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NREL Spectral Standards Development and Broadband Radiometric Calibrations

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ABSTRACT

We describe a final version of revisions to current ASTM reference standard spectral distributions used to evaluate photovoltaic device performance. An NREL developed graphical user interface for working with the SMARTS2 spectral model has been developed and is being tested. A proposed ASTM reference Ultraviolet (UV) spectra for materials durability is presented. Improvements in broadband outdoor radiometer calibration, characterization, and reporting software that reduce uncertainties in broadband radiometer calibrations are shown.

1. Final Version Revised Spectral Irradiance Standards

We reported on existing and proposed revised consensus standard spectral irradiance distributions at the 2002 IEEE Photovoltaic Specialists Conference [1, 2]. The draft spectra were approved with no negatives by full committee ASTM G03 on weathering and durability. As of January, 2003, the standard will move to full ASTM society-level ballot, probably by June of 2003. If approved with no negative comments the revised standard will be designated as ASTM G173, as the revisions were extensive enough to require a new designation. ASTM G159 will then be withdrawn (as E891 and E892 have been). Figure 1 displays the new air mass 1.5 spectra for hemispherical radiation on a 37° equator-facing tilted surface, and the direct normal plus circumsolar spectrum. The conditions are for sea level air mass (AM) 1.5, rural aerosol profile with optical depth 0.084, United States Standard Atmosphere of 1976, precipitable water 1.42 cm, and ozone of 0.34 atm-cm.

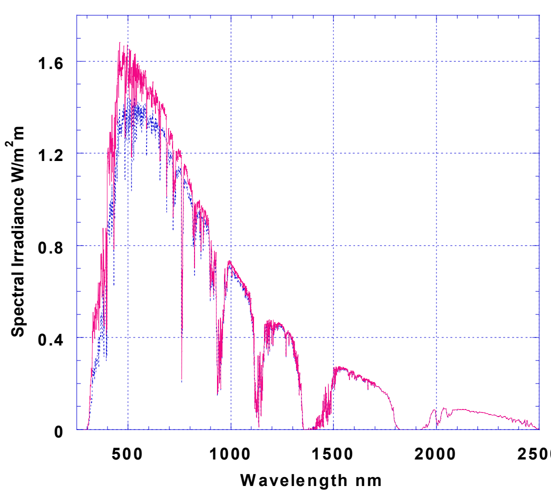

Figure 1. Revised direct normal (lower line) and hemispherical 37° tilt spectrum at AM 1.5. Spectra extend to 4000 nm, displayed only to 2500 nm.

The SMARTS2 spectral transmission model [3] is used to compute the revised spectral standards. NREL has developed an Excel®-based user interface to allow users to (1) reproduce the spectra at will, and (2) produce test spectra for different atmospheric conditions for performance comparisons and analysis. Figure 2 shows sample screen shots of the interface.

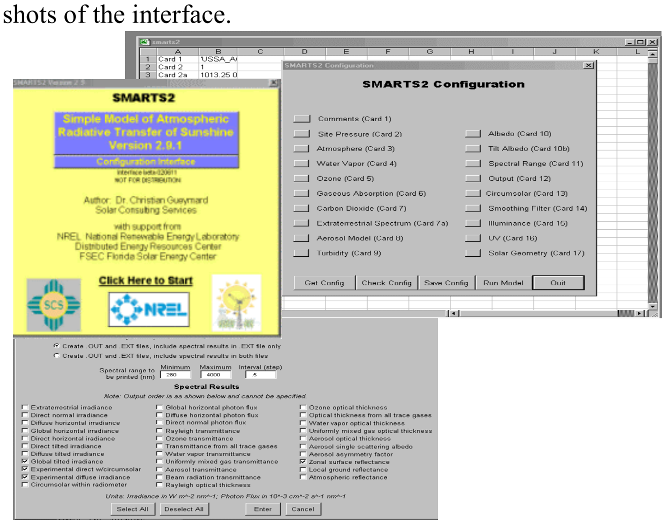

Figure 2. NREL-developed Excel Visual Basic based graphical user interface for SMARTS2 model input file configuration.

Later in 2003, after validation testing, we are planning to make the SMARTS2 model and the interface publicly available through the NREL Renewable Resource Data Center (Rredc). Prospective users may contact the lead author at daryl_myers@nrel.gov to obtain the model, and interface, or more information.

2. ASTM Approval of Ultraviolet Reference Standard

During the effort to revise the reference spectra for PV performance applications, the weathering and durability industry participants in ASTM committee GO3 requested the development of a reference Ultraviolet (UV) standard spectrum. Several candidate spectra were proposed, again based on the SMARTS2 spectral model. In Jan. 2003, the committee voted to accept a draft standard proposed by NREL to represent an upper limit for a naturally occurring UV exposure spectrum. The spectrum chosen represents United States Standard Atmosphere (USSA) conditions at air mass 1.05 at 2-kilometer elevation with somewhat reduced total column ozone of 0.30 atm-cm and aerosol optical depth 0.05.

Figure 3 displays the proposed UV reference spectrum, which will be submitted for full ASTM Society ballot later in 2003.

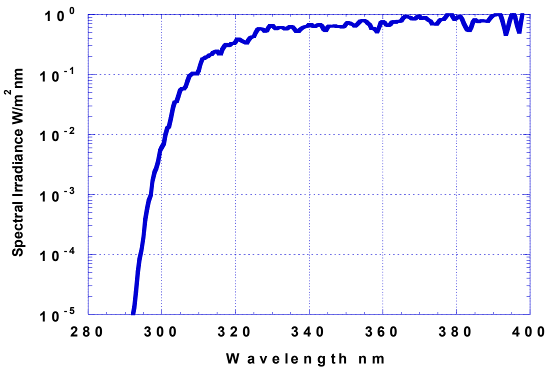

Figure 3. Proposed weathering and durability UV reference spectrum for USSA, 2-km Altitude, AM 1.05, Aerosol optical depth of 0.05, and total column O3 of 0.30 atm-cm.

3. Broadband Radiometer Calibration Improvements

During 2002, we upgraded our Radiometer Calibration and Characterization (RCC) software for broadband radiometer calibrations at NREL. Improvements include a new graphical user interface, integrated calibration history database, and reporting functionality [4,5]. The new RCC processes responsivity data is based on more accurate diffuse reference irradiance measurements and zenith angle information described in [5] and [6]. The new ISO-compliant calibration report for broadband radiometers is shown in Fig. 4. The new software also performs functional fits to the cosine response curve of each individual radiometer, based on the calibration data in 46 2-degree-wide zenith angle bins.

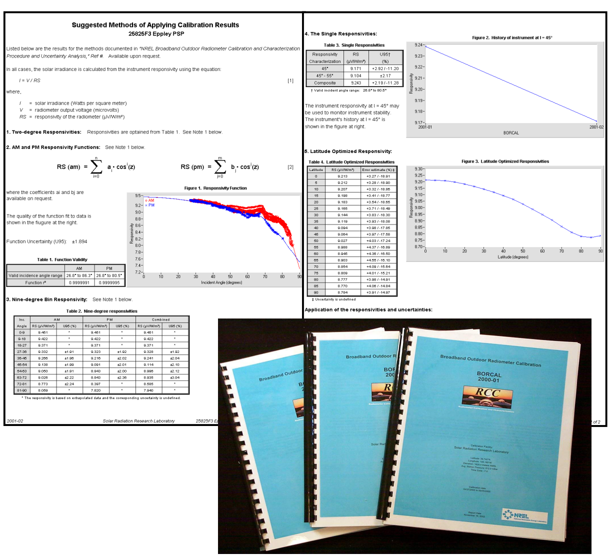

Figure 4. Detailed calibration reports as generated by new version of RCC. Hardcopy and CD-rom versions of reports are available to instrument owners.

The form of the fitted function is :

$$Rs(\Theta)_{AM/PM} = \sum_{i=0}^{i=N} a_i \bullet Cos^i(\Theta)$$

where Θ is the zenith angle, the a_i are 46 coefficients (for each of the morning and afternoon zenith angle sets) fit from the calibration data, and Rs(Θ) is the responsivity at a given zenith angle. The particular coefficients for fitting the cosine response curve for a given instrument are available upon request at the completion of an NREL BORCAL event. Figure 5 portrays the repeatability of about +/-1% (or 10 W/m^2 at 1000 W/m^2 full scale) of this outdoor determination of cosine response for an NREL control pyranometer over seven BORCAL events in 2001 and 2002.

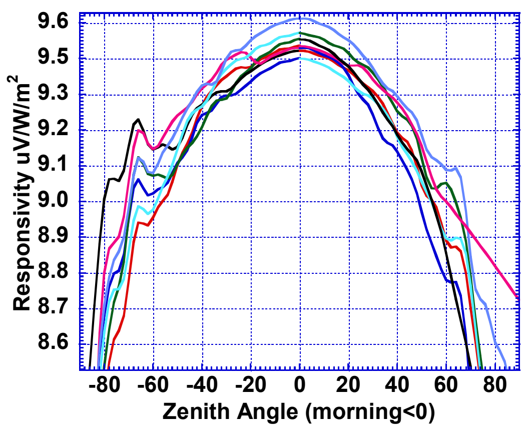

Figure 5. Repeatability of control pyranometer fitted cosine response function for seven BORCAL events in 2001/2002.

Variations in the functional fits in Fig. 5 are probably due to changing temperature and solar azimuth geometry over the 2-year period of the calibrations.

Summary

The Solar Radiometric Measurements task continues to provide technical support for consensus standards, spectral modeling, and optical metrology needs of the PV industry and research and development programs.

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