SOLAR SPECTRUM

Newsletter of the Resource Applications Division

Volume 17, Issue 1 – July 2004 of the American Solar Energy Society®

SOCOL, A FORTRAN PROGRAM FOR CALCULATING ENERGY COLLECTION BY FIXED AND TRACKING COLLECTORS

By Jack Garrison - San Diego State University

Introduction

SOCOL was developed as a means to evaluate solar thermal collectors of different designs alone, while not considering the effect of systems to which a collector may be attached. It uses NSRDB or TMY2 data to calculate the net thermal energy collected per unit collection area. The net thermal energy is the solar radiation energy absorbed by the absorber minus the loss of thermal energy by the absorber to the environment. Manifold losses and losses by thermal systems to which the collector is attached are not included. By providing information about the energy collection properties of different collectors, SOCOL can lead to the appropriate choice of a collector as an energy source for a thermal system. SOCOL can also be used for site selection, orientation and feasibility studies of a particular collector. Rather complete information concerning SOCOL can be found on the web site: www.sci.sdsu.edu/SOCOL/.

Discussion of SOCOL

For the calculation of energy collection, the essential optical and loss properties of a collector can be treated without involving details of mechanical design and heat transfer. The essential properties for calculating energy collection by 14 thermal collectors are contained in SOCOL. These include a single glazed and a double glazed air flat plate collector and 12 evacuated collector designs. The last two of these are single axis and two-axis, evacuated, high concentration, tracking collectors. Because of its wide application, a planar PV electric collector has been added. Recently, SOCOL has been modified to allow 6 different modes of tracking for the normally fixed collectors, so any of the collectors in SOCOL can be in a tracking mode.

SOCOL grew out of a program SOLRAD used to study the properties of solar radiation [eg. See: Gueymard and Garrison, Solar Energy 62, 291-307(1998)]. It still includes parts of this program. The output of SOCOL contains information about the solar radiation and surface meteorological data. This allows

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Inside This Issue

Solar Spectrum is the newsletter from the Resource Applications Division of the American Solar Energy Society and is published on a semi-annual basis. The purpose of this newsletter is to inform division members of events in the resource assessment field and activities of the division and its members.

Success of the newsletter depends on your contributions.

You are encouraged to send comments, letters, or short articles to the Editor:

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I would like to thank Jack Garrison and Gary Vliet for their contributions to this newsletter.

Deadline for contributions to the next newsletter is October 1, 2004.

Frank Vignola

Resource Applications Division Officers

Gary Viet, Chair
Ed Kerns, Vice Chair
Jim Augustyn, Secretary

Upcoming Events

A Solar Harvest Growing Opportunities
July 11-14, 2004

Portland, Oregon
Information: ASES
2400 Central, G-1
Boulder, CO 80301
Tel 303-443-3130
Fax 303-443-3212
Email: ases@ases.org
http://www.ases.org

ISES World Congress
Bringing Water to the World
Aug 14-19, 2005

Orlando, Florida
Dr. Jan-Olof Dalenbäck
Information: ISES 2003 World Congress,
c/o Building Services Engineering,
Chalmers University of Technology
Se-4129 Göteborg, Sweden
Fax: +46 31 772 1152
Email: jod@vsect.cchalmers.se
http://www.congrex.com/ises2003

RAD Division Officers and Board—In transition

The Resource Applications Division of ASES in undergoing re-organization. The makeup of the division and its board will be discussed at the next RAD division meeting at Solar 2004.

There is an ongoing discussion The division meeting has tentatively been scheduled for Monday, July 12, 2004 from 5:30-6:30 pm. This is a chance to help shape the future of the RAD division.

Currently the RAD division activities are mainly associated with the annual conference. In the past the division has put together forum or workshops, helped select reviews for the review of papers, and suggested members of the conference technical review committee. The division also helps in the nominations of the division member to the ASES board.

Email Addresses for Resource Applications Division Members

In order to open communications between RAD division members, the following members circulated their Email address at the RAD division annual meeting. If you are not on this list and would like to add your name to the list, contact Solar Spectrum's editor and your Email address will be added to the list and published in the next newsletter.

Please notify the editor of changes.

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ASES/RAD Meeting At ASES 2003, Austin, Texas

June 24, 2003

by Gary Vliet

Meeting called about 4:15 PM by Frank Vignota

Attendees:
Frank Vignola
Gary Vliet
Ed Kern
Dave Renné
Richard Perez
Charlie Whitlock
Cecile Warner

Each attendee made a few comments:

Dave Renné (NREL): Resource Assessment people at NREL are now scattered in 3 program areas. This has both positive and negative aspects, but it provides an opportunity to do more analytical work on applications. There is a movement in the National Weather Service toward fully automated observations. The NASA Surface Radiation Budget data base goes back to 1982, and high resolution GOES data extends back to 1990. Need to attract more people to be active in division. Should we refocus/rename the division?

Richard Perez/Re. Satellite Data: High resolution data for 6 years archived for all North America. Working with colleagues in Germany and others abroad to ensure consistent analysis. His satellite-derived data resolution is about 10-km (6 miles).

Gary Vliet/UTAustin: The Texas Solar Radiation Data Base (TSRDB) network is being phased out. All NREL loaned instruments/site to be retained, but local site personnel will interact directly with NREL, and hopefully continue data collection/archiving. Gary is moving toward a "phased" retirement. Noted that in general the TSRDB agreed quite well with NREL's NSRDB Texas sites, except that the direct normal values along gulf coast in winter are much higher than the NSRDB and also generally somewhat higher in west Texas (Trans Pecos area).

Ed Kern: Suggested that more emphasis should be and is being put on applications. He noted that PV manufacturers feel current data is adequate.

Charlie Whitlock/NASA: Release 5 of the Surface Solar Energy (SSE) data set is expected out later this year. This version will have the true 1-degree resolution. They are moving from Staylor Model to the Pinker Model. There is still a question about the validity of the diffuse values above about 55 latitude. NASA eventually expects to be forecasting solar radiation data based on predicted weather (cloud cover) 2 weeks in advance at a 1-degree resolution (~ 67 miles).

Frank Vignola: He is also going into a phased retirement (1/2 time). Plans to continue current NW network. Noted direct normal data in the NW area appears to have increased 10-20% in last 2-3 decades. He sees interests in the application of radiation data to meet customer (utility) needs.

Future Activities

Newsletter – There was no discussion about news articles or issues, but there is an assumption that Frank V. will be continuing this effort.

Forum for ASES 04 – There was a recommendation that a forum on Resource Assessment – Hybrid systems – Hybrid Energy Economy be scheduled for ASES '04 at Portland and maybe be geared to the Pacific NW area. Renné, Perez and Warner are to organize this as committee with Renné being the 'Chair'. A title and brief descriptions will need to be provided to ASES some time this fall.

Officers - An "election" was held. Vliet will be Chair this coming year. Ed Kern will become Vice-Chair. Renné is to speak with Jim Augustyn about being Secretary.

Reviewers for Next Year – All 7 agreed to serve as blind reviewers. Frank will arrange for who (2) will serve on the on-site review committee.

Division Name – After some discussion it was generally agreed to rename the division "Resource Applications Division" . This still has the RAD "handle" but will hopefully broaden the division to become more involved in a variety of technologies.

Meeting adjourned at 5:40 PM

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Resource Application Sessions at SOLAR 2004

Resource Modeling for Applications
Wednesday July 14, 2004 from 8:30-10:00

From the ASES brochure, the talks for the Resource Modeling for Applications session is as follows.

Solar Renewable Energy Data Sets from NASA Satellites and Research
P. Stackhouse, NASA Langley Research Center; C. Whitlock, W. Chandler and J. Hoell, Science Applications International Corporation and T. Zhang, Analytic Services and Materials

Solar Resource Assessment in the Foggiest City on Earth
J. Augustyn and T. Geer, Augustyn + Company and F. Schwarz, M. Kim and K, Knox, San Francisco Public Utilities Commission

Analysis of Short-term Solar Radiation Data
G. Vijayakumar, S. Klein and W. Beckman, University of Wisconsin-Solar Energy Laboratory

Update of Algorithm to Correct Direct Normal Irradiance Measurements Made with a Rotating Shadow Band Pyranometer
J. Augustyn and T. Geer, Augustyn + Company; T. Stoffel, National Renewable Energy Laboratory; F. Vignola and R. Kessler, University of Oregon; E. Kern and R. Little, Schott Applied Power Corporation and B. Boyson, Sandia National Laboratories

Cumulative Frequency Distributions for Daily Global Illuminance
V. Satyamurty and P. Ravikumar, Indian Institute of Technology, INDIA

Generation of Monthly Average Hourly Ambient Temperatures from Monthly Average Daily Temperature
P. Ravikumar, Indian Institute of Technology, INDIA

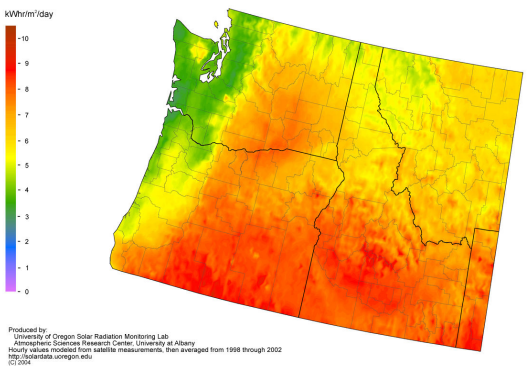
Resource Assessment Irradiance Modeling
Wednesday July 14, 2004 from 10:30-12:00

High Performance Model for Clear-Sky Irradiance and Illuminance
C. Gueymard, Solar Consulting Services

Sensitivity of Spectroradiometric Calibrations in the Near Infrared to Variations in Atmospheric Water Vapor
D. Myers and A. Andreas, National Renewable Energy Laboratory

Status of High Resolution Solar Irradiance Mapping From Satellite Data
R. Perez and M. Kmiecik, ASRC, The University at Albany; K. Moore, Integrated Environmental Data; S. Wilcox, R. George and D. Renné, NREL; F. Vignola, University of Oregon and P. Ineichen, University of Geneva

Progress on an Updated National Solar Radiation Data Base
S. Wilcox, M. Anderberg, R. George, W. Manion, D. Myers and D. Renne, NREL; W. Beckman, University of Wisconsin-Madison; A. DeGaetano, Northeast Regional Climate Center; C. Gueymard, Solar Consulting Services; R. Perez, SUNY Albany; M. Plantico



Average July Direct Normal Beam Irradiance for the Pacific Northwest

Solar Resource Assessment Maps for the Pacific Northwest Now available on the Web

by Frank Vignola

Global, beam, and diffuse irradiance data on a 0.1° grid are now available for the Pacific Northwest. Richard Perez and Frank Vignola have completed a study of the region's solar resource. Maps are produced and accessible on the Web at: http://solardata.uoregon.edu/NorthwestSolarResourceMaps.html, see figure above.

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the properties of the energy collected by a collector to be related to properties of the solar radiation and surface meteorological data. One example of such a relation has been demonstrated: Using the output from SOCOL one can, for example, make a least squares fit of calculated annual net solar energy collection by a particular collector to an equation involving K_b, K_d, latitude, operating temperature and ambient temperature as variables. This uses the annual energy collection at 35 selected sites (using mostly measured data) calculated by SOCOL. The rms error is a few percent. [See: Garrison, Solar Energy 73, 241 – 255 (2003)].

The most recent development of SOCOL has occurred on a Compaq Presario 2700 laptop computer with a 1.13 GHz Pentium III processor using Microsoft Windows XP. To calculate hourly solar energy collection for one year for one collector requires about 20 seconds. Much of this time is involved in calculating the contribution of diffuse radiation. This uses collection from 400 equally spaced points over the sky and corresponding ground reflection points. For the sky, the prescription of Perez, Seals and Michalsky [Perez, et al, Solar Energy 50, 235-245 (1993)] is used with luminance replaced by irradiance.

This paragraph is provided for those who wish to sample the operation of SOCOL. Compaq Visual Fortran has been installed in the Compaq Presario computer. On compiling the SOCOL Fortran program socol.f , the output file socol.exe is produced. This "executable" file can be downloaded from the above web site. To calculate energy collection of a particular collector with your PC, you must assemble socol.exe and the input data file for one or more years from TMY2 or NSRDB data in the same folder. One must go to the beginning of socol.f to match the names there to the names of the input data files. Then go to the START menu in the lower left corner of your PC computer and click on to the option "Run….". In the window which appears, type in "cmd" (command) in the box to the right of "Open". Then click "OK". A blackened window appears with a command line (It comes from the System32 file "cmd"). Type in the command "cd" (change directory) and follow this by the address of the folder containing socol.exe and the input data. Then hit "return". To run socol.exe , type the command socol.exe and hit "return". When socol.exe is run it asks for a variety of input. This input is described in the on screen queries by socol.f and in the beginning of socol.f in detailed comments. The output file for socol.exe is "ec.dat" which will appear in the same folder. It must be deleted or renamed before socol.exe can be run again. (In the above procedure, one can create a "shortcut" to avoid going through the START menu in the future.) Currently, SOCOL is programmed to read data for 47 stations and used for years with mostly measured data.

SOCOL (socol.f, socol.exe) calculates solar energy collection by thermal collectors using two different selective absorbers whose properties are contained in SOCOL. Energy collection by another selective absorber can be calculated by giving input data to SOCOL for this third absorber. Similarly, SOCOL contains information on the properties of two PV collectors, while information for a third can be given to SOCOL as input data. The kind of output information that is desired for "ec.dat" is requested by SOCOL as input. Output can be very brief, or quite comprehensive. The difficulty in using SOCOL (socol.f, socol.f) seems to be mainly in deciding what to use as input. SOCOL has many comments throughout telling what it is doing, the sources of the equations used, and at the beginning, comments about the input.

Some individuals may wish to do calculations using SOCOL for a novel collector not found in SOCOL. This requires determination of the Angular Response of the collector by ray tracing and inclusion of formulas for calculation of energy losses. Energy losses are discussed along with references in the part of SOCOL where energy losses are calculated. The method of calculating angular response

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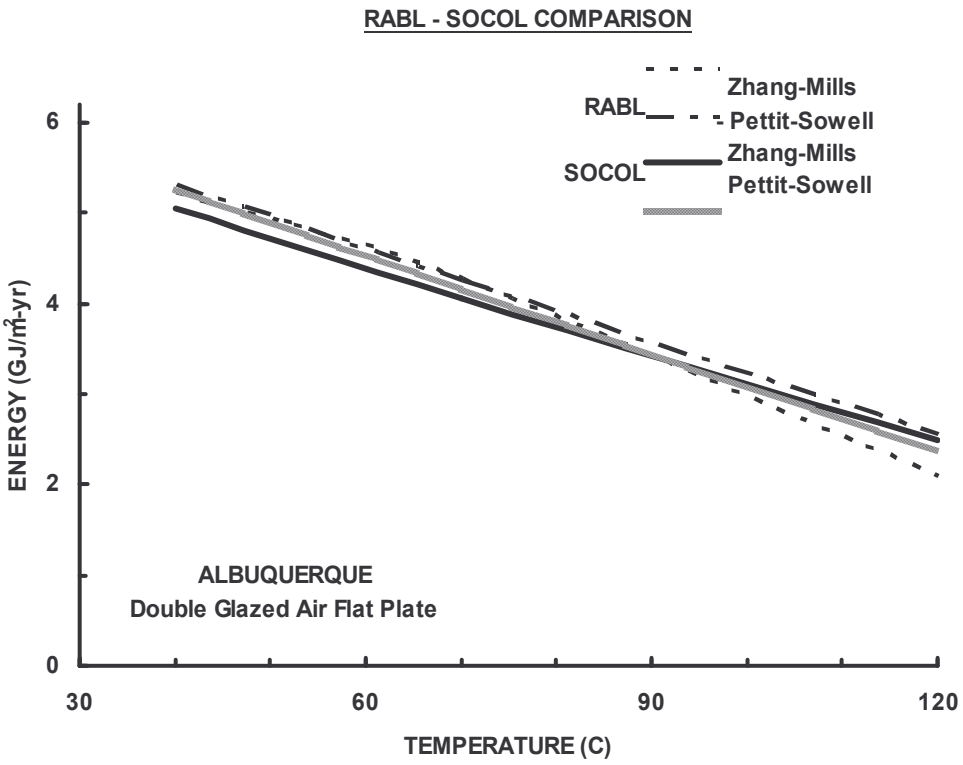

Fig. 1: Comparison of solar energy collection for a double glazed air flat plate collector as calculated by SOCOL and by Rabl.

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will be included on the web site when it is brought up to date in the near future.

Validation of SOCOL

SOCOL has been checked in many different ways to verify that it is calculating the desired quantities correctly. Most of the errors have been found early in this work. More recently a few minor errors have been found which have little affect on the calculated solar energy collection. Below are the results of two tests of the validity of calculation of energy collection by SOCOL.

Fig. 1 compares solar energy collection for a double glazed air flat plate collector calculated by SOCOL at Albuquerque, NM with collection calculated by the entirely different method of Rabl [Solar Energy 27, 215 – 235 (1981)]. This is for the two selective absorbers whose properties are included in SOCOL.

Table 1 compares annual average daily solar radiation energy incident in a square meter calculated using SOCOL with the calculations of Marion and Wilcox [NREL/ TP –463 –5607 (1994)]. This is shown for Albuquerque, NM and Albany, NY. To make this comparison, a collector in SOCOL must, in effect, be removed. This is done by setting its Angular Response equal to the cosine of the angle of incidence of the solar radiation, or, equivalently, setting the optical efficiency equal to unity. The collector energy loss must also be set equal to zero.

The above two comparisons are an indication of the validity of using SOCOL for solar energy collection calculations. The above two tests do not test the validity of the Angular Response and heat losses for the collectors other than the double glazed air flat plate collector. The difference between energy

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collection by the different collectors occurs only by differences in their Angular Response, determined by ray tracing, and differences in their energy loss. The calculation of energy loss for the collectors is described in SOCOL where the calculation occurs. The ray tracing and energy losses have been checked and repeated to attempt verification of their approximate validity. Beyond what has been done, SOCOL needs independent evaluation by other interested parties.

Suggestion

The Renewable Resource Data Center has a solar web site at http://rredc.nrel.gov/solar/ with solar radiation data and references to sources of these data. It also has certain codes and algorithms. It seems that further extension in the direction of providing tools for using these data is very desirable. Many individuals would like an easy way to get started or to provide quick answers. A program developed along the lines of SOCOL would be useful. One does not need to know how it works to use it. It can provide the information to decide whether a solar collector is feasible for an application and help select the type of collector most suitable for the application. Persons involved in installing solar collectors could find it very useful.

In its present form, SOCOL, probably should not be used at this web site, except with the expectation that it will be improved or replaced by a new program in the future.

Table 1. YEARLY AVERAGE SOLAR RADIATION (kWh/m²/day)

Fixed South Facing Area --- Direct + Diffuse Radiation

	Albuquerque		Albany	
Tilt of Normal (deg)	Marion & Wilcox	SOCOL	Marion & Wilcox	SOCOL
0	5.6	5.6	3.8	3.8
Latitude - 15	6.3	6.3	4.3	4.4
Latitude	6.4	6.4	4.3	4.3
Latitude + 15	6.2	6.2	4.1	4.1
90	4.1	4.1	3.0	3.0

One Axis N - S Tracking --- Direct + Diffuse Radiation

	Albuquerque		Albany	
Tilt of Axis (deg)	Marion & Wilcox	SOCOL	Marion & Wilcox	SOCOL
0	7.8	7.8	4.9	5.0
Latitude (Polar)	8.5	8.5	5.4	5.4

Two Axis Tracking --- Direct + Diffuse Radiation

	Albuquerque		Albany	
	Marion & Wilcox	SOCOL	Marion & Wilcox	SOCOL
	8.8	8.9	5.6	5.6

Concentrating Collector Tracking --- Direct Radiation Only

	Albuquerque		Albany	
Tracker	Marion & Wilcox	SOCOL	Marion & Wilcox	SOCOL
1-Axis E-W Horizontal Axis	5.1	5.0	2.5	2.5
1-Axis N-S Horizontal Axis	5.9	5.9	2.8	2.9
1-Axis N-S Tilt=Latitude (Polar)	6.4	6.5	3.2	3.2
2 - Axis	6.7	6.8	3.3	3.4

RESOURCE APPLICATION DIVISION
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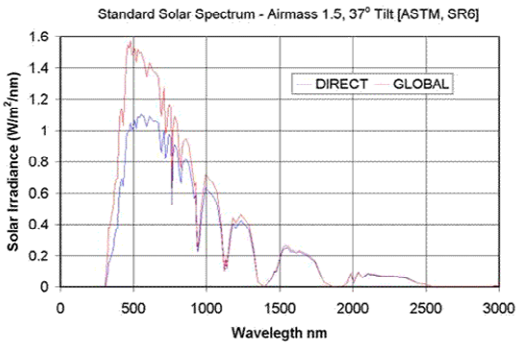
WORKSHOP: TERRESTRIAL SOLAR SPECTRAL MODELING FOR RENEWABLE ENERGY APPLICATIONS

Presented by Daryl Myers

A workshop Terrestrial Solar Spectral Modeling for Renewable Energy Applications will be held on Wednesday, July 14, 1:30 – 5:30PM at Solar 2004 in Portland, Oregon. A fee of $75 will be charge that includes CD-ROM with SMARTS and SPCTRL2 models and manuals, workbook and references, workshop examples and hard copy of presentation. A minimum 5 and a maximum 25 will be accommodated at the workshop.

This workshop will identify, demonstrate, and teach examples of available tools for participants to compute terrestrial solar spectra for renewable energy engineering and research applications. Applicable areas include: Photovoltaics, Daylighting, and Materials Performance (absorbers, reflectors, degradation). The workshop will include a historical overview of atmospheric spectral transmission models; the extraterrestrial solar spectrum; constituents of the atmosphere and their spectral transmission; radiometry versus photometry; descriptions and demonstrations of MODTRAN/LOWTRAN high-resolution model [Commercial Product version] (direct beam transmittance and sky radiance); SERI SPCTRL2 model low-resolution model [QuickBasic and Excel Spreadsheet]; and FSEC Simple Model of Atmospheric Radiative Transfer of Sunshine (SMARTS) [FORTRAN]. Students may bring a Laptop with CD-ROM reader, so they can follow along as the examples and demonstrations are presented.



Direct and global standard solar spectrum at 1.5 Airmass 37° Tilt.