Shade Performance Evaluation using UV Shade Chart

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Abstract. Using the ultraviolet radiation shade chart representing in equidistance projection, performance evaluation of shade against ultraviolet radiation is assessed.

Introduction

The ultraviolet radiation shade chart (UV Sky Chart) is used to visualize the strength of the ultraviolet radiation in the sky. Using the chart enables you to find out where a shade should be placed to reduce exposure to ultraviolet radiation. The chart was prepared by sorting through an enormous volume of measured ultraviolet radiation values to select the measured values for the sunny weather in summer. The reason for doing this is that shades are designed for conditions when the ultraviolet radiation is the strongest.

Discussion

The ASPF means Architectural Sun Protection Factor (Kawanishi, 2007, 2009, 2014; Kawanishi and Konno, 2006; Kawanishi and Otsuka, 2014a).

Analogous to the SPF of sunscreen, ASPF is the factor by which shade structures decrease erythemal UV irradiance, thereby increasing the time that can be spent in that place before a given amount of sun damage.

$$\mathrm{ASPF} = \mathrm{UV\ Index}_{\mathrm{unshaded}} \div \mathrm{UV\ Index}_{\mathrm{shaded}} \qquad (1)$$

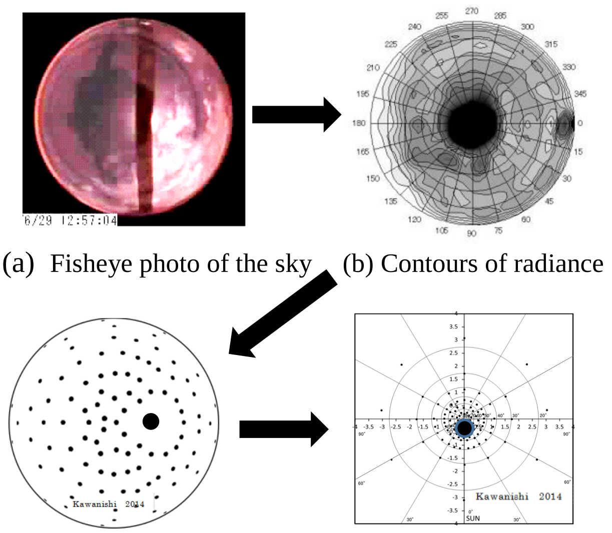
Using the ASPF, We can estimate how much the risk of sunburn can be delayed for people underneath a shade. Figure 1(a) is a fisheye photograph of the sky, (b) is a contour plot of the radiance of the hemispheric ultraviolet radiation (Kawanishi and Otsuka, 2014b), also with stippling to show the strength of the radiance. Measurements on which these are based were taken at Okinawa, Japan (Lat.24,Lon.124) from June 2011 to July 2012. The ultraviolet radiation in the vicinity of the sun is strong, and in the region close to the circumference formed by the horizon, the ultraviolet radiation is weak. The hemispheric shade chart (c) appears as (d) in 'equidistant' projection; projected onto a horizontal surface above the location. A picture of the shading obstructions is overlaid on the chart, and the points in the sky are counted to find out the fraction of ultraviolet radiation received beneath the shade structure. The number of points on the chart is proportional to the fractional UV Index received. Figure 2 shows the chart made by equidistance projection for a solar altitude of 70 degrees

$$\mathrm{ASPF} = (P_{dhs} + N_{skyhs}) \div \{C_f\,(P_{skyhs} - P_i)\} \qquad (2)$$

Here, P_{dhs} is the number of points corresponding to direct UVR, P_{skyhs} is the number for sky UVR, and P_i is the number inside the shade section, which is the ultraviolet radiation that enters under the shade, and C_f is a correction factor for the solar altitude, which is not necessary between 50 and 90 degrees, but is 1.2 at 40 degrees, and 1.4 at 30 degrees.

For a solar altitude from 60 to 90 degrees, there are 100 solar radiation points and 100 sky UVR points in this chart, the total number of points is 200, and:

$$\mathrm{ASPF} = 200 \div \{C_f \times (100 - P_i)\} \qquad (3)$$



(a) Fisheye photo of the sky (b) Contours of radiance

(c) UV shade chart (d) Chart in equidistant projection

Figure 1 Process of the chart.

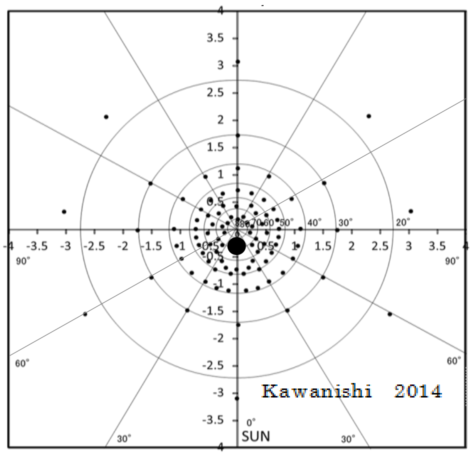
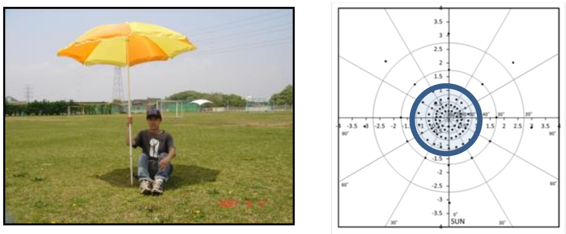


Figure 2. Ultraviolet radiation shade chart for a solar altitude of 70 degrees.

The vertical and horizontal axes in Figure2 are respectively the standardized quantities L_w, L_d obtained from dividing the width L_1 and the depth L_2 of the shade by the height L_h of the shade. For example, with a parasol of radius 1.7 m and a height at the edge of 1.7 m, 1.7 divided by 1.7 is 1, and a circle of radius 1 is drawn as in Figure 3. If the points inside the circle are counted, they number 50, and subtracting 50 from 100 and dividing by 200, the ASPF is found to be 4.



(a) Parasol (b) Parasol on chart

Figure 3. Parasol and the chart

The protection performance of the shade against the solar UVR classified as in Table 1 using the ASPF. There are 4 categories in the performance evaluation: Bad, Good, Good Protection, and Excellent Protection.

Table 1 Index of ASPF and performance evaluation.

ASPF	Subrun Time (min)	Evaluation	Contents
1～2	15	Bad	
3～5	45	Good	Lunch,Tea
6～9	90	Good Protection	Sports
10～	150	Excellent Protection	Work

Figure 4 gives application examples of shades with various shapes. The width and depth of the shade is standardized by dividing by the height of the shade, and a graph is copied onto the values on the chart. The points within the frame of the shade are then counted and the ASPF can be calculated from formula (3).

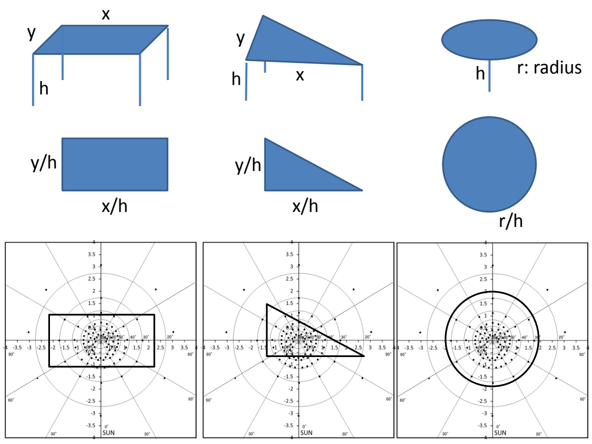


Figure 4. Differently shaped shade structures and their corresponding charts.

Different charts are applied to different solar elevation angles. It should be noted that the calculations presented are approximate only. They are specific to clear-sky conditions and with aerosol conditions similar to those at the measurement location. This is because the sky radiance distribution is a function of cloud and aerosol conditions. For example, under pristine conditions, the direct/diffuse ratio is larger (Zeng et al., 1994). The concept would also be improved by taking account of human geometry (Seckmeyer et al., 2013), rather than considering the irradiance falling on a horizontal surface.

References

Toshimasa Kawanishi, 2007, UV Shade Chart, Proc. of UV Conference, Switzerland pp.157-158.

Toshimasa Kawanishi, 2009, Shade performance evaluation for ultraviolet radiation protection, Proceeding of 43rd Annual Conference of the Australian and New Zealand Architectural Science Association.

Toshimasa Kawanishi, 2014, Shade Evaluation Method against Ultraviolet Radiation, UV Workshop 2014, National Institute of Water and Atmospheric Research, New Zealand.

Toshimasa Kawanishi、Masaya Konno, 2006, Beach Sunshade Design using Sky Ultraviolet Radiation Distribution, Journal of Environmental Engineering、Architectural Institute of Japan, 601, pp.59-64.

Toshimasa Kawanishi、Fumikazu Otsuka, 2014a, Making of UV Shade Chart using Radiance distribution of Sky Erythema Ultraviolet & Architectural Sun Protection Factor for Beach Shade, Journal of Environmental Engineering, Architectural Institute of Japan, 79,700, pp.563-569.

Toshimasa Kawanishi、Fumikazu Otsuka, 2014b, Distribution of Sky Erythema Ultraviolet Radiance for Low Latitude & Architectural Sun Protection Factor for Sunshade, Journal of Environmental Engineering Architectural Institute of Japan, 79, 696, pp.201-207.

Zeng, J., McKenzie, R., Stamnes, K., Wineland, M., Rosen, J. 1994. Measured UV spectra compared with discrete ordinate method simulations. Journal of Geophysical Research 99(D11): 23019-23030.

Seckmeyer, G., Schrempf, M., Wieczorek, A., Riechelmann, S., Graw, K., Seckmeyer, S., Zankl, M. 2013. A novel method to calculate solar UV exposure relevant for the vitamin D production in humans. Photochemistry and Photobiology 89: 974–983.