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Selection of cloudless sky conditions by applying solar global ultraviolet irradiance measurements

María-Antonia Serrano [a,*], José V. Boscà [b]

[a] Instituto de Ingeniería Energética, Universitat Politècnica de València, Valencia, Spain
[b] Universitat Politècnica de València, Valencia, Spain

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ABSTRACT

Taking advantage of UV (295–385 nm) irradiance measurements is one of the objectives of this paper. A new index termed k_t'' is established for this band. This new index works as a 'zenith angle independent clearness index' for band measurements and has similar applications to those of k_t' for broadband measurements. The new index may be applied to identify cloudless instants from UV band measurements. Both indexes were correlated throughout the period 1998–2004 with a R^2 of 0.85. A selection criterion of $k_t''_{UV} > 1.1$ classified cloudless sky conditions with a probability of 95% in comparison with a selection that two criteria-applying broadband measurements would make. This index may be of interest for classifying cloudless sky conditions when only UV band measurements are available. An estimation method from the literature was applied to the period 1998–2004. This method was previously validated for the UV band with a measurement campaign made in Valencia (Spain) in the summer season.

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1. Introduction

Spectroradiometers and photo-detectors are commonly used to measure solar radiation. A few seconds are enough for the measuring instrument to explore the whole solar spectrum and provide a complete set of irradiances with precise wavelength ranges of nanometres. However, in the second half of the twentieth century spectral measurements were not so common and most meteorological and radiation stations recorded irradiance measurements from the whole spectrum, namely broadband irradiance, and also from bands of the spectrum of special interest.

Radiation of bands of the solar spectrum is measured and analysed for many reasons. Researchers focus their interests in different bands of the ultraviolet spectrum such as the bands UV-A, UV-B, and UV-C, whose ranges and nomenclature were standardised by the Commision Internationale de l'Eclairage (Barth et al., 1999), mainly due to the interest in knowing its influences over the animal life and plants and also its incidence on the ageing of materials and objects.

These bands of the ultraviolet spectrum are measured and analysed by many researchers. Among many of them, we could highlight some works, such as that of Kudish and Evseev (2012) who parameterised the three solar UV-B radiant components (direct, global and diffuse) as a function of relative optical air mass, and also they determined the UV-B optical depth by parameterisations applying similar procedures which are used in this work. Jacovides et al. (2012) also managed measurements of global and diffuse (broadband, UV-B and UV-A) irradiances to study their components and relations with the broadband radiant fluxes, and they also applied measurement techniques, similar to ours, such as applying a disk to shadow the instrument to measure diffuse irradiance. Regarding the UV band, Parisi and Kimlin (1999) analysed the

Abbreviations: k_t, clearness index; k_t', zenith angle independent clearness index; k_{tUV}, UV band clearness index; δ_{CDA}, the optical depth of a clean and dry atmosphere; EM, estimation method; T_B, Band Factor; k_t'', zenith angle independent band clearness index; BCC, band clearness criterion; GDC, global and diffuse criterion.

* Corresponding author at: Instituto de Ingeniería Energética, Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain. Tel.: +34 963877007x75.259.
E-mail address: mserranj@fis.upv.es (M.-A. Serrano).

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dependence of the irradiance of this band according to the orientation of the object. In another study, Parisi et al. (2000) compared the diffuse erythemal UV irradiance in tree shade with the corresponding in full sun. Turnbull et al. (2005) performed spectral UV irradiance measurements for six specific shade environments in full sun and in the shade, to investigate the biologically effective UV irradiance for pre-vitamin D3 production.

A band alike UV-A is that of wavelength range 295–385 nm. There are available large databases with irradiance measurements of that band in Spain since it has been measured for more than 20 years by stations of the Spanish Meteorological Agency and by groups of researchers such as ours at the Polytechnic University of Valencia. That is why the interest of this paper is focussed on the band UV (295–385 nm), which hereafter will be referred to as UV band, and its irradiance being measured beneath the atmosphere of Valencia, Spain.

When the measurements managed were broadband irradiance, to make a selection of cloudless conditions was very well solved. Below there are summarised two broadband methods to do that. Broadband measurements also have served to classify band measurements when they were available. However, some techniques and methods are missing to classify band measurements when they are the only available.

The objective of this work is to provide a method to select cloudless instants when the available measurements are direct normal UV band irradiance, or, failing that, UV global horizontal irradiance. To reach that objective a new index, k_t'', for the band UV will be defined. This new band index will be applied to identify conditions of cloudless sky from the UV band irradiance at the instant when the measurement was taken. A new criterion to identify cloudless conditions from UV band irradiance measurements based on the new band index was established.

To determine that index a parameterisation of the optical vertical thickness under a clean and dry atmosphere and the determination of a Band Factor were previously needed. Therefore, these parameters were cited and summarised from the literature, and validated to be applied to the UV band. Also, an estimation method (EM), with the purpose to yield direct normal band irradiance from global horizontal, was previously validated for the band UV, and then applied, to make a better use of our databases.

Finally, the new band criterion for cloudless skies was validated by comparisons, in a period of two years reserved for this purpose, with the results performed by two other classification methods based on broadband measurements.

2. Data utilised and methodology

Two solar radiation databases were applied in this study. The first database contained measurements from 1996 to 2004 made at the Universitat Politècnica de València (UPV) by the group of researchers on Solar Radiation of this university, which the authors were members, and was led by Professor Dr. Javier Cañada. This group is integrated in the Solar Radiation Group of Valencia (SRGV), Spain. The second database consists of measurements made by the authors in a special measurement campaign, also at the UPV, held in June and July 2006. The UPV coordinates are 0°20′18″W–39°28′49″N and the measurements were made on a flat roof at about 15 m above the sea level.

2.1. SRGV and experimental campaign databases

The database contains measurements taken every half hour in all atmospheric conditions during the period between 1996 and 2004 and includes a total of 50672 registered instants — with the only exception of data missed due to momentary breakdowns or errors.

The database contains the following variables:

1 Broadband global and diffuse horizontal irradiances were measured with two pyranometers: a) the first was an Eppley model 8-48 pyranometer with a spectral range of 285–2800 nm and b) the second pyranometer was equipped with a 7.6 cm wide shadow-band with a radius of 31.70 cm for the diffuse irradiance. The diffuse irradiance measurements were corrected using Drummond's formula, as summarised in Iqbal (1983), although the use of this isotropic correction can lead to some error, see for example a study by Batlles et al. (1995) made in another region of Spain. The pyranometers had a class 1 precision following the specifications of the World Meteorology Organization (WMO), and its cosine response is within ±2% from 0 to 70° zenith angle and ±5% for 70–80° zenith angles. The field measurement uncertainty of the pyranometers is considered to be below 5%, according to the manufacturer.

2 UV band global horizontal irradiance was measured with an Eppley TUVR pyranometer, placed on a horizontal surface, with a spectral range, given by the manufacturer, of 295–385 nm. Its cosine response is ±3.5% from 0 to 70° zenith angle, and its linearity is ±2% over the normal range of operation. Under these conditions, Mehos et al. (1992) and Riordan et al. (1990) have established that errors associated with the experimental data are conservatively estimated at 15%, which is not in accordance with the expectation of the manufacturer (5%).

The SRGV carried out periodic calibrations of the above instruments using procedures recommended by the manufacturers, as can be seen in Cañada et al. (2000, 2003). The broadband pyranometers were compared yearly against a reference Eppley PSP especially kept for calibrations, and the calibration constant had remained practically constant. The TUVR pyranometer was calibrated by the manufacturers at the end of 1995 and afterwards was calibrated yearly in comparison with the measurements of a spectroradiometer LICOR-1800, and a decrease in the calibration constant of 12% in 3 years was confirmed. In February of 1999, the manufacturer calibrated it again and a decrease in the calibration constant of 2.5% per year was observed. The most recent calibration of this instrument was made in May 2002.

A measurement campaign was carried out in June and July, 2006, with the objective of checking the EM. Hourly measurements of global and diffuse horizontal irradiances of the UV band were performed taking advantage of an automatic system that registered instrument signals every minute.

The measurements were the following:

1 Global horizontal broadband irradiance was measured with a Kipp & Zonen CM11 pyranometer.

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