SERI/TP-215-1999
UC Category: 63
DE83011980

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Roland Hulstrom

June 1983

Presented at the 1983 Annual Meeting of the
American Solar Energy Society
Minneapolis, Minnesota
1-3 June 1983

Prepared under Task No. 1473.00
WPA No. 424

**Solar Energy Research Institute**
A Division of Midwest Research Institute

1617 Cole Boulevard
Golden, Colorado 80401

Prepared for the
**U.S. Department of Energy**
Contract No. EG-77-C-01-4042

Printed in the United States of America
Available from:
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price:
Microfiche $4.50
Printed Copy $7.00

# SPECTRAL SOLAR RADIATION - NEW DATA

by

Roland L. Hulstrom
Solar Energy Research Institute
Golden, Colorado 80401

## ABSTRACT

Several areas of solar research require an accurate knowledge (data) of the spectral content of solar radiation at the earth's surface for various atmospheric conditions, times during the day (air masses), geographic locations, and for the various seasons (monthly). Areas of solar research include photovoltaics, biomass, materials studies, and solar simulation.

As one of its major research thrusts, the Renewable Resource Assessment and Instrumentation Branch (RRAIB) of the Solar Energy Research Institute (SERI, Golden, CO) has been developing improved analytical models, instrumentation, and data sets to meet the various needs for such by the previously mentioned areas of solar energy conversion research. This paper presents a brief summary of selected results of such research. References are given for detailed descriptions of the various individual areas of effort/research and new spectral solar radiation data sets. This research has been funded by the Department of Energy (DOE) under Contract No. EG-77-C-01-4042.

## 1. RIGOROUS SPECTRAL MODELS

Recently there have been significant advances in radiative transfer modeling for space and military applications. Computer codes have been developed to solve the equation of radiative transfer much more rigorously than in the past. In addition, improved molecular absorption data have been developed. The RRAIB (SERI) has taken advantage of these developments and currently has three rigorous codes in operation. One of these, entitled SOLTRAN, is a direct beam radiation model. The other two are Monte Carlo codes entitled BRITE and FLASH, which are capable of calculating direct beam (including circumsolar), diffuse (for any portion of the sky), and reflected solar radiation. Detailed descriptions of all models are given by Bird[1].

The three rigorous models can be used to generate terrestrial solar spectral irradiance data as a function of surface pressure, relative air mass (solar zenith angle), atmospheric conditions (turbidity, water vapor, ozone, temperature, etc.), and viewing geometry (i.e., flat plate tilted collectors, concentrators, etc.). The Monte Carlo codes are capable of treating cloud cover, with the limitation of considering clouds as uniform layers within the atmosphere. For cloudless sky conditions, the RRAIB has compared the prediction of the three rigorous models with experimental data, for a limited range of conditions, and found them to be in reasonable agreement (±5%, for global irradiance) with the experimental data. In certain areas of the spectrum, the RRAIB has adjusted certain absorption properties of water vapor. Much more comparison of modeled vs experimental data is required before the rigorous models can be fully verified. The RRAIB plans to do such over the 1983-1988 time period.

The first application of the rigorous models, by the RRAIB, has been the generation of new terrestrial solar spectral irradiance data sets for "standard" atmospheric conditions, Matson[2] et al. Such data is being utilized by the ASTM as standards for terrestrial solar spectral irradiance. The current standards are No.s E891-82 and E892-82. The former is for the direct beam (including circumsolar) and the latter is for global (direct, sky diffuse, and ground reflected) on a tilted surface ($37^{o}$ oriented south). The recently adopted (SERI) ASTM standards utilize the extraterrestrial solar spectrum (constant) of Thekaekara[3], while the more recent (SERI) data sets utilize the Neckel and Labs extraterrestrial spectrum. Tabular data sets and a complete comparison of the two sets of data is given in Bird and Hulstrom[4,5].

## 2. SIMPLE SPECTRAL MODEL

The SERI RRAIB recognizes the fact that rigorous radiative transfer codes (SOLTRAN, BRITE, AND FLASH) require large computing capabilities and cost. To alleviate this problem, the RRAIB investigated methods of simplifying the rigorous codes by using a single homogeneous layer and a simple Beer's law approach. By using a single homogeneous layer model, based on the work of Leckner[6] and Brine and Iqbal[7], the RRAIB has been able to produce a simplified model that greatly reduces the computation time as compared to the rigorous codes. This was made possible by comparison with the SERI rigorous codes and appropriate modification of the simplified methods by the RRAIB, Bird[8]. It should be noted that such comparisons are limited in the range of atmospheric conditions and they are only for the direct normal irradiance, diffuse, and global horizontal irradiance as apposed to the global irradiance on tilted surfaces. Future effort, by the RRAIB, will address comparisons of the simplified model (SPECTRAL) with experimental data and the rigorous codes for tilted surfaces and a wider range of atmospheric conditions.

## 3. INSTRUMENTATION/MEASUREMENTS

At the beginning of FY1979 (October 1978) conceptual work was initiated at SERI (RRAIB) which addressed an advanced spectroradiometer designed specifically for semiautomatic collection of direct beam, diffuse, and global (on various orientations) solar irradiance. The specificaitons for such an advanced instrument were generated by the rigorous radiative transfer models described previously.

After the competitive purchasing process was completed, a contract was finalized in early 1979 with the Baird Corporation to build the instrument and to develop the appropriate software to operate it. The instrument was delivered to SERI in August of 1980. Some of the unique features of this instruments are:

- Continuous dynamic absolute irradiance calibration.
- Continuous wavelength calibration.
- Continuous monitoring of the broadband solar irradiance during the spectral scan.
- A full 180$^{o}$ field-of-view (F.O.V.) with excellent cosine response for the measurement of global spectral irradiance on any flat plat surface.
- A 5$^{o}$ collimator for the measurement of direct beam spectral irradiance.
- A continuous tracking disk attachment for the measurement of diffuse spectral solar irradiance.
- A wavelength coverage of the region from 0.250 to 2.5 m with a resolution of 0.75 nm in the visible (0.250 to 0.850 m) and 12 nm in the infrared (0.750 nm to 2.5 nm).

- An excellent signal-to-noise ratio, even for diffuse sky radiation, due to the utilization of cooled detectors (40$^{o}$C below ambient).
- Completely automated/computerized operation, data processing, and arachiving.

A complete description of the Baird/SERI solar spectroradiometer and selected measurements utilizing this instrument are given by Bird, Hulstrom, Kliman, and Eldering[9].

At the beginning of FY81 the need and preliminary specifications for a portable solar spectroradiometer for the measurement of incident outdoor solar spectral irradiance and indoor laboratory solar simulators were defined. After the competitive purchasing process was completed, the Li-Cor Inc. Model 1800 spectroradiometer was selected. The features of this unit are:

- Capable of measuring global (horizontal and tilted surface), direct beam 5.7$^{o}$ F.O.V.), and diffuse solar irradiance;
- Capable of measuring indoor spectral irradiance of solar simulators;
- Spectral range of .300-1.100 m (silicon detector);
- Performs a complete wavelength scan in 27 seconds at 2 nm resolution;
- Half-power bandwidth of 6 nm;
- Microprossor controlled data acquisition, processing and archiving;
- Battery operated (or AC) for 6-8 hours of continuous operation, up to two weeks of data logging (memory for about 27 data files); and
- Field portable weight of 6.4 kg (14 lbs), 16.3 x 20.1 x 36.0 cm (6.4" x 7.9" x 14.2").

This portable spectroradiometer will be utilized to collect terrestrial solar radiation spectra for various atmospheric and cloud cover conditions for comparison with modeled data. In addition, calibration of indoor solar simulators will be performed on a routine basis.

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