How much shade outdoors is healthy?

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Abstract. Shading in the natural and artificial environment of humans can limit the availability of solar radiation quite drastically. For vitamin D-weighted exposure the direct sun plays a minor role only. Instead, sky radiance has been found to be the dominant factor for human solar UV exposure. To determine the vitamin D_3–weighted exposure the solar spectral radiance must be known from all directions. Shading of buildings or trees reduces the incident radiance significantly. Within a city we found reductions of typically more than 50% compared to unshaded areas. We also found the reduction of exposure to be not simply proportional to the shaded fraction of the sky. As expected, the actual reduction strongly depends on the location. This was demonstrated in a movie taken by an all-sky camera. The incident radiance is also highly variable in time due to the presence of clouds. While in summer vitamin D-weighted radiation is plentiful, the situation in winter is completely different.

Introduction

Ultraviolet radiation from the sun causes a considerable global disease burden, including acute and chronic health effects on the skin, the eyes and the immune system (Seckmeyer et al. 2012). Negative effects of an increased UV exposure include erythema, and it is a fundamental parameter in the genesis of skin cancer (Haluza et al. 2014, Lucas et al. 2006). On the other hand, UV is essential for vitamin D_3 production of humans (WHO 2008). There is evidence that low vitamin D levels could be seen as an indicator of health risk relating to some sorts of cancers, infectious diseases (e.g., dental caries, pneumonia), and autoimmune diseases (e.g., diabetes mellitus type 1, multiple sclerosis) amongst others. Furthermore, there are established links with musculoskeletal disorders, Parkinson’s disease and rickets (Grant 2016, IARC 2008). The main source of vitamin D for humans is synthesis in skin due to solar UVB radiation (280–315 nm). Dietary intake usually contributes only a small percentage (10%) to the necessary supply (Biesalski et al. 2002). There are large seasonal differences in the production of vitamin D (Webb et al. 2010), which are mainly caused by the varying solar zenith angle and the different areas of skin that are exposed to solar radiation.

Earlier exposure investigations (e.g., by Diffey (2010) and McKenzie et al. (2009)) were based on the irradiance incident on horizontal or vertical surfaces. To better represent the UV dose of a human outdoors, Godar and Pope (2012) converted the weighted irradiance of a horizontal plane into that of a cylinder by using geometric conversion factors. However, these theoretical estimations were performed for an unobstructed location only. Kawanishi (Kawanishi 2010) used hemispherical images to estimate the shadowing of the sky by sun shades, although the subject of his study was the protection against erythemally-weighted radiation on a horizontal plane. Additionally, one single location may not be representative for an urban environment, because obstructions at different locations differ in shape and size, and therefore cover different parts of the sky. The irradiance on a horizontal surface should not be used for exposure calculations because the radiation field of the sky would have to be described by a single number only, which does not reflect the complex reality. Instead, the quantity “radiance” should be used (describing the radiant energy per unit solid angle and per unit area), thus taking into account the complex radiation field. Seckmeyer et al. (2013) developed an exposure model based on radiance in combination with a 3D-voxel model of a human. Most surfaces show a very low reflectivity in the UV range, therefore the radiance from obstructed directions can be neglected, which enables the determination of the exposure of a human by calculating the multidirectional downwelling radiance originating from unobstructed directions.

Discussion

To include the effect of obstructions of sky radiation in various directions we employed an all-sky camera with a fish-eye lens. The obstructions were determined under cloudy sky, which enabled a high contrast between shaded

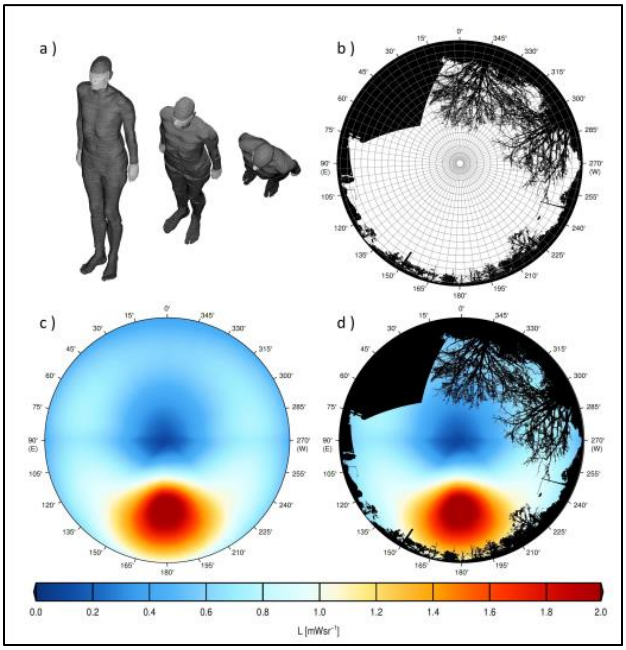

Figure 1. Visualization and sky radiance for calculating the UV exposure of a human with winter clothing from different angles (a). Obstruction by buildings (b) combination of sky radiance and projection areas (c) sky radiance, projection areas and obstructions combined (d)

and unshaded areas. Figure 1a shows the 3D model human wearing typical winter clothing: a hat, only hands and face exposed. Figure 1c shows the radiance distribution for clear sky on 21 March at noon in Hannover 52° N multiplied by the projection area from the corresponding incident and azimuth angle for a human with the face oriented towards the sun. Figure 1b displays the shadowing effect of a building; the black areas are obstructions covering the sky and the white area is unobstructed sky. Figure 1d and figure 2 combines all effects a-c.

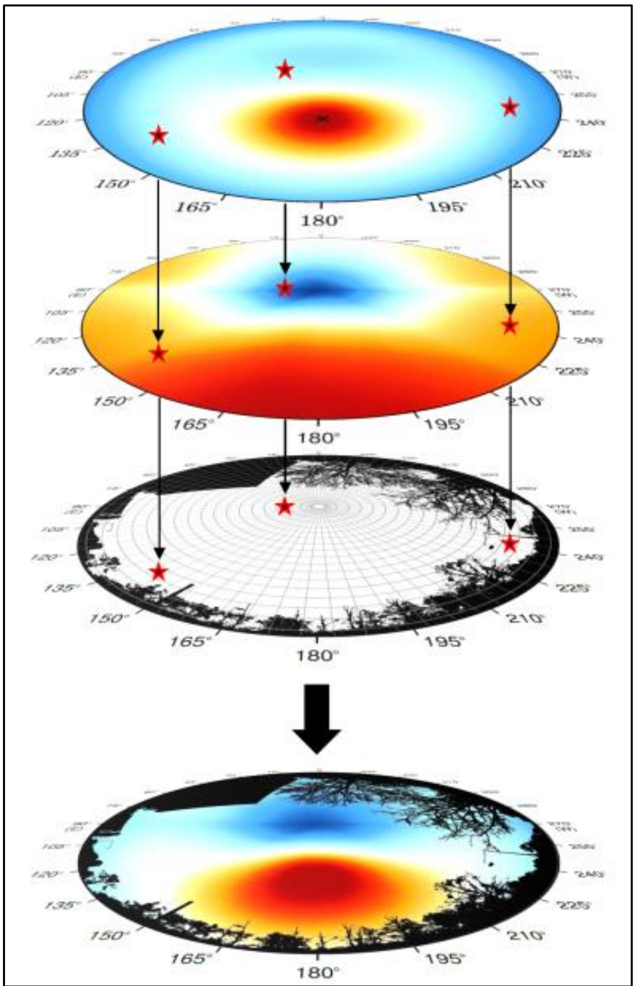

Figure 2. Simulated sky radiance (a), projection area for winter clothing (b), typical obstruction measurement with the all-sky camera (c) and in (d) the resulting sky radiance distribution of the combined effect of a-c.

Conclusions

There are large seasonal differences in the production of vitamin D that result in an insufficient vitamin D supply in humans living at middle or high latitudes. In a recent paper (Seckmeyer, G. et al., 2018 accepted) it has been found that the UV exposure in winter is several factors lower in Europe compared to mid-latitude sites in New Zealand. These large differences are due to differences in latitude and cloudiness. However, low UV exposure levels do not only occur in winter time; obstructions in urban environments reduce the exposure by at least 40-60%. While in summer sufficient UV is available, in winter it is hardly possible to gain enough UV exposure. Situations in autumn and spring should be further examined including cloudy conditions.

References

McKenzie, R., Liley, B., Johnston, P., Scragg, R., Stewart, A., Reeder, A., Allen, M. 2013. Small doses from artificial UV sources elucidate the photo-production of vitamin D. Photochemical & Photobiological Sciences 12: 1726–1737;doi:10.1039/c3pp50041a.

Diffey, B.L. 2010. Is casual exposure to summer sunlight effective at maintaining adequate vitamin D status? Photoderm. Photoimmunol. Photomed. 26(4): 172-176.

Godar, D.E., Pope, S.J., Grant, W.B., Holick, M.F. 2012. Solar UV Doses of Young Americans and Vitamin D3 Production. Environ. Health Perspect. 120(1): 139.

Grant, W.B. 2016. The role of geographical ecological studies in identifying diseases linked to UVB exposure and/or vitamin D. Dermatoendocrinol 8(1): e1137400.

Haluza, D., Simic, S., Höltge, J., Cervinka, R., Moshammer, H. 2014. Connectedness to nature and public (skin) health perspectives: Results of a representative, population-based survey among Austrian residents. Int. J. Environ. Res. Public Health 11(1): 1176-1191.

IARC, W.G.o.V.D. 2008. Vitamin D and cancer/a report of the IARC Working Group on Vitamin D. *No. 5*. 449 p.

Kawanishi, T. 2010. Evaluation of Ultraviolet Radiation Protection of a Membrane Structure Using a UC Shade Chart. Proceedings of ANZASCA2010.

Lucas, R., McMichael, T., Smith, W., Armstrong, B. 2006. Solar Ultraviolet Radiation: Global Burden of Disease from Solar Ultraviolet Radiation. Environmental Burden of Disease Series, No. 13. World Health Organization, Geneva.

McKenzie, R.L., Liley, J.B., Björn, L.O. 2009. UV Radiation: Balancing Risks and Benefits. Photochem. Photobiol. 85(1): 88-98

Seckmeyer, G., A.Zittermann, McKenzie, R., Greinert, R. 2012. Solar Radiation: 13. Solar radiation and human Health. *In*: Geuymard, C. (ed.). Encyclopedia of Sustainability Science and Technology, pp. 9649-9672. Springer.

Seckmeyer, G., Schrempf, M., Wieczorek, A., Riechelmann, S., Graw, K., Seckmeyer, S., Zankl, M. 2013. A Novel Method to Calculate Solar UV Exposure Relevant to Vitamin D Production in Humans. Photochem. Photobiol. 89(4): 974-983

Seckmeyer, G., Mustert, C., Schrempf, M., McKenzie, R.L., Liley, J.B., Kotkamp, M., F, B.A., Gillotay, D., Slaper, H., Siani, A.M., Smedley, A.R.D., Webb, A. accepted. Why is it so hard to gain enough Vitamin D by solar exposure in the European winter? Meteorol. Z., 2018, accepted

Webb, A.R., Kift, R., Durkin, M.T., O'Brien, S.J., Vail, A., Berry, J.L., Rhodes, L.E. 2010. The role of sunlight exposure in determining the vitamin D status of the U.K. white adult population. Br. J. Dermatol. (163): 1050-1055.

WHO 2008. World Health Organization, International Agency for Research on Cancer. Vitamin D and cancer. IARC Working Group Reports. WHO Press 5: 148.