: laurent.vuilleumier@meteoswiss.ch