Short wavelength cut-offs and maximum spectral irradiance wavelengths comparison of the spectra for erythema and pre-vitamin D$_3$ synthesis

A.V. Parisi, D.J. Turnbull, J. Turner

Faculty of Sciences
Toowoomba, Australia
Introduction

• Minimisation of UV exposures necessary to reduce the risks of skin cancer and sun-related eye disorders
• Beneficially, UVB exposures required to initiate the first stage of the synthesis of pre-vitamin D₃
• Requires optimisation of the solar UV exposures to humans
• Requires understanding of the complex interactions between the factors influencing the solar UV
Aims

The aims of this research were

- To compare the short wavelength cut-offs ($\lambda_c$) and
- the wavelengths of the maximum spectral irradiances ($\lambda_{\text{Max}}$)
- for the spectral UV for the initiation of the formation of pre-vitamin D$_3$ (UVD$_3$) and for the erythemal UV (UV$_{\text{Ery}}$)
Spectral Solar UV

• Integrated automated cloud and spectral UV measurement system employed

• UV spectroradiometer enclosed in a weather proof container:
  • double monochromator
  • 280 to 400 nm in 0.5 nm increments every 5 min

• Located on an unshaded roof at University of Southern Queensland, Toowoomba, Australia
Cloud Cover

- Total sky imager installed on a building roof
- Weatherproof installation with battery backup
- Every 5 min images acquired & processed to calculate fractional cloud cover
Spectral UVD₃

- Employed spectral UV data at 5 min intervals in the first six months of 2003
- Example solar UV spectrum for solar zenith angle of 7.5°
- Action spectrum for the photolysis of 7-dehydrocholesterol (7-DHC) in skin to pre-vitamin D₃ (Webb, 1993)

- Weighting the UV spectrum with the action spectrum gives the spectral UVD₃
Spectral UVD$_3$

- Compare to UV spectrum for SZA of 77.2°
- Short wavelength cut-off, $\lambda_{CD3}$ defined as wavelength at which irradiance was 0.1% of the maximum
- $\lambda_c$ and $\lambda_{Max}$ for the spectral UVD$_3$ shift to longer $\lambda$ for higher SZA
Spectral UVD$_3$

- Comparison of spectral UV$_{D3}$ and UV$_{Ery}$
- In this case SZA = 13.8°
- The peak of the spectral UV$_{D3}$ shifts to a longer wavelength compared to that for UV$_{Ery}$
Cut-off Wavelengths over a day

- Variation over a typical summer’s day on 8 Jan
- The $\lambda_c$ for the UV$_{D3}$ are shifted to longer $\lambda$ by an average of 1 nm compared to $\lambda_c$ for the UV$_{Ery}$

![Graph showing cut-off wavelengths over a day]
UVD$_3$ Cut-off Wavelength

- 12,493 data points over first 6 months of 2003
- Variation of the $\lambda_{CD3}$ for the spectral UVD$_3$ for all the SZA and the atmospheric conditions
- $\lambda_{CD3}$ ranges from 290 to 300 nm
UVD$_3$ Cut-off Wavelength

- Cloud free cases (<2% cloud)
- 2,460 cloud free cases
- $\lambda_{CD3}$ ranges from 290.5 to 298.5 nm
- Spread of data is less, but general variation with SZA is similar
Ratios

- Ratio of the $\lambda_C$ for the $UVD_3$ compared to those for the $UV_{Ery}$
Ratios

- Ratio of the $\lambda_{\text{Max}}$ for the $\text{UV}_{D3}$ compared to those for the $\text{UV}_{Ery}$
- $\text{UV}_{D3}/\text{UV}_{Ery} \geq 1$ for SZA up to $\sim 60^\circ$
• Classified data into SZA ranges and cloud cover into octas
• No effect on the cut-off wavelength with cloud cover
• Data point is mean
• Error bars are ± 1SD
Wavelength of Max Irradiance, $\lambda_{\text{MaxD3}}$

- $\lambda_{\text{MaxD3}}$ remains relatively unchanged for the range of cloud cover and SZA
- Majority of values are 310.5 nm with an increase to 312.5 nm for larger SZA

![Graph showing wavelength of max irradiance vs SZA](image-url)
**UVD₃ Irradiances**

- **Effect of cloud considered on UVD₃ irradiances**
- **Data points are means of the irradiances in each SZA range for each octa category**
- **Error bars are ± 1 SD**
- **Minimal effect of cloud for 0-5.5 octa**
- **Cloud effect for 5.5-8.0 octa range**
Dosimeters for Previtamin $D_3$

- Action spectrum for the synthesis of previtamin $D_3$ (Webb, 1993) can be approximated by the spectral response of polysulphone.

- Use of this action spectrum allows calibration of polysulphone dosimeters to measure UVD$_3$.
Conclusions

• $\lambda_c$ and $\lambda_{\text{Max}}$ of the UVD$_3$ and UV$_{\text{Ery}}$ have been compared for the SZA range of $4.7^\circ$ to $80^\circ$

• Averaged over 6 months, the $\lambda_c$ for UVD$_3$ is higher by 0.9 nm than that for UV$_{\text{Ery}}$

• The $\lambda_{\text{Max}}$ is higher for the UVD$_3$ compared to the UV$_{\text{Ery}}$ for SZA less than $\sim 60^\circ$ and less than that for UV$_{\text{Ery}}$ for higher SZA

• $\lambda_c$ of the UVD$_3$ is not influenced by clouds

• $\lambda_{\text{Max}}$ is relatively unchanged by cloud cover and SZA

• The magnitude of the UVD$_3$ is influenced only for more than 5.5 octa cloud

• Polysulphone dosimeters can be used to measure UVD$_3$ in different environments