Report
From the COST-726 Short Term Scientific Mission
Technical assistance in the PMOD/WRC broadband calibration campaign.
31/07/2006 to 11/08/2006 Davos, Switzerland
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The Short Term Scientific Mission's reporter took place during the period 31/07/2006 to 11/08/2006. The actions made during this mission can be summarised as follows:

- José Manuel Vilaplana came with two erythemal broadband instruments (one Kipp&Zonen and one Yankee) and the photodiode used as reference for the relative spectral response measurements at El Arenosillo laboratory. These two broadband instruments ware fully characterized and calibrated at the home observatory just before coming to the PMOD/WRC calibration campaign.

- All the broadband attending this campaign ware indoor characterized in angular response and relative spectral response during the first days of the campaign.

- There ware compared the results of the indoor characterization of the angular response and the relative spectral response (RSE) performed previously for two broadband instruments at El Arenosillo and afterward in Davos. They were also compared the first matrix of the ratios between irradiance weighted by the measured RSE of the broadband and the CIE erythemal weighted irradiance as a function of the solar zenith angle and the total ozone content.

- Determination of the relative spectral response of the photodiode used as reference at El Arenosillo for broadband radiometer calibration.

Following, it will be presented the main results of the intercomparison of the two laboratories by using a YES UVB-1 and a Kipp&Zonen.

The calibration procedure is well described in [Seckmeyer et al. 2005] and could be summarized in the following steps:

1. Indoor characterization of the broadband in angular response and relative spectral response.

2. Evaluation of the deviations of the integrated irradiance weighted with the broadband spectral response (RSE) versus the CIE erythemal irradiance as a function of the SZA and total ozone content by using a radiative transfer model.

$$ADA(\theta, O_3) = \frac{\int_\lambda I \cdot CIE \cdot d\lambda}{\int_\lambda I \cdot RSE_B \cdot d\lambda} \quad (1)$$

   Where I is the spectral irradiance from a radiative transfer model.

3. The estimation of a calibration factor as a function of the solar zenith angle from an outdoor intercomparison versus a high accuracy spectroradiometer.

$$C_B(\theta) \approx \frac{1}{S_B} \cdot \int_\lambda I \cdot RSE_B \cdot d\lambda \quad (2)$$

   Where S_B is the output signal in voltage from the broadband and I is the espectral irradiance measured with the reference spectroradiometer.

4. The determination of a calibration matrix as function of the ozone and solar zenith angle by the combination of steps 2 and 3.

$$I_E \approx S_B \cdot C_B(\theta) \cdot ADA(\theta, O_3) = S_B \cdot ADACAL(\theta, O_3) \quad (3)$$

   Where I_E is the erythemal irradiance measured with the broadband and $ADACAL(\theta,O_3)$ the absolute calibration matrix.

Indoor characterization

Just before the campaign at PMOD/WRC two broadband instruments were characterized at El Arenosillo which were brought to the European calibration campaign at PMOD/WRC. These instruments were a YES UVB-1 that belongs to INTA and the second radiometer was a Kipp&Zonen UV-S-E-T from the University of Extremadura.

The characterization of the broadband radiometer into the laboratory consists of:

a) The determination of the angular response of the instrument.

b) The determination of the relative spectral response of the instrument.

a) Angular response

The angular response of the instruments should follow the cosine law, but in general differs from it; that is a very important point to take into account because it can be source of large errors in the estimation of the UV irradiance [Gröbner et al., 1996]. The cosine error is defined as the ratio between the output signal of an instrument illuminated by a parallel light beam at a certain zenith angle with the corresponding cosine at that angle.

The angular response of the instrument at INTA/El Arenosillo was measured by rotating a DXW 1000W halogen lamp around the centre of the diffuser of the instrument while at PMOD/WRC it was done with a Xe lamp source and WG305 filter and rotating the instrument instead of the lamp.

In the following figures is shown the cosine error estimated for both instruments and in both laboratories.

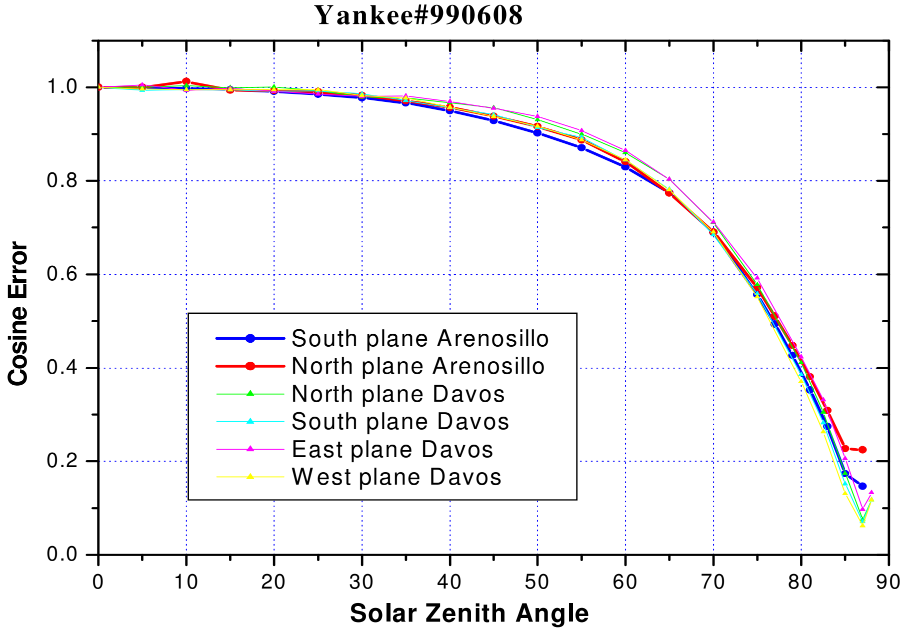

Figure 1: In these figures it is shown the cosine error of the YES UVB-1 from El Arenosillo measured at the home laboratory, at PMOD/WRC and superposed respectively.

In the normal outdoor operation, these instruments are positioned with the cable connector to the north, and that is the criteria that we have followed to define the selected planes to measure the cosine error of the instrument.

The diffuse cosine error fd is defined as

$$f_d = \frac{2\pi \int_0^{\pi/2} C(\theta) \sin\theta d\theta}{\pi} \tag{4}$$

Where C(θ) is the angular response of the radiometer, θ is the zenith angle and a homogenous diffuse sky radiance distribution is assumed. For the YES-UVB-1 radiometer this diffuse error is 0.88 which means that the instrument measurements are approximately 12% below the expected irradiance for diffuse radiation.

For the Kipp&Zonen UV-S-E-T, a similar study is presented in figure 2.

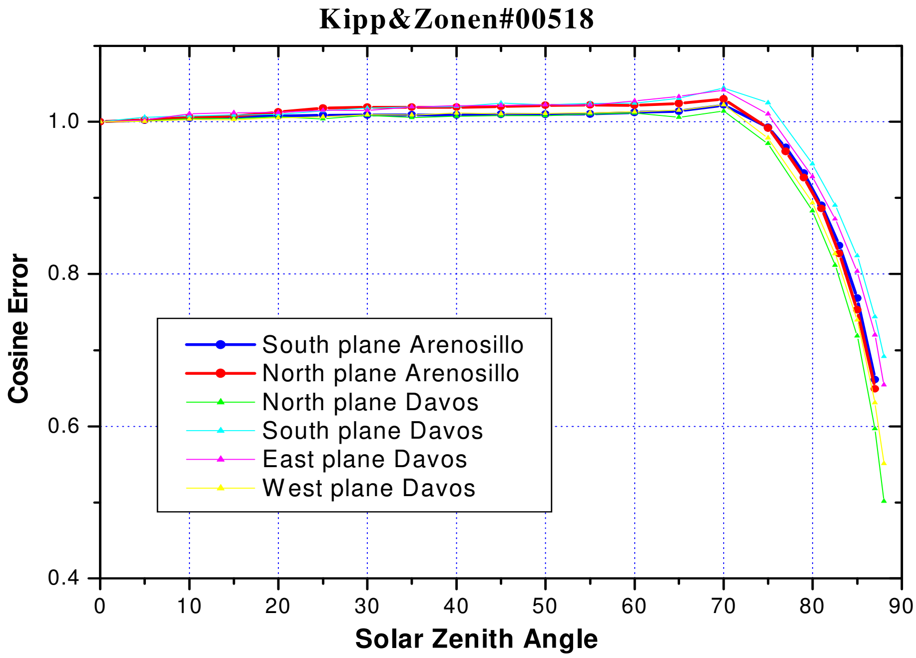

Figure 2: The cosine error for the Kipp&Zonen UV-S-E-T from the University of Extremadura measured al INTA/El Arenosillo, at PMOD/WRC and superposed respectively.

As can be seen, the angular response of this instrument is much better that the one obtained for the YES and shown in figure 1. Up to zenith angles of 75º the cosine error is very low for this instrument. The integrated cosine error fd is 1.01, which implies no error in the estimation of the homogeneous sky radiance.

b) Relative Spectral Response

The relative spectral response was measured in both laboratories for these two instruments and here it will be presented the results.

At INTA/El Arenosillo calibration facilities, the system to measure this spectral response is consisting basically on a 450W Xe lamp source, a double monochromator, an integrating sphere optimised in the UV range with two holes where are setting the calibrated photodiode used as reference and the broadband to be characterized.

The double monochromator is a Gemini 180, 1200l/nm gratings from Jobin Ivon, focal length = 0.18 m, aperture = f/3.8, resolution = 0.15 nm, dispersion = 2.1 nm/mm, accuracy = +/- 0.3 nm, stray light = 10-9 measured at 8 nm, kinematic grating repeatability = +/- 0.04 nm, drive repeatability = +/- 0.06 nm, mechanical range = 0 – 1400 nm, intermediate slit range = 5µ - 7 mm. The spectral response is measured at El Arenosillo in the range from 260nm to 400nm each 1nm and the dark voltage measured before is subtracted from the broadband voltage measured in the scan.

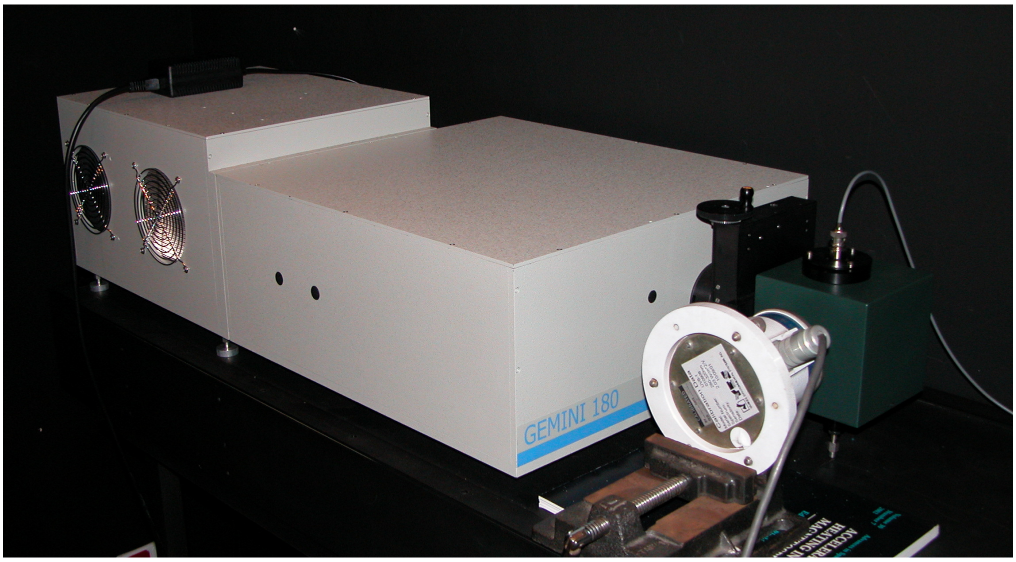

Figure 3: Relative spectral response calibration facility at El Arenosillo.

The reference photodiode sitting in one of the holes of the integrated sphere was calibrated at the Join Research Centre in Ispra (Italy) in 2004, and recently it has been calibrated again at PMOD/WRC in 2006. This calibrated photodiode provides the traceability link between the two laboratories.

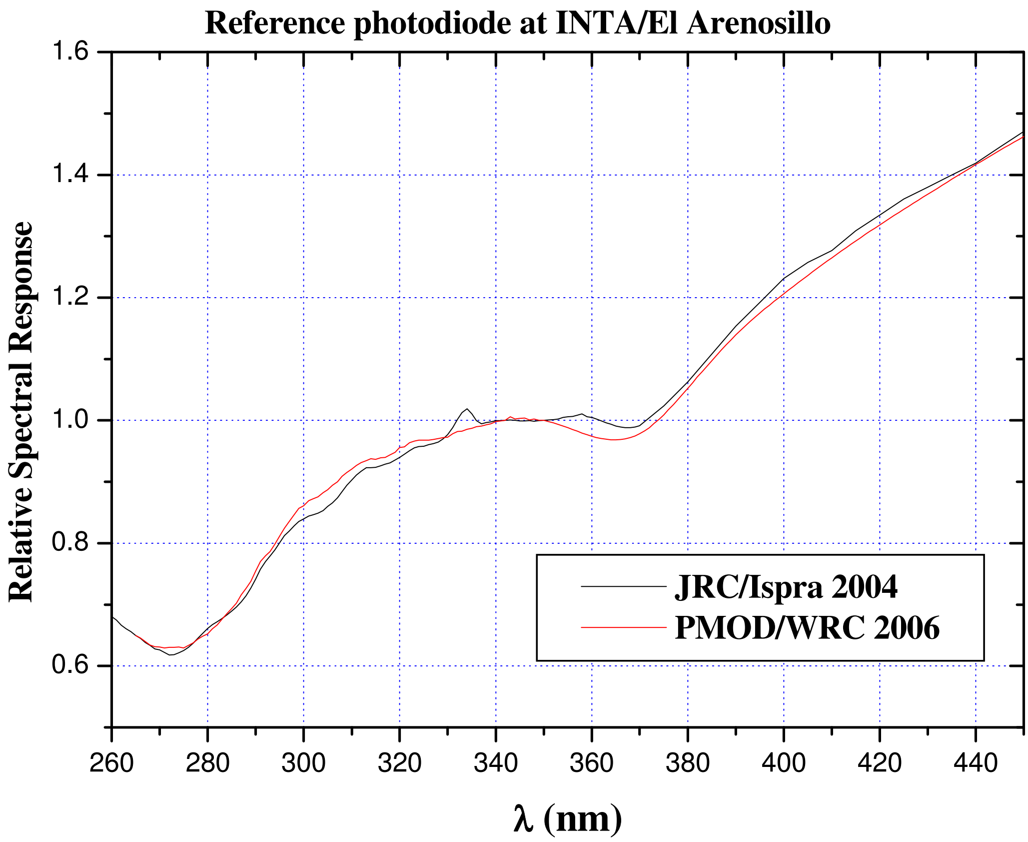

Figure 4: The spectral response of the photodiode used as reference at El Arenosillo for the spectral response facility

At the UV calibration laboratory at PMOD/WRC, the monochromatic source facility to measure the broadband spectral response consists of a Bentham double monochromator with a focal length of 150 mm and a grating of 2400 l/mm. A 300-W Xe lamp is used as the radiation source. The entrance and exit slits are 1.57 nm wide and produce a nearly triangular slit function with a FWHM of about 1.9 nm. (See Schreder et al., 2004 for a more detailed description of this facility)

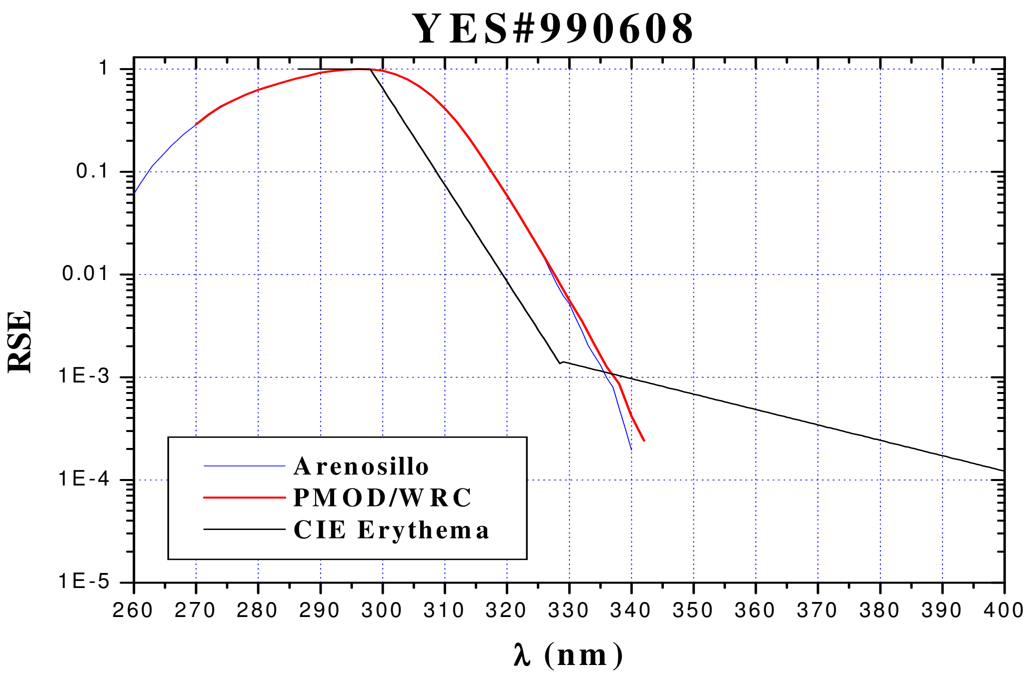

Figure 5: Relative spectral response for the YES UVB-1#990608 measured at El Arenosillo and PMOD/WRC. The measurements are normalised at the maximum.

In figure 5 it is shown the relative spectral response measured for the YES from INTA at the two laboratories. For the two laboratories, the maximum was found at 296nm and only small differences in absolute terms are found between 330nm and 340nm.

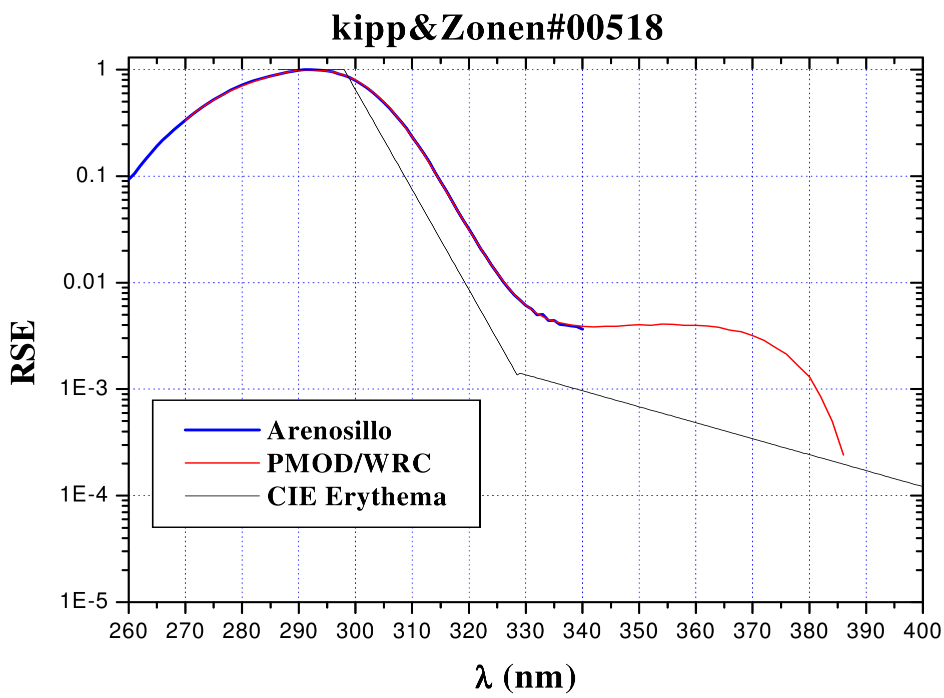

Figure 6: Relative spectral response for the Kipp&Zonen#00518 measured at El Arenosillo and PMOD/WRC

For the Kipp&Zonen, we have followed the same procedures as before. The maximum relative spectral response was at 292 nm for the two laboratories and the curve is very similar until 340nm. The conclusion is that we have to increase the resolution of the acquisition at El Arenosillo, and we will try to improve this calibration after the PMOD/WRC campaign.

Application to solar measurements

Due the substantial spectral differences between laboratory radiation sources and the solar spectrum it is necessary to calibrate these broadband radiometers using the sun as a source. Usually, calibrations are performed relative to a well calibrated spectroradiometer which provides solar spectrum measurements in parallel to the broadband measurements. The calibration factor of the radiometer is obtained by weighting the measured solar spectra with the spectral response function of the radiometer. Finally, the conversion from detector-weighted irradiances to erythemal irradiances is obtained by applying a ... calibration matrix which takes into account spectral variations of the solar spectrum due to the two main parameters total column ozone and solar zenith angle [Lantz et al., 1999].

Conclusions

This study shows the importance of regular laboratory intercomparisons to provide quality controlled radiometer calibrations for solar UV measurements. The measurements at INTA and PMOD/WRC show good agreement in the determination of the relative spectral and angular response for two broadband radiometers of different type. The sensors used in this intercomparison can be used as transfer standards to compare characterisations performed by different laboratories, provided that the radiometers are used in the appropriate conditions (i.e. low humidity and stable temperature).

Due to the very different characteristics of erythemal broadband radiometers from different manufacturers and the possible changes of these characteristics in time, it is advisable to characterise these instruments at regular intervals [Seckmeyer, et al., 2005].

4.- References

G. Seckmeyer et al. (2005): WMO / GAW report Nº164: Instruments to measure solar ultraviolet radiation. Part 2: Broadband instruments measuring erithemally weighted irradiance.

J. Gröbner, M Blumtaler and W. Ambach (1996): Experimental investigation of the spectral global irradiance erros due to a non ideal cosine response. *Geophysical research letters, Vol. 23, nº 18, Pag. 2493-2496.*

J. Gröbner et al. (2002): Quality assurance of reference standards from nine European solar-ultraviolet monitoring laboratories. *Applied Optics* Vol.41, No.21, Pag. 4278-4282

J. Schreder et al (2004): Intercomparison of monochromatic sources facilities for the determination of the relative spectral response of the erythemal broadband filter radiometers. *Optics Letters* Vol.29, No.13, Pag.1455-1457

Kathleen O. Lantz and Patrick Disterhoft (1999): Methodology for deriving clear-sky erythemal caibration factors for UV broadband radiometers of the U.S. Central UV calibration facility. *Journal of Atmospheric and Oceanic Technology.* Vol. 16, Pag. 1736-1752.