PROGRAM AND PROCEEDINGS

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Radiometric Measurements and Data for Evaluating Photovoltaics

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ABSTRACT

The National Renewable Energy Laboratory (NREL) Photovoltaic Radiometric Measurements Task addresses the impact of solar and optical radiation on photovoltaic (PV) devices. The task maintains spectral and broadband calibration capability directly traceable to the National Institute of Standards and Technology (NIST) and the World Radiometric Reference (WRR) of the World Meteorological Organization (WMO). Radiometric resource data and analysis are brought to bear on issues relating to PV performance. Current activities include monitoring the spectral drift in pulse solar simulators, characterizing radiometers, accurate interpolation of averaged radiation and weather data, identifying typical prevailing conditions for PV applications, evaluation of consensus standard spectral references, and technical support for development of PV-related consensus standards.

1. Introduction: Task Objectives

The objective of the NREL PV Radiometrics Measurements Task is to perform traceable calibrations, measurements, and research regarding the influence of optical and solar radiation on photovoltaic devices and systems.

2. Spectral Calibrations and Measurements

The task provides traceable calibrations and measurements and solar resource data collection and analysis to evaluate the impact of optical and solar radiation on PV-device performance. 1000 Watt NIST standards of spectral irradiance are the references for calibrating reference and user spectroradiometers. NREL spectroradiometers are shown in figure 1.

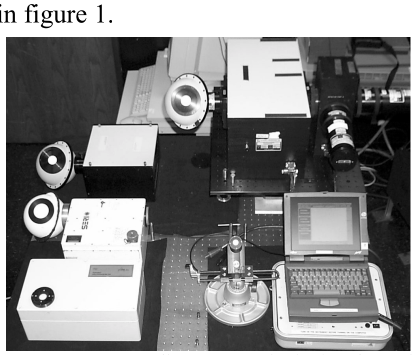

Figure 1. NREL spectroradiometers. Clockwise from front left: Li-1800 [0.3-1.1 um], Geophysical Environmental Research (GER) [0.35 -2.4 um] , Optronic Laboratories (OL) OL-754 [0.18-0.8 um], OL-750 [0.25 -2.4 um], Analytical Spectral Devices (ASD) FieldSpec FR [0.35 -2.4 um]

Reference spectroradiometers calibrate filter radiometers over their response range. Figure 2 shows an OL-754 Ultraviolet (UV) spectrometer calibrating the radiometer monitoring UV exposure in the NREL UV test chamber, and the spectral distribution of the exposure lamps

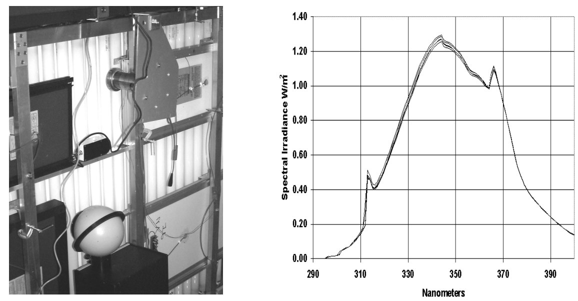

Figure 2a. UV exposure chamber UV monitor calibration against OL-754 spectrometer. 2b. Spectral distribution of exposure lamps.

The UV-exposure tests are run at elevated temperatures (65°C). We characterized the temperature response of the UV monitor to be 5%/°C (25°C to 45 °C). Figure 3 shows relative changes in spectral distribution for the NREL Spire 240 Pulse solar simulator from April 1999 to February 2000.

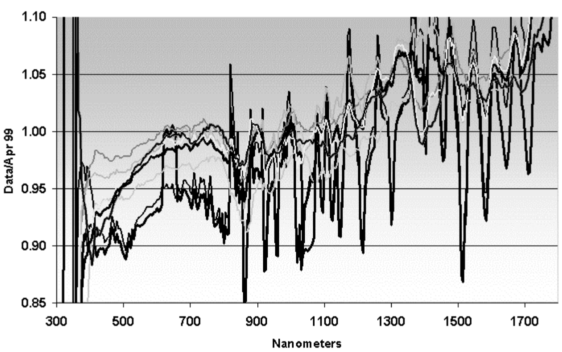

Figure 3. Relative spectral distribution changes in Spire 240 with respect to baseline measurement in April 1999. Light lines are for May - Nov. 1999, heavy gray lines are for Jan. and Feb. 2000

3. Broadband Radiometric Calibrations

NREL broadband pyranometers and pyrheliometers are calibrated against NREL reference absolute cavity pyrheliometers traceable to the WMO WRR. In October, 1999, NREL conducted an intercomparison of absolute-cavity pyrheliometers at the Solar Radiation Research Laboratory (SRRL) to maintain the WRR factors of the NREL and other participating cavity radiometers. Table 4 shows the WRR factors and uncertainty with respect to *System Internationale* (SI) units for NREL cavity radiometers used as the standard for PV reference cell calibrations and at the outdoor test Facility Reference Meteorological and Irradiance System (RMIS).

Table 1. OCT 1999 Intercomparison Results for NREL Working Cavity Pyrheliometers

Cavity Radiometer	WRR Factor	Uncertainty With Respect to SI units
23734 (PV ref)	0.99855	0.35%
29794 (RMIS)+	0.99485	0.50%

+RMIS cavity radiometer operated continuously with window in place.

The task coordinates calibration of radiometers used in PV-performance testing with respect to the NREL working-standard absolute cavity pyrheliometers, assuring traceability of calibrations to WRR.

Our Broadband Outdoor Calibration (BORCAL) procedures produce maps of pyranometer responsivities as functions of zenith and azimuth angle. Calibrations on clear days throughout the year result in a sparse matrix of responsivities. We have developed an interpolation technique to produce a detector angular responsivity map as shown in figure 4

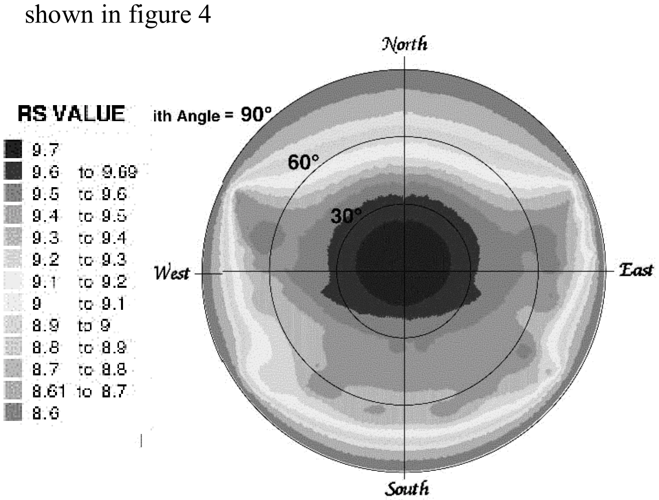

Figure 4. Pyranometer angular-response map derived from outdoor calibration data.

4. Solar Radiation Resources and PV Performance

We began a study [3] to provide a technical basis for evaluating PV-rating conditions. We selected direct-normal irradiance (DNI), turbidity, temperature, total column water vapor, and wind speed from the 30-year (1961-1990) National Solar Radiation Database (NSRDB) when the global normal irradiance was 1000 W/m^2 ± 25 W/m^2 [1,2,3]. The frequency of occurrence of DNI values by hour to determine what DNI values may represent "typical" conditions for various sites is being studied. Figure 5 is a contour plot of the frequency distribution of DNI by hour from 8 a.m. to 6 p.m. for Elko, NV showing representative results.

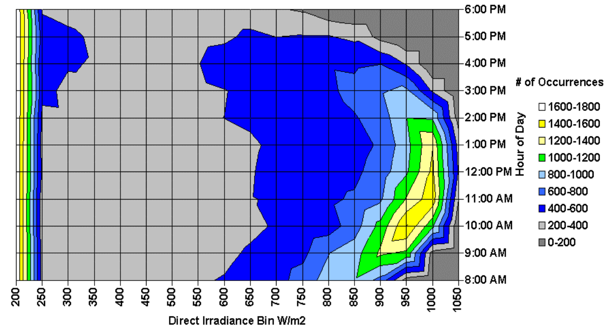

Figure 5. Frequency distribution by hour of DNI for hours 8 a.m. to 6 p.m. for Elko, NV. 1961-1990 hourly data. See also ref [1,2].

We developed a simple algorithm to convert averaged data into data with higher resolution.[4] Figure 6 is an example showing one minute DNI values derived from 24 hourly average DNI.

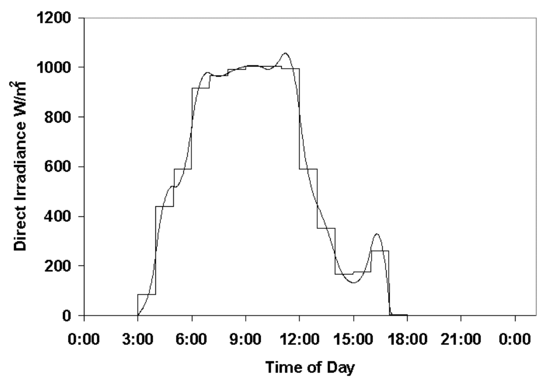

Figure 6. One minute DNI (smooth curve) derived from hourly average DNI (step curve) by a mean preserving interpolator.

5. PV Standards and Codes Support

We are evaluating the American Society for Testing and Materials (ASTM) E892 reference spectrum with respect to measured spectra extracted from the SERI Solar Spectral Data Base [5] for GNI and DNI within 10 W/m² of 1000 W/m² and 850 W/m², as described in [1]

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4. Rymes, M.D. and D. Myers "Mean Preserving Algorithm for Smoothly Interpolating Averaged Data to Higher Resolution" Draft for *Solar Energy*

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