Calibration Certificate

No. 2008-92-10-1

Calibration Item

UVB Pyranometer

Manufacturer	Yankee Environmental Systems, Inc.
Type	UVB-1
Serial number	010938

Customer

PMOD/WRC
Dorfstrasse 33
7260 Davos Dorf
Switzerland

Calibration Mark

2008-92-10-1

Date of calibration

20 June - 11 July, 2008

Davos Dorf, 22 September, 2008

Dr. Gregor Hülsen	Dr. Julian Gröbner
In charge of calibration	Head UV Center

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Calibration procedure

The test instrument was installed on the roof platform of PMOD/WRC beside the reference spectroradiometer QASUME[1] (Gröbner et al., 2005). The measurement signal U was recorded on an Agilent 34970A data acquisition system. The darksignal of the instrument U_{dark} was obtained during the night (20 UT to 3 UT) (Hülsen and Gröbner, 2007).
Secondary calibration standards T68522 and T68523 were used during the calibration.

Calibration results:

The calibration of the test instrument is obtained from the following equation (Webb et al., 2007):

$$E_{\mathrm{CIE}} = (U - U_{\mathrm{dark}}) \cdot C \cdot f_n(\Theta, \mathrm{TO_3}) \cdot Coscor(\Theta)$$

where E_{CIE} is the erythemal weighted irradiance in $\mathrm{Wm^{-2}}$
U is the raw signal of the test instrument in Volt
U_{dark} is the dark offset in Volt
C is the calibration coefficient, determined for the solar zenith angle (SZA) $\Theta = 40°$ and the total column ozone $\mathrm{TO_3} = 300\ \mathrm{DU}$
$f_n(\Theta, \mathrm{TO_3})$ is a function of Θ and $\mathrm{TO_3}$; it is normalised at $\Theta = 40°$ and $\mathrm{TO_3} = 300\ \mathrm{DU}$
$Coscor(\Theta)$ is the cosine correction function in dependence of the SZA

Calibration coefficient C:

C = 0.1103 $\mathrm{Wm^{-2}V^{-1}}$
u = 0.0078 $\mathrm{Wm^{-2}V^{-1}}$

The expanded uncertainty of measurement **u** is obtained from the variability of the erythemal weighted irradiance of the test instrument relative to the reference spectroradiometer combined with the uncertainty of the reference spectroradiometer.

The reported expanded uncertainty of measurement **u** is stated as the standard uncertainty of measurement multiplied by the coverage factor $\mathrm{k} = 2$, which for a normal distribution corresponds to a coverage probability of approximately 95%.

[1] The QASUME spectroradiometer B5503 is made available by the Institute of Health and Consumer Protection of the Joint Research Centre of the European Commission, Ispra, Italy through a collaboration agreement with PMOD/WRC.

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The calibration vector $f_n(\Theta, \mathrm{TO_3})$ is obtained from radiative transfer calculations using the spectral response function of the test instrument to convert from detector weighted to erythemal weighted irradiances (see calibration certificate 2008-92-10-2). It is normalised at 40° SZA and total ozone column of 300 DU (f_0=0.161). Model spectra were obtained using the sdisort solver of libRadtran 1.1 with the following input parameters: 16 Streams, Standard atmosphere Midlatitude summer (afglms), Albedo 0.035, AOD: $\beta = 0.02$, $\alpha = 1.6$, Altitude=1610 m.a.s.l., SSA=0.95, g=0.7

$f_n(\Theta)$: — corrtab_YES010938-glo_sdisortPMOD072007_1932008.dat —

SZA \ $\mathrm{TO_3}$	200	220	240	260	280	**300**	320	340	360	380	400	420	440	460	480	500
0	1.324	1.264	1.213	1.170	1.132	1.100	1.072	1.048	1.027	1.008	0.992	0.978	0.966	0.955	0.946	0.938
5	1.321	1.262	1.211	1.168	1.130	1.098	1.071	1.046	1.025	1.007	0.991	0.977	0.965	0.954	0.945	0.937
10	1.314	1.255	1.204	1.162	1.125	1.093	1.066	1.042	1.021	1.003	0.988	0.974	0.962	0.952	0.943	0.935
15	1.301	1.243	1.194	1.152	1.116	1.085	1.058	1.035	1.015	0.997	0.982	0.969	0.958	0.948	0.939	0.932
20	1.283	1.227	1.178	1.138	1.103	1.073	1.047	1.025	1.006	0.989	0.975	0.962	0.951	0.942	0.934	0.928
25	1.261	1.206	1.159	1.120	1.087	1.058	1.034	1.013	0.995	0.979	0.966	0.954	0.944	0.936	0.929	0.923
30	1.234	1.181	1.137	1.099	1.068	1.041	1.018	0.998	0.982	0.967	0.955	0.945	0.936	0.929	0.923	0.918
35	1.202	1.152	1.110	1.075	1.046	1.021	1.000	0.982	0.967	0.955	0.944	0.935	0.928	0.922	0.917	0.913
40	1.167	1.120	1.081	1.049	1.022	**1.000**	0.981	0.966	0.953	0.942	0.933	0.926	0.920	0.916	0.913	0.910
45	1.128	1.085	1.050	1.021	0.998	0.978	0.962	0.949	0.938	0.930	0.923	0.918	0.914	0.912	0.911	0.910
50	1.087	1.049	1.018	0.993	0.973	0.957	0.944	0.934	0.926	0.920	0.916	0.913	0.912	0.912	0.913	0.915
55	1.044	1.012	0.986	0.966	0.950	0.938	0.929	0.922	0.918	0.915	0.914	0.914	0.916	0.919	0.922	0.927
60	1.003	0.977	0.957	0.942	0.932	0.924	0.919	0.917	0.917	0.918	0.921	0.925	0.930	0.936	0.944	0.951
65	0.967	0.948	0.935	0.927	0.922	0.920	0.921	0.923	0.928	0.934	0.942	0.951	0.961	0.971	0.983	0.995
70	0.940	0.930	0.925	0.925	0.927	0.932	0.940	0.949	0.961	0.973	0.987	1.002	1.018	1.035	1.052	1.070
75	0.932	0.933	0.938	0.947	0.959	0.974	0.990	1.008	1.028	1.049	1.071	1.095	1.119	1.144	1.170	1.196
80	0.961	0.975	0.994	1.016	1.040	1.067	1.095	1.125	1.157	1.190	1.224	1.258	1.294	1.330	1.368	1.405
85	1.067	1.099	1.134	1.172	1.213	1.256	1.300	1.346	1.393	1.442	1.491	1.541	1.593	1.644	1.697	1.750
90	1.240	1.277	1.317	1.360	1.406	1.455	1.505	1.558	1.612	1.667	1.724	1.782	1.841	1.901	1.962	2.024

For an isotropic radiation distribution (diffuse sky radiation) $Coscor(\Theta)$ is equal to the inverse of the diffuse cosine error of the test instrument f_{dif} (see calibration certificate 2008-92-10-3). For clear sky conditions, the cosine correction function $Coscor(\Theta)$ can be approximated by radiative transfer calculations and by using the measured directional response angres(Θ). The following table was derived with the sdisort solver of libRadtran 1.1 with the same input parameters as used for $f_n(\Theta, \mathrm{TO_3})$.
Then,

$$1/Coscor(\Theta) = \frac{angres(\Theta)}{\cos(\Theta)} \cdot \frac{E_{\mathrm{dir}}}{E_{\mathrm{glo}}} + f_{\mathrm{dif}} \cdot \frac{E_{\mathrm{dif}}}{E_{\mathrm{glo}}}$$

where E_{dir}, E_{dif}, and E_{glo} are the model calculated direct, diffuse and global irradiances respectively.

Coscor(Θ): — coscor_YES010938-glo_sdisortPMOD072007_1932008.dat —

Clear Sky:

SZA	Coscor(Θ)	SZA	Coscor(Θ)	SZA	Coscor(Θ)
0	**1.076**	35	**1.127**	70	**1.265**
5	**1.082**	40	**1.144**	75	**1.262**
10	**1.084**	45	**1.161**	80	**1.238**
15	**1.089**	50	**1.184**	85	**1.211**
20	**1.098**	55	**1.208**	90	**1.198**
25	**1.105**	60	**1.232**		
30	**1.115**	65	**1.253**		

Diffuse (isotropic) Sky:

Coscor(Θ)=1.207

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Measurement conditions:

Number of measured solar spectra	362
Minimum SZA	23°
Maximum SZA	72°
Minimum UV Index	0.5
Maximum UV Index	9.9
Total column ozon [DU]	296 to 322

Atmospheric conditions:

21 June, 2008	Clear sky in the morning; mix of sun and clouds in the afternoon.
25 June, 2008	Clear sky with some cirrus clouds.
26 June, 2008	Clear sky in the morning; mix of sun and clouds in the afternoon.
28 June, 2008	Mostly clear sky.
03 July, 2008	Overcast sky with altostratus clouds.
09 July, 2008	Clear sky with some cirrus clouds.
10 July, 2008	Mostly clear sky.
11 July, 2008	Clear sky in the morning; mix of sun and clouds in the afternoon.

Comments:

The absolute spectral irradiance is traceable to the primary irradiance standard of the Physikalisch-Technische Bundesanstalt (PTB), Germany, through the transfer standards F300, F304, F324, F330, F376 (Gröbner and Sperfeld, 2005).

References

J. Gröbner and P. Sperfeld. Direct traceability of the portable QASUME irradiance scale to the primary irradiance standard of the PTB. *Metrologia*, 42:134–139, 2005.

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