

# SOLAR SPECTRUM

Newsletter of the Resource Assessment Division

Volume 13, Issue 2 – November 2000

of the American Solar Energy Society®

## Estimating Direct Radiation from Global

by Daryl Myers

Many times we at NREL are asked for means of estimating direct radiation from global horizontal measurements. In 1987, Eugene Maxwell developed an empirical model for estimating HOURLY DNI from GH data. His results were documented in a 67 page SERI (NREL) report Maxwell, E.L., "A Quasi-Physical Model for Converting Hourly Global Horizontal to Direct Normal Insolation" SERI TR 215-3087, National Renewable Energy Laboratory, August 1987.

As a service to the RA community, I'd like to outline the algorithm here. We really should pursue an archival journal publication describing this model and its performance in detail. Model validation based on measured NREL Solar Radiation Research Laboratory data for the year 1998 shows a MBE of about - 50 W/m<sup>2</sup>, with RMSE of 150 W/m<sup>2</sup> for all estimates with zenith angle < 80 degrees (See Figs. 1-2).

Here is the algorithm in outline form:

Assume solar constant is 1370 W/m<sup>2</sup> at mean earth-sun distance.

Compute "Day Angle"

$D = 2 * \delta * (\text{Day of year} - 1) / 365$  radians

(Jan 1 = DOY 1)

Compute Extraterrestrial Normal (direct beam), ETRN, as function of "day angle"

$$\text{ETRN} = 1370 * [ 1.00011 + 0.034221 * \cos(D) + 0.00128 * \sin(D) + 0.000719 * \cos(2 * D) + 0.000077 * \sin(2 * D) ]$$

(Continued on page 6)

DISC MODEL Minus Measured DNI for 3300 SRRL Hourly Data 1998

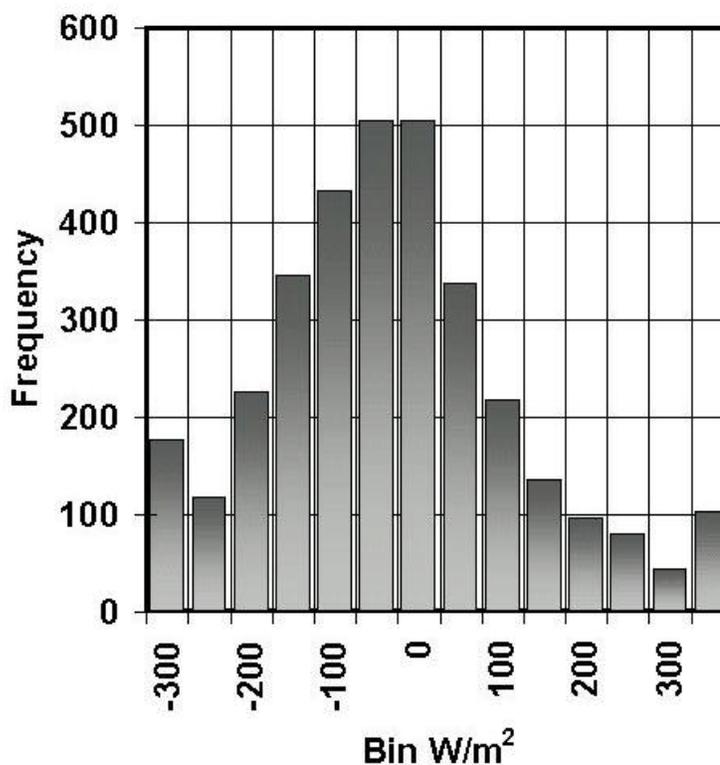


Fig. 1: DISC model histogram for 3300 data points at SRRL

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**Solar Spectrum** is the newsletter from the Resource Assessment 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:

Frank Vignola  
Department of Physics  
1274-University of Oregon  
Eugene, OR 97403-1274  
Tel (541) 346-4745  
Fax (541) 346-5861  
email: fev@darkwing.uoregon.edu

I would like to thank Daryl Myers and Roberta DiPasquale for their contributions to this newsletter.

Deadline for contributions to the next newsletter is February 1, 2001.

*Frank Vignola*

**Resource Assessment Division  
Officers & Board Members**

Gary Vliet, Chair  
Bob Cable, Vice Chair  
David Renné, Secretary

Ray Bahm	June 2001
Mark Beaubien	June 2002
Doug Balcomb	June 2002
John Dunlop	June 2002
Dan Greenberg	June 2001
Bill Marion	June 2001
Rob Nelson	June 2001
Richard Perez	June 2002



## Upcoming Events

**Forum 2001**  
April 21-25, 2001  
**Solar Energy:**  
**The Power to Choose**

Washington, DC  
*Information:* ASES  
2400 Central, G-1  
Boulder, CO 80301  
Tel 303-443-3130  
Fax 303-443-3212  
Email: ases@ases.org  
<http://www.solarenergyforum.org>

Presented By: American Institute of Architects—Committee on the Environment; American Society of Mechanical Engineers—Solar Energy Division; American Solar Energy Society; American Society of Heating Refrigerating and Air-Conditioning Engineers; Interstate Renewable Energy Council; Maryland DC Virginia Solar Energy Industries Association; National Association of Home Builders; Potomac Region Solar Energy Association; Society of Building Science Educators; Solar Energy Industries Association; Sustainable Buildings Industry Council; Utility PhotoVoltaics Group

### RAD Division Nominees

It is time to elect new RAD Division officers and board members for the next year.

At the next RAD division meeting, the current Vice Chair, Bob Cable will take over as Chair of the RAD division.

Nominated for Vice Chair is Roberta DiPasquale of NASA Langley/SAIC Surface Solar Energy Project. Nominated for secretary is David Renné of the National

Renewable Energy Laboratory.

The Board nominees are Jim Augustyn of Augustyn and Company, Bill Marion of the National Renewable Energy Laboratory, Lorin L. Vant-Hull of the University of Houston, and Rob Nelson of Heliakos.

If elected, these officers and board members will start their duties at the annual RAD division board meeting.

### Email Addresses for Resource Assessment 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.

Augustyn & Company. [parsley@solarcat.com](mailto:parsley@solarcat.com)  
Ray Bahm..... [r.bahm@ieee.org](mailto:r.bahm@ieee.org)  
Bruce Bailey ..... [awssci@delphi.com](mailto:awssci@delphi.com)  
Roberta DiPasquale..... [roberta@saisun02.larc.nasa.gov](mailto:roberta@saisun02.larc.nasa.gov)  
John Dunlop ..... [jrdunlop@mcimail.com](mailto:jrdunlop@mcimail.com)  
Eppley Laboratory Inc. [eplab@mail.bbsnet.com](mailto:eplab@mail.bbsnet.com)  
Tracy Gardner... [tgardner@nrel.nrel.gov](mailto:tgardner@nrel.nrel.gov)  
Jack Garrison..... [jgarriso@sciences.sdsu.edu](mailto:jgarriso@sciences.sdsu.edu)  
Chris Gueymard..... [chris@fsec.ucf.edu](mailto:chris@fsec.ucf.edu)  
Bill Marion ..... [bill\\_marion@nrel.gov](mailto:bill_marion@nrel.gov)  
Ken Miller ..... [ecskamil@aol.com](mailto:ecskamil@aol.com)  
Ross McCluney... [RMcCluney@fsec.ucf.edu](mailto:RMcCluney@fsec.ucf.edu)

Bob Nelson ..... [rnelson@heliakos.com](mailto:rnelson@heliakos.com)  
Richard Perez..... [Perez@asrc.albany.edu](mailto:Perez@asrc.albany.edu)  
Helen Powers..... [power@udel.edu](mailto:power@udel.edu)  
Dave Renné ..... [drenne@nrel.nrel.gov](mailto:drenne@nrel.nrel.gov)  
Martin Rymes..... [mrymes@nrel.nrel.gov](mailto:mrymes@nrel.nrel.gov)  
Lary Sherwood .... [ASES@IGC.APC.ORG](mailto:ASES@IGC.APC.ORG)  
Mike Sloan ..... [sloan@vera.com](mailto:sloan@vera.com)  
Frank Vignola ..... [fev@oregon.uoregon.edu](mailto:fev@oregon.uoregon.edu)  
Lorin Vant-Hull..... [vanthull@uh.edu](mailto:vanthull@uh.edu)  
Gary Vliet..... [gvliet@mail.utexas.edu](mailto:gvliet@mail.utexas.edu)  
Cecile Warner ..... [cecile@nrel.nrel.gov](mailto:cecile@nrel.nrel.gov)

# NASA COMMERCIAL WEB SITE EXCEEDS 1000 DATA CUSTOMERS

by Charlie Whitlock

Approximately 11 months ago, a NASA Langley Research Center Release 2 Surface Solar Energy (SSE) web site was made available to the public. This web site is the product of a commercial outreach project that reformats NASA Earth Science Enterprise radiation and meteorology science data for the Solar Energy Industry. The SSE web site is primarily directed toward the general needs of the Solar Energy Industry for designing passive and active solar systems. However, a broader audience in education as well as the general

public has shown an interest in the web site. SSE is indebted to our partners who tutored us in the needs of industry and provided valuable inputs for conversion of NASA science parameters to industry-specific parameters suitable for business use. We are also grateful to the American Solar Energy Society, the Solar Energy Industries Association, the Solar Energy Society of Canada Inc., and the World Bank for invitations to annual meetings and short courses.

The National Aeronautics & Space Administration (NASA) and NRCan are co-operating to facilitate the use of NASA's global satellite data with RETScreen. Access to such weather data will allow users around the globe to better evaluate potential RET projects where ground monitoring station weather data are not available. RETScreen which now has more than 8,500 users in greater than 160 countries worldwide, can be downloaded free-of-charge at the following website address: <http://retscreen.gc.ca>

## NASA Surface Solar Energy Data Sets for Commercial Applications

### Introduction

Renewable energy technologies are changing the face of the world's energy market. These technologies range in complexity from the introduction of solar ovens and simple photovoltaics panels into rural communities - to the construction of commercial buildings with integrated photovoltaics and large thermal and wind generating power plants. Crucial to the success of the emerging renewable market is the availability of accurate, global solar radiation and meteorology data. The Surface Solar Energy (SSE) project is developing the commercial potential of

NASA's cloud, radiation, and meteorology data by working closely with partners from government, commercial industry, educational, and non-profit organizations. The Release 2 SSE data set, which is accelerating the realization of economic and societal benefits from NASA earth science data, is available via the Internet (<http://eosweb.larc.nasa.gov/sse/>). Cur-

rently useful in a number of applications, future versions of these data (planned for Release 3 and beyond) have the potential to significantly advance the global adoption of renewable energy technologies.

### Web Site Usage and Performance

Since June 1999, the SSE web site has generated approximately

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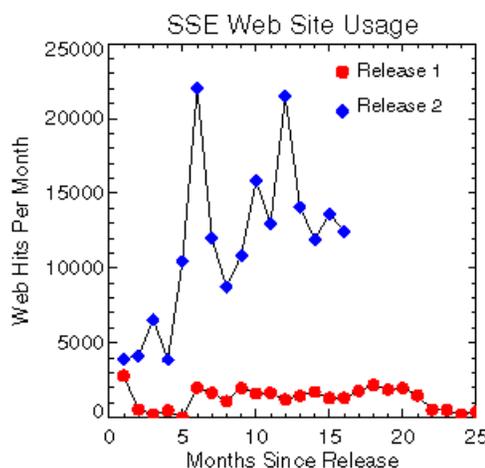


Fig. 1: Web site use increases dramatically

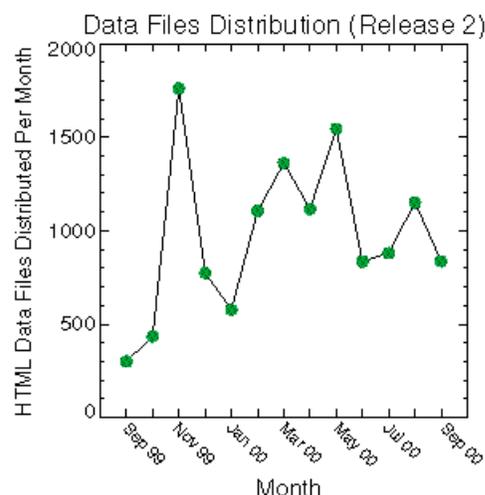


Fig. 2: 1000 files per month distributed.

# Resource Assessment Division Meeting

## Minutes 20 June, 2000

### Madison, Wisconsin

by David Renné



In attendance: Dave Dobson, Cecile Warner, Dave Renné, Bill Marion, Tim Townsend, Rob Nelson, Bob Cable, Roberta DiPasquale, Loren Vant-Hull, Richard Perez, Jim Augustyn, Frank Vignola.

The meeting was called to order at 12:30 PM in the Monona Center Terrace, 20 June, 2000 during ASES 2000. Cecile Warner, the outgoing Chair, opened the meeting and introduced Gary Vliet as the new Chair. Cecile also commented on the quality of the Solar Spectrum, the Division's newsletter, and thanked Frank Vignola for his continued service in producing the newsletter.

Gary discussed the make-up of the Division leadership. The new Vice Chair is Bob Cable, and the Secretary is Dave Renné. Outgoing Board members are Richard Perez, Tim Townsend, Bob Cable, and Jim Augustyn. New incoming Board members are Doug Balcomb, Richard Perez, John Dunlop, and Mark Beaubien. Those continuing on the Board with one more year of service are Ray Bahm, Dan Greenberg, Bill Marion, and Rob Nelson.

Dave Renné gave a report on the ASES Divisions Committee meeting, which was held via telephone conference call on 30 May. The following topics were reviewed and discussed:

- Newsletter: The RAD newsletter is done regularly, thanks to Frank Vignola. It was suggested that ASES/HQ not put the newsletter under "member services" on their web site, but rather under a category such as "publications" or newsletters".
  - Division nominations: We need to establish a RAD Nomination Committee. We agreed that it is best to get the ballot included in the general ASES ballot that goes out around mid-Fall. A Nomination Committee was appointed to select Division candidates. The Committee includes Renné, Vignola, Cable, Vliet, and Augustyn. Vliet will communicate the results to Larry Sherwood. We need four Board nominees, a Vice Chair, and a Secretary.
  - Program: The next ASES conference is in Washington, DC in April 2001. Gary Vliet, Cecile Warner, and Richard Perez are to serve as a program committee. One possibility is a tutorial on solar resource measurements. This tutorial could also be presented at the IECEC meeting in Savannah, Georgia in July 2001.
  - Technical Reviewers for 2001: Bill Marion and Bob Cable will serve as paper reviewers, and Roberta DiPasquale has agreed to serve as the "traveling" reviewer.
- We then went around the room and each attendee discussed pertinent resource assessment activities:
- Dave Renné gave an overview of the United Nations Environment Programme/Global Environment Facility (GEF) Solar and Wind Energy Resource Assessment project. This project is currently in the PDF/B stage where the GEF has allocated \$300K to develop the full Project Brief. The funds have been used to support two technical workshops (Golden, CO and Riso, Denmark) and three regional workshops (Nairobi, Kenya, New Delhi, India, and S.J. dos Campos, Brazil). Current plans are to submit the Project Brief to the GEF for review in early September.
  - Frank Vignola discussed his five-year funded program to conduct a solar resource assessment for the Pacific Northwest. The client is Bonneville Power Administration. He is also developing a web site, and wants to include a number of features such as the solar position calculator. He wants the site to offer a package of solar resource assessment tools within the next two years.
  - Bill Marion is transferring DATSAV2 cloud cover and related data from about 22,000 weather stations around the world onto DVD. About 10,000 of these stations have good quality data.
  - Roberta DiPasquale described the new NASA Surface Solar Energy data base. The database, to be released in August., will provide worldwide solar data at 1<sup>0</sup> resolution based on model runs at 280 km resolution, covering the period 1983-1991.
  - Gary Vliet gave a status report

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# Resource Assessment Division Meeting Minutes 20 June, 2000 Madison, Wisconsin

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on the Texas Solar Radiation DataBase. He is maintaining a 15-station network, but there is no funding after August 31. He did some comparisons of these data with the NSRDB, and found good comparison with global horizontal values, but not with direct normal.

- Jim Augustyn has developed a new version of the DQMS for the DOE/ARM Program. He has also set up a 7-station network for Concentrating Solar Power sites.
- Richard Perez is concentrating on applications work.

The RAD has good representation at the ASES 2000 Conference.

There was a Forum on "Use of Solar Resource Data", a session on "Solar Radiation Measurements and Observations", and a Session on "Solar Radiation Analysis". There was generally good attendance at all sessions.

Upcoming solar resource assessment events included the ISES Millennium Conference in Mexico City in late September (in conjunction with ASES), and an ISES meeting in Copenhagen (occurring currently).

The Solar Spectrum newsletter was discussed next. Again, Frank was complimented on a good job, and Frank has agreed to continue with it. Deadlines for the next two issues are 1 October and 1 Febru-

ary. Upcoming articles should be developed on the UN Project, the NASA solar databases, and the ISES Conference. There was some discussion on changing the name of the Solar Spectrum.

Under New Business, Cecile noted that we need to keep good technical expertise represented on the ASES Board. She feels there is a move to give the Chapters greater strength on the ASES Board relative to the Divisions. She will start an e-mail dialogue on this, and raise it at the upcoming ASES Board meeting.

Gary Vliet adjourned the meeting at 1:50 PM.

## UO Solar Radiation Monitoring Lab Launches an Enhanced Web Site

The University of Oregon Solar Radiation Monitoring Laboratory launched an enhanced web site in December. The new web site contains 5 minute, hourly data from the UO Solar Monitoring network as well as the daily data previously offered.

The improvement to the web site is part of a project sponsored by the Bonneville Power Administration and the regional solar radiation data monitoring consortium to make Pacific Northwest Solar

University of Oregon  
Solar Radiation Monitoring  
Laboratory

The UO SRML, in sunny Eugene, Oregon, operates monitoring stations throughout the Pacific Northwest to provide high quality scientific data for solar energy resource evaluation and long-term climate studies.

This work is made possible by

- ◊ Bonneville Power Administration
- ◊ Eugene Water and Electric Board
- ◊ National Energy Technology Lab
- ◊ National Renewable Energy Lab
- ◊ Northwest Power Planning Council
- ◊ Portland General Electric

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radiation data more accessible and to provide tools to facilitate the use of the data.

The web site is structured into four sections. The first is the solar data, the second is useful tools to manipulate the data, the third is educational information, and the fourth is publications. As there are a variety of data needs, the data section contains short interval ar-

chived data along with long-term summary data, daily data, and monthly hourly average data files. The tools section and the educational materials section are under construction, and will be added to as subsections are completed. PV lesson plans for high school science students are already available at the site. The web site is <http://solardata.uoregon.edu>.

# Estimating Direct Radiation from Global

(Continued from page 1)

Compute Declination DEC from D:

$$\text{DEC} = [0.006918 - 0.3999912 * \cos(D) + 0.070257 * \sin(D) - 0.006758 * \cos(2 * D) + 0.000907 * \sin(2 * D) - 0.002697 * \cos(3 * D) + 0.00148 * \sin(3 * D)] * 180 / \delta \text{ degrees}$$

Compute Equation of time (minutes) EQT from D:

$$\text{EQT} = [0.000075 + 0.001868 * \cos(D) - 0.032077 * \sin(D) - 0.014615 * \cos(2 * D) - 0.040849 * \sin(2 * D)] * 229.18 \text{ min.}$$

Compute Hour angle HA from longitude L, time zone T, Local Standard Time, LST (decimal hours) (NOTE: TZ and Longitude negative WEST of Greenwich, Positive East of Greenwich,  $0 < \text{west long} < -180$   $0 < \text{east long} < 180$ )

$$\text{HA} = 15 * [ ( \text{LST} - 0.5 - 12.0 ) + ( \text{L} - \text{T} * 15 ) / 15 + \text{EQT} / 60 ]$$

NOTE: For HOURLY data, geometry is assumed for MIDDLE OF PREVIOUS HOUR, so LST of 10:00 computed for LST 9:30 or 9.5; Assuming time stamp 10:00 means hourly average, 9:00 to 10:00.

Compute Zenith Angle from usual equations (LAT=Latitude):

$$Z = \text{ACOS}( \cos(\text{DEC}) * \cos(\text{HA}) * \cos(\text{LAT}) + \sin(\text{DEC}) * \sin(\text{LAT}) )$$

Compute extraterrestrial on horizontal surface, ETRH, by modifying ETRN by cos(z)

$$\text{ETRH} = \text{ETRN} * \cos(z)$$

Compute global clearness index Kt from measured global, G

$$\text{Kt} = \text{G} / \text{ETRH}$$

Compute Air Mass AM from Z and Kasten's formula

$$\text{AM} = 1 / \{ \cos(Z) + 0.15 * [ (93.885 - Z)^{-1.253} ] \}$$

Bias Errors DISC MODEL - MEASURED DNI  
3300 Hours of SRRL DNI

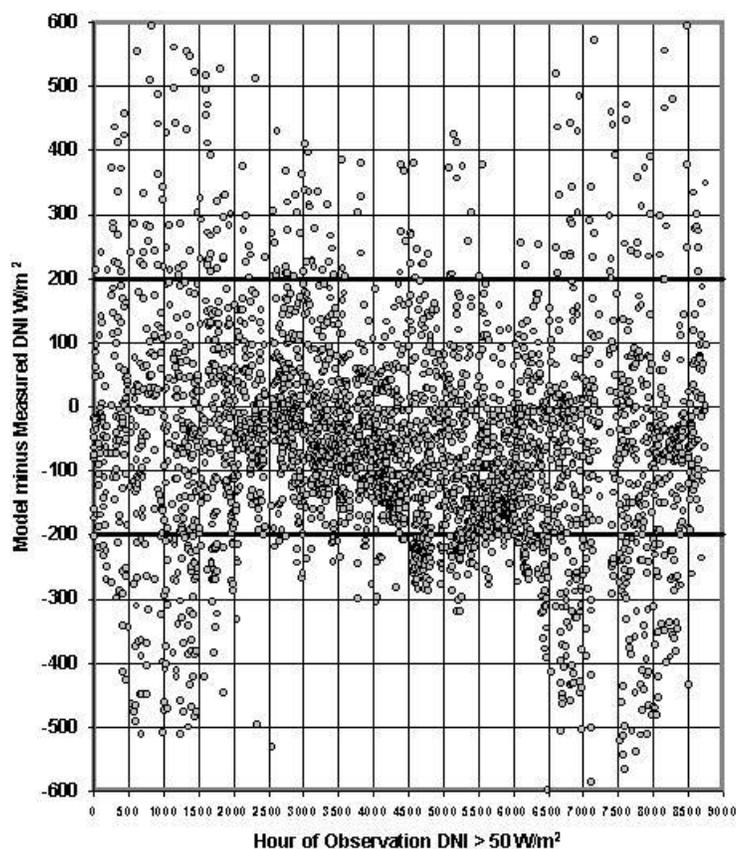


Fig. 2: Bias error for the DISC model.

Correct AM for Station Pressure:

$$\text{AM} = \text{AM} * ( \text{P station} (\text{mB}) / 1013.25 )$$

if  $\text{Kt} \leq 0.6$ , compute A,B,C from Kt

$$A = 0.512 - 1.56 * \text{Kt} + 2.286 * \text{Kt}^2 - 2.222 * \text{Kt}^3$$

$$B = 0.370 + 0.962 * \text{Kt}$$

$$C = -0.280 + 0.932 * \text{Kt} - 2.048 * \text{Kt}^2$$

if  $\text{Kt} > 0.6$

$$A = -5.743 + 21.77 * \text{Kt} - 27.49 * \text{Kt}^2 + 11.56 * \text{Kt}^3$$

$$B = 41.40 - 118.5 * \text{Kt} + 66.05 * \text{Kt}^2 + 31.90 * \text{Kt}^3$$

$$C = -47.01 + 184.2 * \text{Kt} - 222.0 * \text{Kt}^2 + 73.81 * \text{Kt}^3$$

Compute DKN from A,B,C, and Kt

$$\text{DKN} = A + B \text{EXP}(C * \text{AM})$$

Compute KNC from Air Mass, AM (pressure corrected)

$$\text{KNC} = 0.886 - 0.122 * \text{AM} + 0.0121 * \text{AM}^2 - 0.000653 * \text{AM}^3 + 0.000014 * \text{AM}^4$$

Compute DIRECT Clearness Index, Kd from KNC and DKN

$$\text{Kd} = \text{KNC} - \text{DKN}$$

Compute Direct Irradiance, DNI, in  $\text{W}/\text{m}^2$ , from Kd and ETRN

$$\text{DNI} = \text{Kd} * \text{ETRN}$$

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## Estimating Direct Radiation from Global

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The author has also developed an EXCEL spreadsheet which executes the model. The spreadsheet requires input of latitude, longitude, time zone, and station pressure, plus the ability to paste in 8760 hours (including nighttime) of GLOBAL HORIZONTAL HOURLY AVERAGE DATA.

The sheet then computes the DNI estimates for  $Z < 80$  degrees, and the MEAS-MODEL bias errors on an hourly basis.

The Model file is about 5 MB in size; but may be compressed for

e-mail delivery to interested parties. Another alternative is to provide requestors with only the first few rows (say a day, the first 24 rows) of the sheet, and allow them to copy the remaining 8,736 or so rows within their EXCEL environment.

**References** for the Earth radius vector (ETRN calculation) DEC, EQT, and AM are:

for ETRN correction, DEC, EQT, M:

Spencer, J.W., 1971 "Fourier Series Representation of the Position of the Sun" Search VOL 2 No 5

P. 172

For AM calculation:

Kasten, F. and Young, A. 1989. Revised optical air mass tables and approximation formula. Applied Optics 28 (22), 4735-4738.

for Kt and Kd definitions:

Liu, B.Y.H., and R.C. Jordan, 1960, "The Interrelationship and Characteristic Distribution of Direct, Diffuse, and Total Solar Radiation" Solar Energy Vol IV, No. 3 pp 1-19.

For more information contact the author at daryl\_myers@nrel.gov.

## NASA Surface Solar Energy Data Sets for Commercial Applications

(Continued from page 3)

**110,000 hits** with over **1000 registered data users**. In the US, 296 customers from 44 states access the data. Around the world, there are 722 foreign users from 74 countries. Users include BP Amoco, Shell, Duke Solar Energy, Siemens Solar Industries, DuPont, International Financial Corporation, The World Bank, UNESCO, Winrock International, the Jet Propulsion Laboratory, the US Department of Energy, and the USDA Forest Service.

The Release 1 web site was scientific in nature. Collaboration with users from the solar energy industry helped to make Release 2 user friendly and understandable to the general renewable energy community. Release 2 has been popular beyond expectations and is the "No. 1 accessed web site" at the Langley Distributed Active Archive Center. The November 1999 peak in web site usage corresponds to a Natural Resources Canada (NRCAN) announcement of the availability of the NASA data for use with their renewable energy software tool RET-

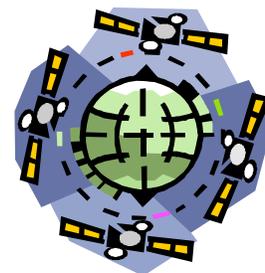
Screen™. The software was designed to evaluate the annual energy production, costs, and financial viability of renewable energy technologies. RETScreen™ is becoming an international standard for designers, government agencies, and lending institutions. Canadian supplied ground site data or NASA SSE data are used as inputs. Over 8,500 users (1,500 in the U.S.) in 160 countries are registered users of RETScreen™.

### Highlights

- Solar Energy International (SEI) has incorporated the SSE data set into SEI's PV Design On Line Course. Students currently attending online courses will learn to access the data set and use the data to design photovoltaic systems.
- Sun Frost is working with the Center for Renewable Energy and Sustainable Technology (CREST) to implement algorithms for sizing battery-based vaccine refrigerator systems (as a model for designs of typical battery-based systems) utilizing the SSE data set.

- CREST is incorporating the SSE data set into a new Professional version of SolarSizer, a commercial software tool for sizing renewable energy systems.
- The United Nations Environment Programme (UNEP) and NRCAN are cooperating to increase the awareness and enhance the usefulness of RETScreen™, and the SSE data set, internationally. As part of this collaboration, a greenhouse gas emission's mitigation model is being developed for RETScreen™. This model will allow users to calculate emissions avoided by the proposed renewable energy technology being evaluated. At the discretion of the users, either ground site or

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**In This Issue...**

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## NASA Surface Solar Energy Data Sets for Commercial Applications

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NASA SSE data will be inputs to these model calculations.

- A CD-ROM consisting of a subset of the SSE data set and the RETScreen™ software is being developed and will be provided to UNEP for users in developing countries without access to the Internet.

### Planned Release

A future Release 3 of the SSE web site will be available in late 2000. This release will have improved accuracy, higher resolution, and will contain additional engineering parameters for the wind, ground-source heat pump, and biomass heating renewable energy technologies.

### Partners

The following organizations have made significant contributions to the success of

the SSE project:

- **Langley Distributed Active Archive Center**
  - Hosts the SSE web site.
- **The National Renewable Energy Laboratory (NREL)**
  - Provides the WRDC ground site insolation data that are incorporated into the SSE web site as part of an Inter-agency Agreement.
- **Solar Energy International (SEI)**
  - Participates in a cost-sharing partnership, which involves subcontractors Sun Frost, Inc. and the Center for Renewable Energy and Sustainable Technology (CREST). All three advise on the renewable energy industry, and develop applications of the data.
- **Natural Resources Canada (NRCan) CANMET Energy Diversification**

### Research Laboratory

- Provides temperature, wind, humidity, and insolation data from 1000+ sites to verify SSE data.

- **Solar Household Energy, Inc.**

- Advises on SSE web site development.

- **Dozier Middle School, Grafton Bethel Elementary School**

- Used the SSE data in classroom instruction and participated in a contest to design a logo for the SSE.

### Acknowledgement

This work was made possible by joint funding from the NASA Applications, Commercial, and Education Division and the NASA Clouds and Earth's Radiant Energy System Project.