Calibration of Solaria

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Abstract. Solar UV spectral measurements have been made at Lauder and other global sites since the late eighties using spectroradiometers that have a wide dynamic range and that are calibrated to absolute traceable standards. However, these are unsuitable for absolute spectral measurements of solaria because of their size, lack of pointing flexibility and slow measurement times. For spectral measurements in the HRC UV and vitamin-D project a small Ocean Optics USB4000 miniature spectrometer has been used. The strengths and limitations of this system are outlined. Variations within solaria are shown and conclusions drawn about the overall accuracy. Solar and spectra from the solaria are shown. Using the erythemal and vitamin-D action functions, weighted irradiances are calculated for erythema and vitamin-D and compared with solar values. The "efficiency" of sunbeds compared with the sun in producing vitamin-D with minimum erythemal effects is discussed.

Background

The NIWA solar UV spectrometer system is a standard design and includes a large (300 mm focal length) double monochromator with a photomultiplier detector, precision secondary standard calibration lamp facility and accurate temperature control. They are in use in several countries, mainly in collaborative solar UV research programmes. The accompanying paper by Michael Kotkamp has more information.

Miniature Spectrometer for Solaria use

For measurements in the confined space of solaria, we had to find a suitable compact alternative. An Ocean Optics USB4000 spectrometer was chosen.

The advantages of this spectrometer are:

- Compact, light, easy to point within Sun-Bed chamber
- Direct USB computer connection for power and data
- Fast spectrum acquisition (seconds)

The disadvantages are:

- Limited dynamic range (300:1)
- Expect stray light issues (single grating spectrometer)
- Relatively insensitive in UV (front illuminated CCD detector)
- Detector dark signal strongly depends on temperature (10% change in 5 mins observed)

Spectrometer Stray light correction

Figure 1 shows the effect of stray light in the critical 300nm region. Note the y scale used: the spectrum peak at 360nm is about 400,000 counts. The black plot is with no filter and the dark blue plot is with a 280nm cut off Schott filter in the input light path. The signal below 280nm is the same with and without the cut-off filter showing that there is no signal from the sun-bed lamps in this wavelength region. This enables the region between 250-270nm to be used as an estimate of the stray light above 270nm. The fitted red line is used as a baseline for calculations using the spectrum. Results using this correction agree reasonably well with transfer calibrations from Figure 1 measurements using a lamp identical to the ones in the Auckland bed by both a NIWA standard solar spectrometer and the miniature spectrometer.

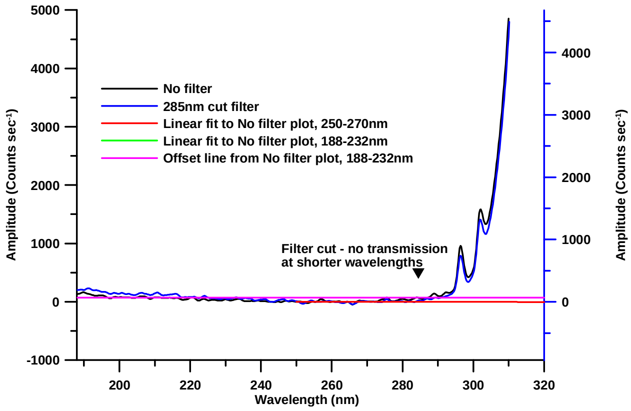

Figure 1. Effect of stray light in the UVB region

Solaria Used in the Vitamin-D project

Two locations, Dr. Wishart's Phototherapy Clinic in Auckland, and the Moana Pool in Dunedin were used for the controlled UV exposure of some subjects in the Vitamin-D Project. The calibration of the solaria was an essential part of determining the length of exposure. Table 1 shows the technical details of each solarium.

Location	Designation	Tubes
Auckland Dr Wishart	UV-A chamber Daavlin	36 x Light Sources F72 T12 BL-HO
Auckland Dr Wishart	UV-B chamber Daavlin Spectra 726-SP-2X	24 x Philips 'TL' UV-B
Dunedin Moana Pool	Hapro Luxura Newer Blue bed	26 x 100 W R Maxlight + face
Dunedin Moana Pool	Older Cream bed	24 x 100 W Cosmedico Brilliant + face

Table 1. Technical details of the four solaria used.

Uniformity and Stability of Dunedin Solaria

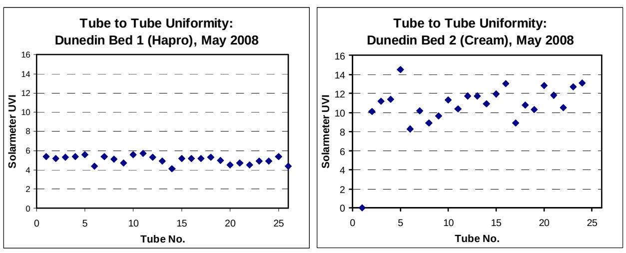

Figure 2. Tube to tube uniformity in two sunbeds

The spatial and temporal uniformity of the sunbeds was measured using a hand held solar meter. This gives a relative scale because the solar meter is designed for measuring solar spectra. Results are shown in Figure 2, and in Tables 2 and 3.

•	• 0.5 m (leg)		• 1.0 m (waist)		• 1.5 m (chest)	
Mean	Lower	Upper	• Lower	• Upper	• Lower	• Upper
Bed 1	5.6	5.7	• 5.6	• 6.0	• 6.6	• 6.1
Bed 2	12.1	11.5	• 12.6	• 12.1	• 13.0	• 12.4

Table 2. Longitudinal uniformity along two sunbeds

Sunbed	RMS %
Auckland UV-A Chamber	1.4
Auckland UV-B Chamber	5.5
Dunedin Bed 1 (Hapro)	7.3
Dunedin Bed 2 (Cream)	3.0

Table 3 Temporal changes derived from at least 5 measurements over the 2-year study period

Comparing Sunbed and Solar Spectra

Figure 3 compares weighted irradiances from the Auckland beds with those from typical summer and winter solar spectra. Note the logarithm scale used on the y-axis. Unweighted spectra, and action spectra for vitamin D production and erythema are shown in the accompanying paper by McKenzie et al. Conspicuous in these plots is the larger irradiance of the UVA solaria in the 320–380nm region and the UVB solaria in the 300-320nm region, compared with the summer solar spectrum.

Table 4 summarises the results of all sunbed measurements. Ratios of Vitamin D weighted irradiance to erythemal weighted irradiance represent the “Efficiency” of producing vitamin D, based on the currently accepted action spectra for the production of vitamin D and erythema. Higher efficiency means higher vitamin D production for a given erythemal irradiance. Based on the currently accepted action spectra for vitamin D production and erythema, most sunbeds are not as efficient as summer sunlight in producing Vitamin-D. According to this definition, their efficiency should be approximately the same as for winter sunlight.

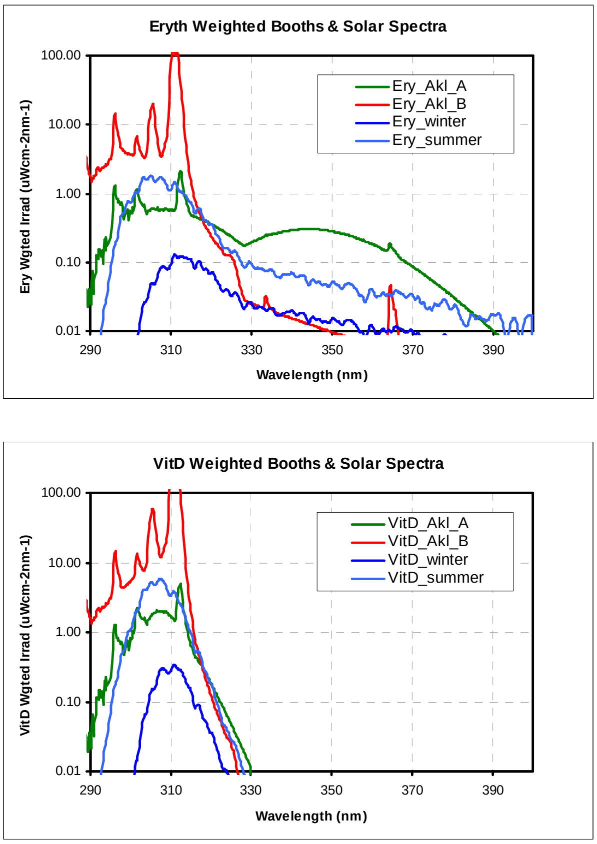

Figure 3. Spectra weighted by the action spectrum for erythema (upper panel) and vitamin D production (lower panel) from sunbeds compared with sunlight.

	Akl_ Bed A	Akl Bed B	Dun Bed 2	Dun Bed 1	Winter Sun	Summer Sun
UVA	17515	1527	11484	11147	1797	6162
UVB	156.9	5544.9	193.8	67.0	17.9	206.6
UV_{Ery}	30.0	408.1	28.8	13.8	2.6	28.2
UV_{VitD}	34.8	997.4	42.1	14.8	3.2	56.7
UVI	12.0	163.3	11.5	5.5	1.0	11.3
t(2SED)	11.1	0.8	11.6	24.1	128.1	11.8
VitD/Ery	1.16	2.44	1.46	1.07	1.22	2.01
%UVB	0.89	78.41	1.66	0.60	0.99	3.25

Table 4. Comparison between sunbeds and sunlight. Weighted irradiance values have units of μWcm^{-2}. t(2 SED) is the time in minutes to achieve an exposure of 2 SED (i.e., 200 Wm^{-2} of erythemally weighted UV, which approximates one minimum erythemal dose (MED) for sensitive skin.