



RESEARCH ARTICLE

Linking the Ultraviolet Index to the “shadow rule” for sun protection: A theoretical model applied with a southern hemisphere example

Caradee Y. Wright^{1,2,3}  | Nathan J. Downs⁴ | Thandi Kapwata^{3,5} |
David Jean du Preez⁶ | Bianca Tod⁷ 

¹Climate Change and Health Research Programme, Environment and Health Research Unit, South African Medical Research Council, Pretoria, South Africa

²Department of Geography, Geoinformatics and Meteorology, University of Pretoria, Pretoria, South Africa

³Department of Environmental Health, University of Johannesburg, Johannesburg, South Africa

⁴School of Mathematics, Physics and Computing, University of Southern Queensland, Toowoomba, Queensland, Australia

⁵Climate Change and Health Research Programme, Environment and Health Research Unit, South African Medical Research Council, Johannesburg, South Africa

⁶FORRS Partners GmbH, Munich, Germany

⁷Division of Dermatology, Department of Medicine, Faculty of Medicine and Health Sciences, Stellenbosch University, Cape Town, South Africa

Correspondence

Caradee Y. Wright, Climate Change and Health Research Programme, Environment and Health Research Unit, South African Medical Research Council, Pretoria, South Africa.
Email: cwright@mrc.ac.za

Funding information

South African Medical Research Council and the National Research Foundation

Abstract

Personal solar ultraviolet radiation (UVR) exposure has positive and negative impacts on human health. Excess solar UVR exposure can be avoided through safe sun practices such as using sun protection and avoiding unprotected outdoor exposure when solar UVR levels are high. The shadow rule indirectly determines the sun's altitude by observing the length of a person's shadow during the course of the day. When the shadow cast by the sun on a horizontal surface is shorter than the height of the person casting the shadow, the solar UVR intensity is high and is deemed to have more risk. The magnitude of this risk depends on factors such as a skin type, sun protection used etc. The UV Index is a standardized measure to describe the intensity of solar UVR with respect to the human action spectrum for sunburn. It is frequently reported in weather forecasts aimed at the public. Here, we demonstrate the potential utility of the shadow rule and how it may be understood in relation to the UV Index in a subtropical southern hemisphere setting. Its use as a simple awareness tool for sun protection in locations where the UV Index is not made public has value in promoting sun exposure awareness and reducing personal exposure risk.

Abbreviations: CIE, International Commission on Illumination; DU, Dobson units; SZA, solar zenith angle; TCO, total column ozone; UVI, ultraviolet index; UVR, ultraviolet radiation.

This is an open access article under the terms of the [Creative Commons Attribution-NonCommercial](https://creativecommons.org/licenses/by-nc/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.

© 2025 The Author(s). *Photochemistry and Photobiology* published by Wiley Periodicals LLC on behalf of American Society for Photobiology.

KEYWORDS

environmental health, photoprotection, public health, solar zenith angle, sun exposure, sun position, UVI

INTRODUCTION

Personal solar ultraviolet radiation (UVR) exposure has positive benefits for human health and wellbeing, such as stimulating the production of vitamin D. Vitamin D deficiency is well established as a causative factor for rickets, a disease still prevalent and widespread globally.¹ It may also play an important role in preventing a range of medical conditions including certain autoimmune diseases and internal tumors.² Short-term effects of excess solar UVR exposure include sunburn and snow blindness, while long-term adverse effects include keratinocyte and melanoma skin cancers and eye diseases such as cortical cataract and pterygium.^{3,4} The main modifiable risk factor to prevent skin cancer is to practice safe sun behaviors including wearing protective clothing, applying sunscreens, staying in the shade and avoiding being outdoors unprotected during the times of the day when solar UVR levels are highest, that is, ~10:00–16:00 h.⁵

The Ultraviolet Radiation Index (UV Index) was originally introduced in 1992 and further developed by the National Weather Service and the US Environmental Protection Agency in 1994.^{6,7} This led to an internationally agreed “Global Solar UV Index”⁸ and was issued as an international standard by the CIE (CIE S 013/E:2003).⁹ The UV Index is used to describe the levels of erythemal (i.e., causing sunburn) solar UVR at different times of the day.⁸ Each exposure category of the UV Index is associated with a personal risk level and sun protection message to assist the public in best protecting themselves from excess solar UVR exposure (Table 1). The UV Index is most appropriate for people with light skin types.

Several countries, including Australia, New Zealand, the United States, and the United Kingdom, predict the

following day's UV Index value by hour of the day, usually for midday or noon, and provide this information to the public as part of routine weather forecasts. A systematic review considered the awareness, understanding, use and impact of the UV Index over a 20-year period and found that while awareness was high, comprehension and use to inform sun safety behaviors was low.⁷ Few studies have assessed the impact of the UV Index as an intervention or its impact on sun-related health outcomes and the results of these studies were heterogenous.^{10–12}

Prior to the introduction of the UV Index, the shadow rule was used around the world as a means of raising awareness about the need for sun protection when the sun's elevation in the sky increased and solar UVR intensity was likely to be high.¹³ The shadow rule of thumb is that “if your shadow is shorter than your height, it is time to avoid sun exposure”.¹⁴ This implies that quantitatively the sun's solar radiation can elicit erythema (or sunburn) for solar zenith angles $\leq 45^\circ$, especially for people with light skin color. A few studies have included the shadow rule in their suite of interventions for sun protection, for example, Carter et al.¹⁵ tested children's ability to correctly use the shadow rule for sun protection in Australia and found that 10-year old children were capable of applying the shadow rule.

Few studies, to the best of our knowledge, have related the shadow rule to the UV Index. One example was conducted in the Northern Hemisphere found that when a person's shadow is approximately the same length as their height (i.e., solar zenith angle = 45°), the UV Index is ~4, and protective measures are necessary.¹⁶ Silva¹⁷ did not relate the shadow rule to the UV Index but did suggest that using this method can lead to overexposure, and the UV Index together with the 5S steps (Slip, Slop, Slap, Seek,

TABLE 1 UV Index: Exposure category, index number, and sun protection message (adapted from epa.gov—<https://www.epa.gov/sites/default/files/documents/uviguide.pdf>) and NZ Cancer Society).

Exposure category	Index number	Sun protection message
Low	1–2	Low protection required. You can safely stay outside
Moderate	3–5	Protection required when spending long periods in the sun
High	6–7	Protection essential. Seek shade, apply sunscreen, wear protective clothing, a hat and sunglasses
Very high	8–10	Protection essential. Seek shade, apply and re-apply sunscreen, wear protective clothing, a hat and sunglasses
Extreme	11+	Reschedule activities for early morning and evening. Full sun protection is essential

and Slide) were more effective for sun protection in the tropics.

The shadow rule may be useful for countries where the UV Index is not broadcast daily to the public as a sun protection awareness mechanism, or for reasons of convenience and accessibility. It is also helpful in places with very sunny climates. In South Africa, for example, in the past, the South African Weather Service did forecast the UV Index. For a short while, the South African media reported the UV Index along with the weather report, but then stopped providing the UV Index since the maximum “index number” remained the same every day, likely as a result of the lack of cloud cover being incorporated into the UV Index model. There are pros and cons of both the UV Index and the shadow rule, including that the former is useful on cloudy days when the latter is not since shadows do not appear.

Since the shadow rule is a simple method of raising awareness about the need for sun protection, we sought to investigate whether the shadow rule may be understood in relation to the UV Index so that it might be used as a simple awareness tool for sun protection in places where the UV Index is not made public regularly via weather

forecasts or for end-users who might find it more convenient, for example, children. In so doing, the shadow rule might be translated into a UV Index-equivalent, when necessary, without the need for modeling predictions of the UV Index on a daily basis for an individual region, particularly in resource-constrained settings. Here, we present the theoretical derivation of the UV Index-shadow rule as well as its application in South Africa.

MATERIALS AND METHODS

Study setting

South Africa is situated at the southern tip of Africa, spanning the Tropic of Capricorn from the mid-latitudes of 22° to 34°S, and is divided into nine Provinces (Figure 1). Its topography ranges from coastal plains to mountain ranges reaching over 3000 m above sea level. The interior of the country is situated on an inland plateau with an average altitude of 1200 m. The general synoptic flow over South Africa is affected by the subtropical continental anticyclone and results in relatively cloudless skies. This

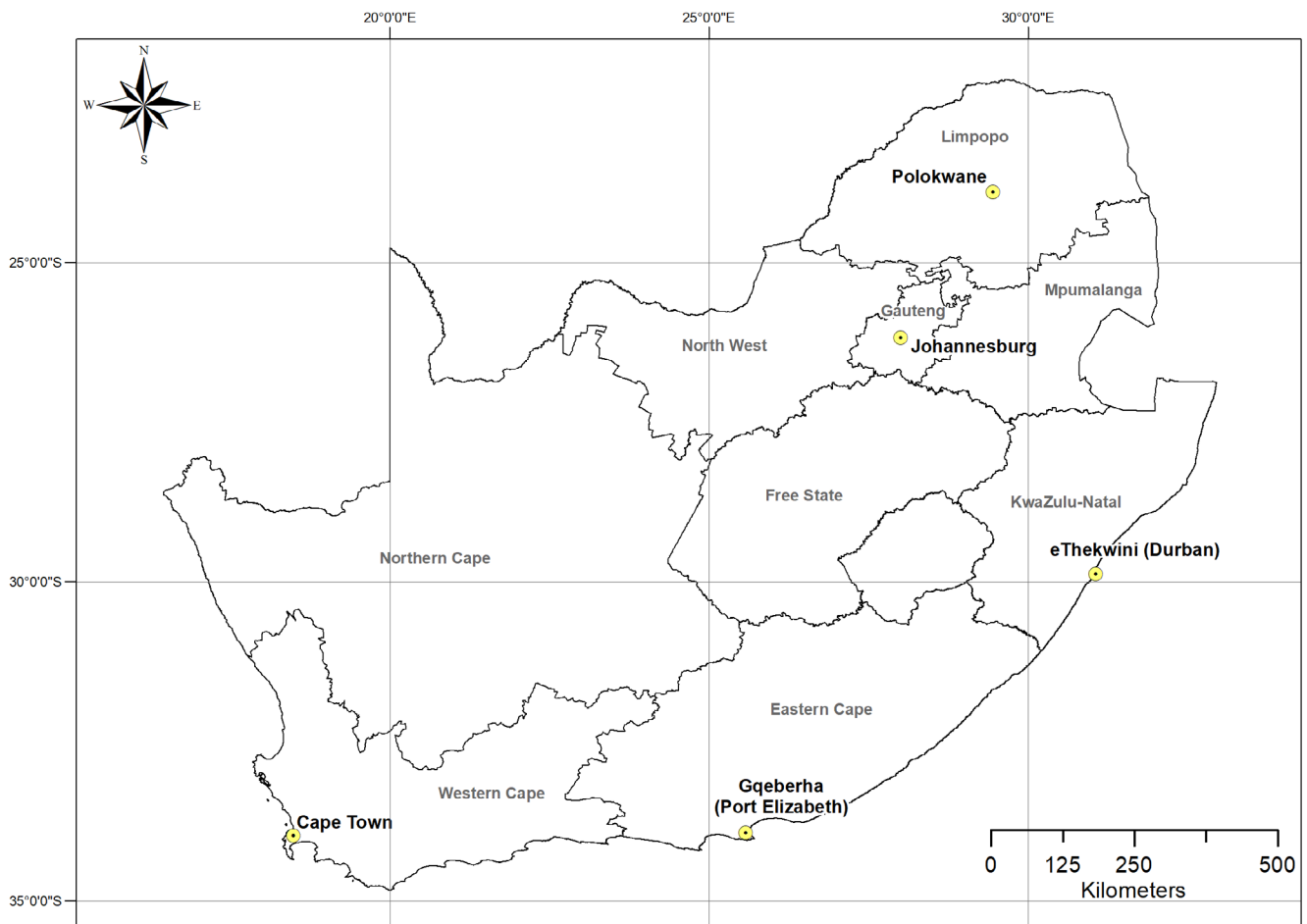


FIGURE 1 The provincial boundaries, major cities and topography of South Africa.

in combination with the latitude and altitude contributes toward very high surface UVR levels in summer and moderate midday levels in winter (Table 2).

As an illustration of the variation in the climate between the Northern and Southern Provinces, Table 2 presents the temperature, UV Index, and number of hours of sunshine per day in the winter and summer in Cape Town (representing the South) and Pretoria (representing the North Highveld) (Data from the South African Weather Services). These conditions, combined with an outdoor lifestyle, lead to the potential for excess solar UVR exposure, depending on personal phenotypic characteristics and behavior in the sun.

Surface solar UVR over South Africa is further affected by factors, such as ozone, solar zenith angle (SZA) and albedo. Atmospheric ozone, predominantly stratospheric ozone attenuates incoming solar UVR. Over South Africa, total column ozone (TCO) is at a maximum (~300 DU) during the early austral spring (September) and declines over the months when surface UVR is highest. TCO reaches a minimum during the late autumn (May). The variability in TCO increases with latitude and as a result, cities located further south may have a larger variability in TCO. Adjusting for seasonality, TCO is notably lower in tropical latitudes compared with higher mid-latitude zones. Decadal averages in TCO over a global tropical latitude of 20°S to 20°N have remained consistently around 260 DU since the year 1980 and up to 2020.¹⁸ At mid-latitudes TCO concentrations are also generally lower than found in the same respective northern latitudes. Typical decadal average TCO from 1980 to 2020 ranges between 350 and 320 DU at 35°N to 60°N, while in the Southern Hemisphere mid-latitudes TCO ranges are closer to 300–330 DU.¹⁸

During the austral winter months (June–July–August), the SZA is at a maximum. As the result, surface UVR is at its minimum due to the increased attenuation of UVR through the atmosphere. During the winter months, shadow lengths are also longer, and reach their greatest midday length during the winter solstice (21 June).

Solar elevation and Solar Zenith Angle

The SZA is the complement of solar elevation and is measured as the angle subtending the zenith and solar position. The UV index and relative shadow length are both functions of solar elevation (or its complementary SZA). Were it not for changing TCO, atmospheric particulate matter and cloud, solar irradiance could be modeled solely as a function of the elevation angle. The solar elevation angle is the primary driver of the solar UV irradiance and is examined here in terms of total relative shadow length or the cotangent of solar elevation where relative shadow

TABLE 2 Weather conditions, including UV Index, in Cape Town and Pretoria. South Africa has a single time zone, all listed cities observe UTC + 2. Data were gathered from the South African Weather Service website (www.weathersa.co.za).

	Southern provinces			Northern provinces		
	Cape Town	eThekweni (Durban)	Gqeberha (Port Elizabeth)	Johannesburg	City of Tshwane (Pretoria)	Polokwane
Latitude	34° S	29° S	33° S	26° S	26° S	23° S
Altitude	0–300 m	8 m	117 m	1753 m	1339 m	1310 m
Average hours sunlight per day	10	14	14	14	9	9
	7	7	9	9	9	8
UV Index	9–10	11	11	12	11+	12
	2–3	4	3	5	4–6	4
Average day-time temperatures (°C)	26	27	26	29	30	27
	19	22	20	16	21	19
Average night-time temperatures (°C)	15	17	18	14	18	17
	8	10	8	2	5	5

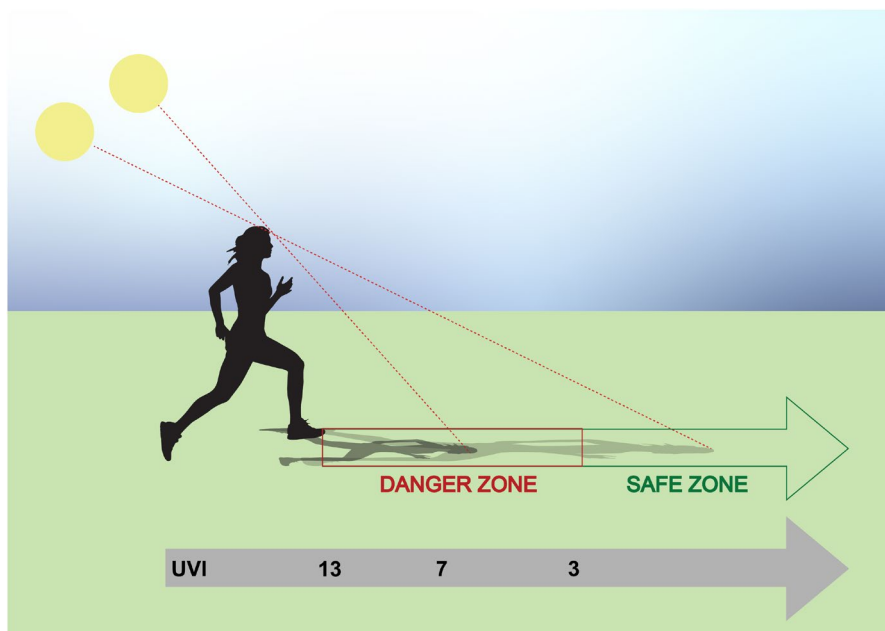


FIGURE 2 Relative shadow length on a horizontal surface.

lengths will match the height of an upright individual when the solar elevation is 45° . This is derived from simple trigonometry. In which case relative shadow length, L measured for a unit height of 1 is calculated as:

$$L = \cot(E^\circ) = \frac{1}{\tan(E^\circ)}, \quad (1)$$

where E° is the solar elevation angle. Solar elevations greater than 45° , such as those that occur near midday in summer result in shadow lengths less than the height of an upright individual. In the equation, when the sun is directly overhead at an elevation angle of 90° , the length of a shadow reduces to zero. Conversely, at low solar elevations, the shadow length tends toward an infinite length as the sun reaches the horizon at sunrise or sunset. At elevation angles above 10° the relative shadow length will fall from more than 5 times an upright individuals height to near zero at midday depending upon site latitude. The length of a shadow can similarly be understood by considering the increasing elevation of a light source as shown in Figures 2 and 3.

The maximum elevation angle of the sun is dependent on geographic latitude. The influence of latitude is easily understood by considering the annual position of the sun for an individual located on the equator. It is easy to imagine the celestial equator as a projection of the Earth's equator into the sky directly above this point. On the equinox, the sun would rise directly in the East and traverse the sky along the celestial equator reaching the zenith and setting due West. For South Africa, latitudes are restricted to between 22 and 34° S. The effect of this latitude restriction is that the celestial equator is offset from the zenith by between 22 and 34° S, depending on location. Here, for an

individual located in Cape Town the sun would still rise directly east and set due west on the equinox but would be restricted to a celestial path 34° north of the zenith (SZA 34°) at midday. Similarly, at South Africa's most northerly latitude, the sun would traverse a northern path reaching to within a maximum of 22° of the zenith. Due to the earth's orbit about the sun and the tilt of the earth's rotational axis, solar position is not however fixed upon the celestial equator at 0° , but instead shifts in declination by $\pm 23.44^\circ$ depending on the season. The equation of time is often used to describe solar celestial declination according to the day number of the year.¹⁵ During the Southern Hemisphere winter solstice (21 June), the sun traverses its most northerly path reaching a maximum elevation in Cape Town of $34 + 23.44^\circ$ from the zenith (SZA 57.44°). On the summer solstice (21 December), the sun will get closer to the zenith reaching $34 - 23.44^\circ$, or 10.56° SZA. For locations above the Tropic of Capricorn, summer solstice elevations will exceed the zenith with the sun reaching the southern celestial hemisphere. From Equation (1), it can be seen that shadow lengths will be minimized during this time of year.

In this research, solar position for all South African locations was determined using Michalsky's¹⁹ algorithm of solar position. The UV index which is a function of solar elevation, TCO, aerosol concentration and cloud fraction was modeled for a cloud-free stable atmosphere of fixed particulate density using the default parameters of Rundel's²⁰ modification to the spectral UV irradiance equations developed originally by Green et al.²¹ and modified by Green et al.²² (1980) and Schippnick and Green.²³ From the surface spectral irradiance, modeled for a

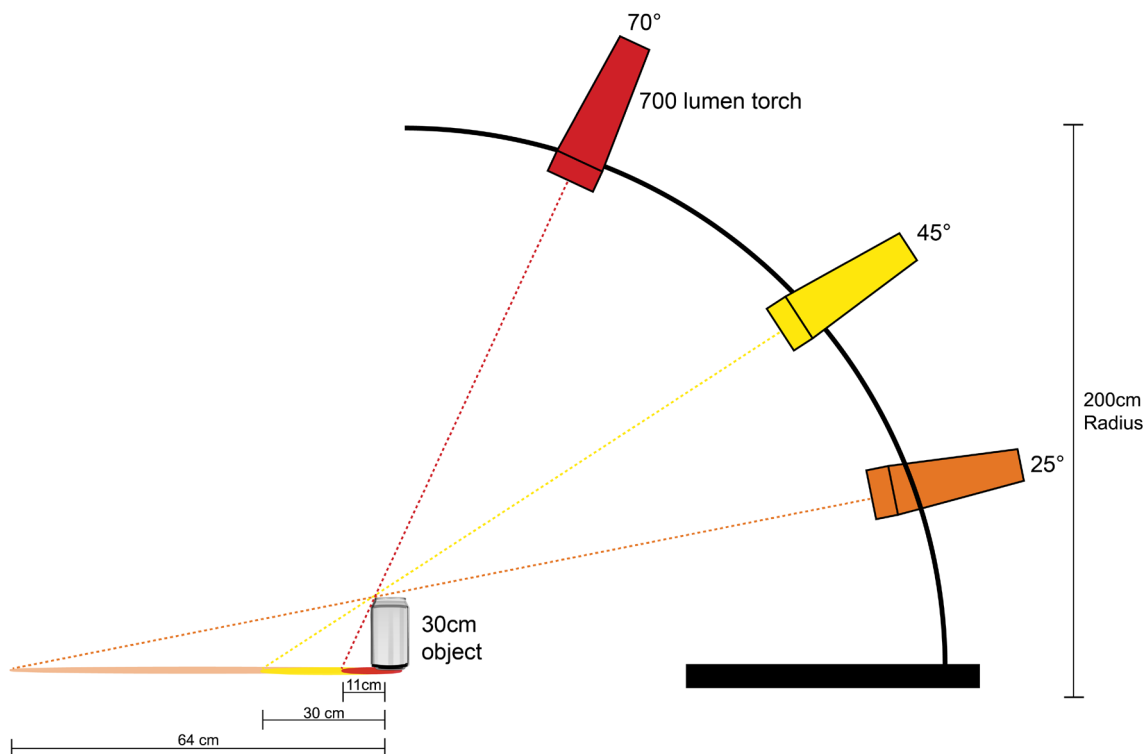


FIGURE 3 Shadow length may be derived as the cotangent of the elevation angle ($1/\tan(E^\circ)$).

defined atmospheric profile and given range in SZA, the UV index can be calculated by weighting to the human action spectrum for erythema²⁴ as:

$$\text{UVI} = \frac{10}{0.25} \int_{290 \text{ nm}}^{400 \text{ nm}} E(\theta, \lambda) S(\lambda) \quad (2)$$

where $E(\theta, \lambda)$ is the modeled spectral solar irradiance derived as a function of SZA, θ and wavelength, λ under a standardized atmospheric profile of fixed TCO and particulate density. $S(\lambda)$ as applied here is the internationally endorsed CIE standardized spectral weighting function for erythema²⁴ and the constant, $\frac{10}{0.25} \text{ m}^2 \text{ W}^{-1}$ reduces the standardized erythemally weighted irradiance to the unitless UV index.²⁵ Using this equation, the erythemally effective irradiance of 0.25 W m^{-2} is the equivalent of a UV index of 10.

The modeled UV index is derived for six population centers spanning the latitude range of Southern Africa. These locations include the cities of Cape Town (33.9249°S, 18.4241°E), Johannesburg (26.2041°S, 28.0473°E), Pretoria (25.7479°S, 28.2293°E), Gqeberha (Port Elizabeth, 33.9608°S, 25.6022°E), eThekwni (Durban, 29.8587°S, 31.0218°E), and Polokwane (23.8962°S, 29.4486°E). TCO concentrations of 200 DU, 300 DU, 400 DU, and 500 DU were modeled for each location respectively to consider the total range and possible fluctuation in seasonal TCO. UV indices modeled between

10 and 90° elevation are shown in Figure 4A. Figure 4B is the corresponding UV index represented as a function of the corresponding shadow length (after substituting into Equation 1) for each of the four TCO concentrations.

RESULTS

The peak daily SZA and UVI are illustrated for the calendar year at each of the six population centers of Cape Town, Johannesburg, Pretoria, Gqeberha, eThekwni, and Polokwane in Figure 5A,B, respectively. Evident in the Figure is the dependence of UV Index on SZA. In summer, near the solstice of 21 December, the SZA in each population center reaches its minimum value. At the same time, the annual UV Index reaches its peak. In winter, the SZA reaches its largest value and the UV Index is minimized.

Table 3 gives a 5-point summary of the minimum, maximum, median, and upper and lower quartile UV index for each of the six population center UV indices modeled in Figure 5 when the SZA is restricted to three ranges, namely, peak midday SZA ranges of $\text{SZA} \leq 27^\circ$; $27 < \text{SZA} \leq 45^\circ$; and $45^\circ \leq \text{SZA} \leq 63^\circ$. At these SZA ranges, the relative shadow length at midday will be less than 0.5, between 0.5 and 1, and between 1 and 2. For SZA ranges where the shadow length is less than 0.5 the UV Index ranges from 10 to 14. For SZA ranges where the relative shadow length is between 0.5 and 1, the UV Index ranges

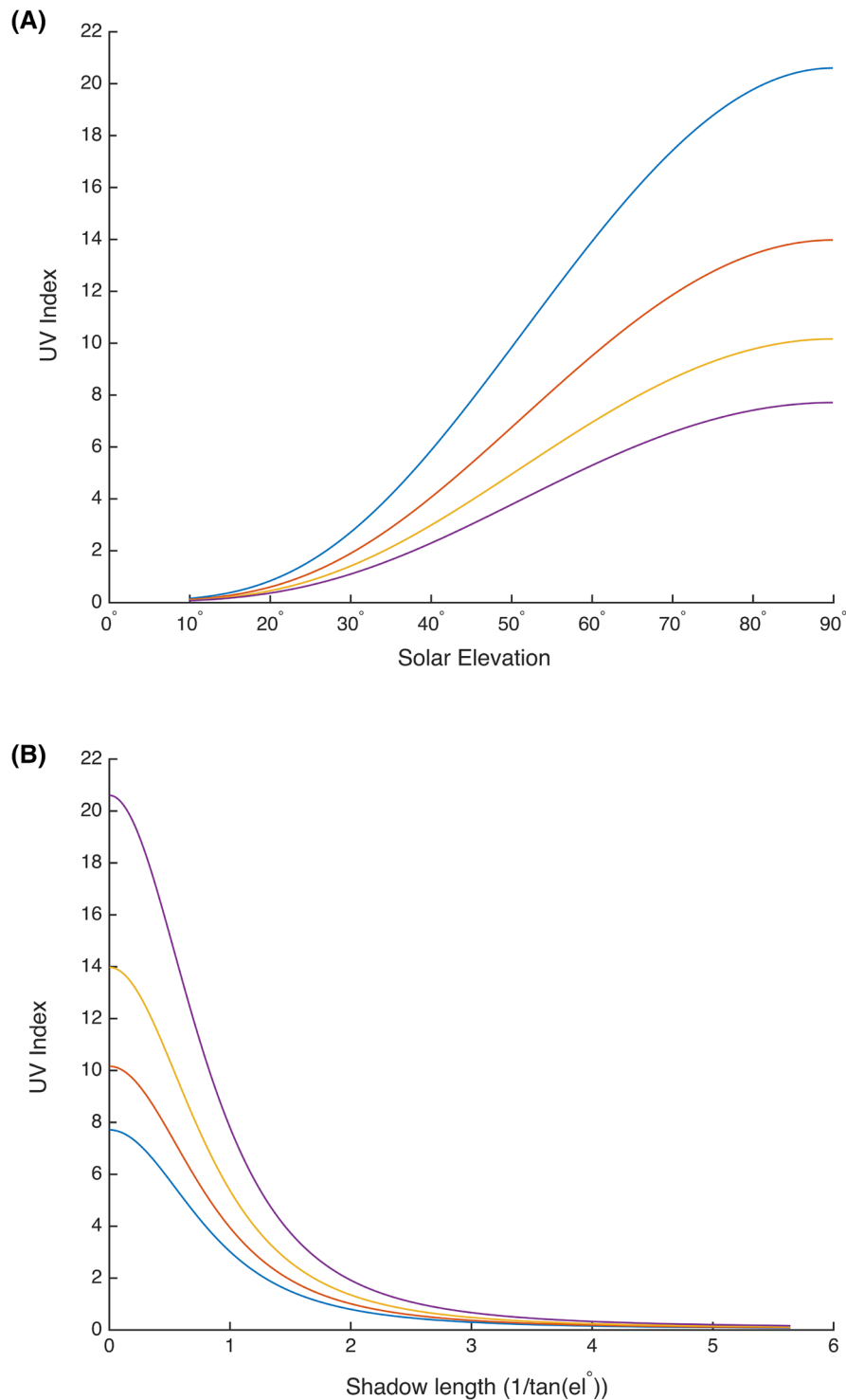


FIGURE 4 (A) Modeled variation in UV index (Equation 2) for changing solar elevation and TCO of 200 DU (uppermost curve), 300 DU, 400 DU, and 500 DU. (B) UV index expressed with respect to shadow length (Equation 1) for 200 DU (uppermost curve), 300 DU, 400 DU, and 500 DU.

from 5 to 10. For SZA ranges where the relative shadow length is between 1 and 2, the UV Index will range between 2 and 5 (low to moderate UV Index category). In ease case shown in the Figure, the TCO is set to 300 DU for all six South African population centers.

From Table 1, if no sun protection is required when the UV Index is low (<3), it might safely be assumed that shadow lengths greater than twice an individual's height will result in the UV Index being less than 3. As the range in UV Index in each of the six population centers ranges

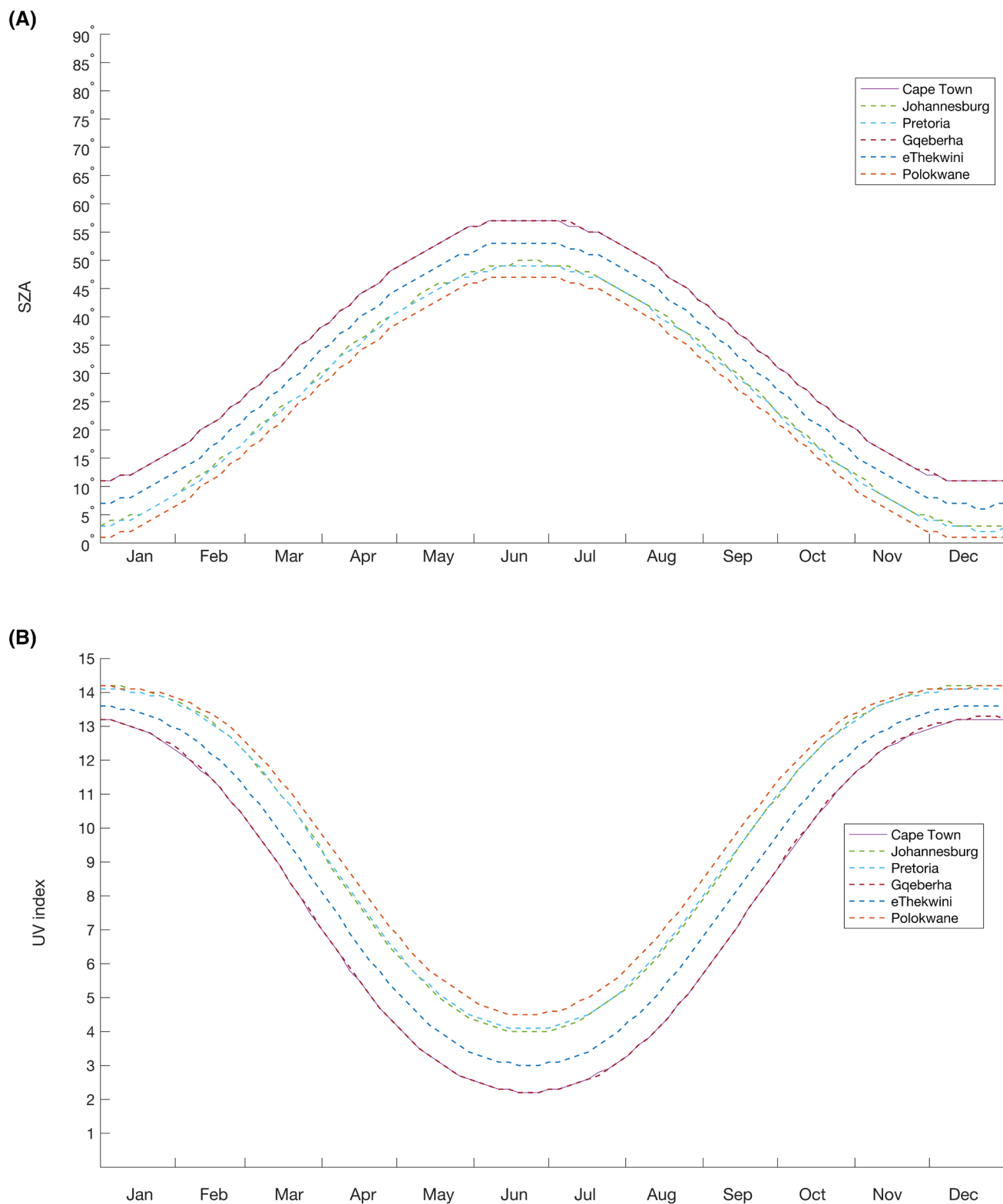
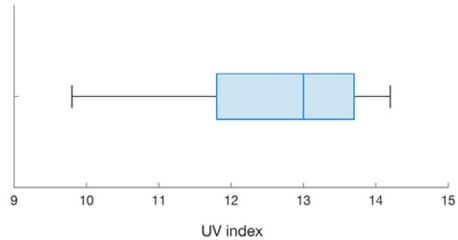
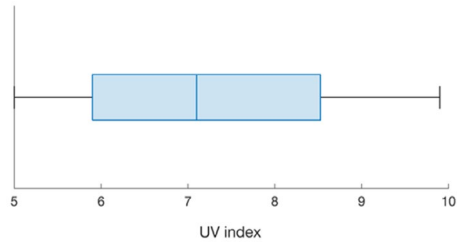
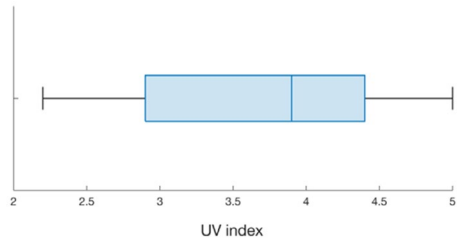


FIGURE 5 (A) Annual variation in daily peak solar zenith angle with time of year for Cape Town, Johannesburg, Pretoria, Gqeberha, eThekweni, and Polokwane. (B) Daily peak UV index modeled (lines) and observed (dots) at 300 DU for Cape Town, Johannesburg, Pretoria, Gqeberha, eThekweni, and Polokwane.

from 2 to 5 in SZA ranges between 45 and 63° (relative shadow lengths between 1 and 2) it might also be safely assumed that the UVI during these periods will be in the low

to moderate range (Table 3). Thus, for cases when the relative shadow length is greater than 1, sun protection may be recommended if an individual intended to stay in the sun

TABLE 3 Relative shadow length and corresponding solar zenith angle (SZA) range. The table includes five-point box plot summary statistics of the annual midday UV index in all six South African cities in Figure 5 over the listed SZA ranges for Cape Town, Johannesburg, Pretoria, Gqeberha, eThekweni and Polokwane. At South Africa's latitude the minimum and maximum midday SZA is 0° and 57° respectively.

Relative shadow length	SZA range	UV Index, Min (Q1, Q2, Q3) Max
0.5 or shorter	$SZA \leq 27^\circ$	
Up to 1	$27 < SZA \leq 45^\circ$	
Up to 2	$45^\circ < SZA \leq 63^\circ$	

for extended periods of time, in line with advice given for UV indices likely to be between 2 and 5. Given that the UV Index is likely to be high, very high or extreme for shadow lengths less than 1 (Table 3), sun protection should be essential during these periods. It may then be concluded that the UV index and potential for harm is greatest when the shadow length is less than the height of an individual.

DISCUSSION

Our work suggests that when a person's shadow is more than half their length, the risk of excess solar UVR exposure is lower than when that shadow is less than half their length, at which time, the UV Index is likely to be high, very high or extreme. The results of this model suggest that the traditional "shadow rule" is in fact a cautious representation of the South African setting, under strictly controlled conditions. In this context, UVI is in a dangerous range at relatively shorter shadow lengths than the traditional shadow rule suggests. While there are caveats to this potential association (see limitations section, below) this is the among one of the few times that the shadow rule of thumb has been considered in relation to

the UV Index metric and presents an opportunity for its testing in the real world (see recommendations, below). Such testing would help us better understand the validity of the approach as well as its acceptability and feasibility.

There is also scope to personalize the UV Index and the shadow rule for different skin types of phototypes. Most studies of sun protection focus on individuals with lightly pigmented skin. At present, insufficient evidence exists to formulate tailored sun protection advice for the spectrum of human skin color. The benefit conferred by sun protection diminishes with increasing skin pigmentation, however, does not reach zero. The risk of sun-induced skin cancer in people with darkly pigmented skin is low, although this has not been quantified. How this risk varies through the spectrum of skin color is also not clear. Photo-aging, pigmentary disorders and ocular sun damage are also relevant in individuals throughout the spectrum of skin color. This is an area that requires extensive research.²⁶

Our motivation behind wanting to understand the relationship between the shadow rule and the UV Index was grounded on the premise that not all locations have a forecast of the UV Index, and moreover, in places where the UV Index is forecast and publicly available, it is not well understood. As mentioned before, a large systematic review found

that while awareness was high, comprehension and use to inform sun safety behaviors was low.⁷ Similarly, among New Zealand and South African schoolchildren, there was an observed lack of awareness among many students in both countries.²⁷ The authors expressed how this provides an opportunity to introduce an innovative and age-appropriate UV Index communication method that combines the level of risk with behavioral responses to UV Index categories and focuses on personal relevance to the UV Index message. The shadow rule of thumb may be a solution to this dilemma, in particular for children since it is a relatively easy concept (shadow is shorter than half of your height, use sun protection) and does not require resources for its implementation. Arguably, under conditions during which the sun cannot be seen, such as under heavy cloud cover, during rain or foggy conditions, the absence of a personal shadow would also indicate a limited need for sun protection. This type of rule empowers people who may not have access to smartphones, Wi-Fi or data, including children. It could also be taught to outdoor workers. There are some caveats however that should still be considered. Cloud type, density, distribution and cloud height all influence the level of solar radiation reaching the surface.²⁸ High cirrus or cirrostratus cloud may prevent the formation of shadows but may still result in high and even elevated levels of diffuse solar radiation, that can cause sunburn.²⁹

The focus here is on providing a memorable method for persons not readily able to access UV index forecasts, for increasing seasonal sun exposure awareness and for application in the Southern African context, where conditions are often dry, and the UV index ranges daily from low to extreme levels depending upon the season. Clearly, any advice that suggests using sun protection when the shadow length is less than a relative length of 1 is useful. However, as highlighted by other authors, advice that emphasizes the value of sun protection in the morning as the sun is rising is even more critical for individuals venturing into the sun than it would be the afternoon when the sun is falling and shadows are growing longer as the day progresses.¹⁶ This and further work, addressing the usefulness or practicality of the shadow rule in rural and remote populations, including South America, Asia, or Australia as part of sun safety and education campaigns may yield information on the potential benefit of adopting “rule of thumb” advice in preventing disease caused by exposure to the sun.

Limitations

This theoretical model is one of the few that link the UV Index to the shadow rule. While we have tried to consider some of the most relevant factors, such as ozone, there are other factors that would require consideration to fully

operationalize its use in all micro-climates and local settings. For example, our model does not include cloud conditions (partly cloudy or full cloud) and cloud would influence the solar radiation reaching the Earth's surface and hence shadow length. Our model also only works on flat ground. More work is needed to understand the effects of slope on shadows and subsequently the shadow length itself. This may be too complex for layperson understanding, and it may be better to suggest that one should be on as flat ground as possible when applying the shadow rule as a sun protection guide. Other caveats may exist and should be carefully considered. It does not give an indication of other portions of the solar spectrum that are becoming relevant, for example, visible light. It may also need to be adapted for urban versus rural areas due to particulate matter influences.

Recommendations

We have reasonable confidence that the theoretical work underpinning our drawing of a relationship between the UV Index and the shadow rule is sound. However, we recommend that the model should be tested in the real world. A mixed-methods, ecological study might consider the UV Index on a given day and time, and have a range of people of different heights and in different places interpret the shadow rule and record their remarks at the same date-time. The two datasets (i.e., time-stamped UV Index and time-stamped shadow length) would then be verified for suitable comparison. Results would indicate the practicality and feasibility of the model, together with its validity. Any issues that arise would then be addressed; whether by amending the model by taking additional factors into account, or by tailoring the shadow rule itself with respect to its interpretation.

For example, the shadow length is between 1 and 2 times a person's height, we noted that the UV index was between 2 and 5 (low and moderate). Advice in these cases should model the standard guide for use of the UV index as outlined by the WHO.⁸ The UV index should always remain as the gold standard for advising the public on sun exposure. Difficulties that may arise with public use of this global metric, including fatigue of static forecasts, inability to access the forecast and general misunderstandings can however be guided by new research into environmental awareness tools as advocated by the shadow rule that has been revised and considered here in the South African context.

CONCLUSIONS

Excess exposure to solar UVR and its subsequent health impacts remain an ongoing pressing health problem in

many countries around the world. We demonstrated the potential use of the shadow rule of thumb and how it may be understood in relation to the UV Index. That is, if your shadow is shorter than half your length (or height), sun protection is necessary, especially during lengthy periods of exposure outdoors. While other factors may influence its practical application (e.g., slopes, clouds), this may be a simple awareness tool for sun protection in locations where the UV Index is not made public and as a general rule that may be used alongside UV Index forecasts to promote sun exposure awareness and reduce overall personal exposure risk.

ACKNOWLEDGMENTS

The South African Weather Service for provision of the solar ultraviolet radiation data. Caradee Y Wright receives research funding from the South African Medical Research Council and the National Research Foundation. We thank Thandi Kapwata from the South African Medical Research Council for making the map.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Caradee Y. Wright  <https://orcid.org/0000-0001-9608-818X>

Bianca Tod  <https://orcid.org/0000-0001-8204-8478>

REFERENCES

- Giustina A, Adler RA, Binkley N, et al. Controversies in vitamin D: summary statement from an international conference. *J Clin Endocrinol Metab.* 2019;104(2):234-240. doi:10.1210/jc.2018-01414
- Reijven PLM, Soeters PB. Vitamin D: a magic bullet or a myth? *Clin Nutr.* 2020;39(9):2663-2674. doi:10.1016/j.clnu.2019.12.028
- Narayanan DL, Saladi RN, Fox JL. Review: ultraviolet radiation and skin cancer. *Int J Dermatol.* 2010;49:978-986. doi:10.1111/j.1365-4632.2010.04474.x
- Yam JCS, Kwok AKH. Ultraviolet light and eye diseases. *Int Ophthalmol.* 2014;34:383-400. doi:10.1007/s10792-013-9791-x
- World Health Organization. Ultraviolet Radiation. 2002 <https://www.who.int/news-room/fact-sheets/detail/ultraviolet-radiation>
- Fioletov V, Kerr JB, Fergusson A. The UV index: definition, distribution and factors affecting it. *Can J Public Health.* 2010;101(4):I5-I9. doi:10.1007/BF03405303
- Heckman C, Liang K, Riley M. Awareness, understanding, use, and impact of the UV index: a systematic review of over two decades of international research. *Prev Med.* 2019;123:71-73. doi:10.1016/j.ypmed.2019.03.004
- World Health Organization, World Meteorological Organization, United Nations Environment Programme, International Commission on Non-Ionizing Radiation Protection. Global Solar UV Index: A Practical Guide. 2002 <https://iris.who.int/handle/10665/42459>
- Commission Internationale de l'Éclairage. CIE S 013/E:2003 International Standard Global Solar UV Index. 2003 <https://scispace.com/papers/cie-s-013-e-2003-international-standard-global-solar-uv-y7axtvn5>
- Morris J, Laing-Morton T, Marno P, Curnow A. An investigation into the awareness and understanding of the ultraviolet index forecasts in the southwest of England. *Photochem Photobiol Sci.* 2010;10:103-108. doi:10.1039/c0pp00232a
- Dixon HG, Hill DJ, Karoly DJ, Jolley DJ, Aden SM. Solar UV forecasts: a randomized trial assessing their impact on adult's sun-protection behaviour. *Health Educ Behav.* 2007;34:486-502. doi:10.1177/1090198106294644
- Bränström R, Ullén H, Brandberg Y. A randomised population-based intervention to examine the effects of the ultraviolet index on tanning behaviour. *Eur J Cancer.* 2003;36:968-974. doi:10.1016/s0959-8049(03)00117-5
- Holloway L. Atmospheric sun protection factor on clear days: its observed dependence on solar zenith angle and its relevance to the shadow rule for sun protection. *Photochem Photobiol.* 1992;56(2):229-234. doi:10.1111/j.1751-1097.1992.tb02151.x
- Downham TF 2nd. The shadow rule: a simple method for sun protection. *South Med J.* 1998;91(7):619-623. <https://pubmed.ncbi.nlm.nih.gov/9671831/>
- Carter OB, Mills BW, Mazzucchelli GN, Carolan CW. Testing children's ability to correctly use the "shadow rule" for sun protection. *Int J Environ Health Res.* 2016;26(3):317-325. doi:10.1080/09603123.2015.1111311
- Sliney DH, Wengraitis S. Is a differentiated advice by season and region necessary? *Prog Biophys Mol Biol.* 2006;92:150-160.
- Silva AA. The shadow rule, the UV index, and the 5S steps in the tropics. *Health Phys.* 2020;119(3):358-362. doi:10.1097/HP.0000000000001220
- World Meteorological Organization (WMO). *Scientific Assessment of Ozone Depletion.* WMO; 2022, GAW Report No. 278.
- Michalsky JJ. The astronomical Almanac's algorithm for approximate solar position (1950-2050). *Sol Energy.* 1988;40:227-235. doi:10.1016/0038-092X(88)90045-X
- Rundel R. Computation of spectral distribution and intensity of solar UVB radiation. In: Worrest RC, Caldwell MM, eds. *Stratospheric Ozone Reduction, Solar Ultraviolet Radiation and Plant Life.* Springer-Verlag; 1986:49-62 https://link.springer.com/chapter/10.1007/978-3-642-70090-3_3
- Green AES, Saada T, Shettle EP. The middle ultraviolet reaching the ground. *Photochem Photobiol.* 1974;19:251-259. doi:10.1111/j.1751-1097.1974.tb06508.x
- Green AES, Cross K, Smith LA. Improved analytic characterization of ultraviolet skylight. *Photochem Photobiol.* 1980;31:59-65. doi:10.1111/j.1751-1097.1980.tb03683.x
- Schippnick PF, Green AES. Analytical characterization of spectral actinic flux and spectral irradiance in the middle ultraviolet. *Photobiol Photochem.* 1982;35:89-101. doi:10.1111/j.1751-1097.1982.tb03815.x
- Commission Internationale de l'Éclairage. Erythema Reference Action Spectrum and Standard Erythema Dose, ISO 17166:1999,

- CIE S 007/E:1998. 1998 <https://www.iso.org/obp/ui/#iso:std:iso:17166:en>
25. Webb AR, Slaper H, Koepke P, Schmalwieser AW. Know your standard: clarifying the CIE erythema action spectrum. *Photochem Photobiol.* 2011;87:483-486.
26. Tod B, Whitaker D, Visser W, et al. Integrated sun protection advice for the south African population. *Int J Dermatol.* 2024;63(3):277-287. doi:[10.1111/ijd.16980](https://doi.org/10.1111/ijd.16980)
27. Wright CY, Reeder AI, Albers PN. School students' knowledge and understanding of the global solar ultraviolet index. *S Afr Med J.* 2015;105(12):1024-1029. doi:[10.7196/SAMJ.2015.v105i12.10120](https://doi.org/10.7196/SAMJ.2015.v105i12.10120)
28. Calbó J, Pagès D, González J-A. Empirical studies of cloud effects on UV radiation: a review. *Rev Geophys.* 2005;43(2):1-28. doi:[10.1029/2004RG000155](https://doi.org/10.1029/2004RG000155)
29. Sabburg J, Calbó J. Five years of cloud enhanced surface UV radiation measurements at two sites (in the northern and southern hemispheres). *Atmos Res.* 2009;93(4):902-912.

How to cite this article: Wright CY, Downs NJ, Kapwata T, du Preez DJ, Tod B. Linking the Ultraviolet Index to the “shadow rule” for sun protection: A theoretical model applied with a southern hemisphere example. *Photochem Photobiol.* 2026;102:67-78. doi:[10.1111/php.14116](https://doi.org/10.1111/php.14116)