SOLAR SPECTRUM

Newsletter of the Resource Assessment Division

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Solar Position Calculator Now a Click Away

by Frank Vignola

Ever want to know the solar declination or the zenith angle without having to run a big program or look in a table in a solar ephemeris? Now a solar position calculator is just a click away on the web at http://solardat.uoregon.edu/formsol.html.

This calculator returns:

- Solar Zenith Angle,
- Declination, Julian Day,
- Equation of Time,
- Hour Angle,
- Earth Radius Vector,
- Instantaneous and Daily Beam and Global Extraterrestrial Radiation Values,
- Sunrise/Sunset Times.

The equations for this calculator were first developed by Joe Michalsky of SUNY Albany and translated into a C program called Solpos available on the NREL RREDC web page.

The inputs for a calculation require:

- Year,
- Month,
- Day,
- Hour,
- Minute,
- Longitude,
- Latitude,
- Timezone.

The longitudes west of Greenwich, such as those locations in the US, are negative while the longitudes east of Greenwich are positive. Sign conventions are similar for the time zones.

The figure on page 1 is an example of output for March 21, 2000. Note that

(Continued on page 8)

Results for Yearday 81, 2000

Inputs	
Year	2000
Month	3
Day	21
Hour	12
Minute	0
Latitude	45
Longitude	-120
Timezone	-8
Pressure	1013
Temperature	10
Aspect	180
Solar Constant	1367

Outputs	
Declination (degrees)	0.6018
Solar Zenith Angle (No refraction)	44.4252
Solar Zenith Angle (With refraction)	44.4093
Julian Day	51625.3333
Equation of Time (minutes)	-6.9888
Hour Angle (degrees)	-1.7472
Extraterrestrial Irradiance Global Horizontal (W/sq m)	983.41
Extraterrestrial Irradiance Direct Normal (W/sq m)	1377.00
Daily Global ETR (W/sq m)	7561.1
Daily Direct Normal ETR (W/sq m)	16634.5
Earth Radius Vector	1.0073
Sunrise (hour)	6.0764
Sunset (hour)	18.1566

Fig. 1: Sample results from the solar position calculator.

Inside This Issue

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:

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I would like to thank Jim Augustyn and Tom Kirk for their contributions to this newsletter.

Deadline for contributions to the next newsletter is October 1, 2000.

Frank Vignola

Resource Assessment Division Officers & Board Members

Cecile Warner, Chair
Gary Vliet, Vice Chair
David Rennè, Secretary

Jim Augustyn	June 2000
Ray Bahm	June 2001
Bob Cable	June 2000
Dan Greenberg	June 2001
Bill Marion	June 2001
Rob Nelson	June 2001
Richard Perez	June 2000
Timothy Townsend	June 2000

Upcoming Events

June 16-21, 2000
Solar Powers Life
Share the Energy

SOLAR2000

Madison, Wisconsin
Information: ASES
2400 Central, G-1
Boulder, CO 80301
Tel 303-443-3130
Fax 303-443-3212
http://www.ases.org/conference/

September 17-22, 2000
Millennium Solar Forum 2000

Mexico City, Mexico
Information: c/o Centro de Investigación en Energía, U.N.A.M.
Apartado Postal #34, Temixco 62580 Morelos, México
Fax—52 (73) 250018
Tel—52 (73) 250052
Email ises2000gi@mazatl.cie.unam.mx

RAD Division Elections Results

Bob Cable of Kramer Junction Operating Company was elected RAD Vice Chair and David Rennè of NREL is was elected Secretary. Congratulations!

Four RAD members were elected to the board. Doug Balcomb of the National Renewable Energy Laboratory, Mark Beaubien of Yankee Environmental Systems, John Dunlop consultant, and Richard Perez of ASRC-CESTM SUNY, Albany. The RAD division again has a strong board.

The new officers take their position in June at the annual meeting. Gary Vliet will also become Chair as is stipulated in the bylaws.

Thanks should be given to Cecile Warner who has served as chair and to Jim Augustyn and Timothy Townsend for the service to the division for the past two years.

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.

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Bruce Bailey............... awssci@delphi.com
John Dunlop .... jrdunlop@mcimail.com
Eppley Laboratory Inc. eplab@mail.bbsnet.com
Tracy Gardner... .... tgardner@nrel.nrel.gov
Jack Garrison.................... jgarriso@sciences.sdsu.edu
Chris Gueymard.......... chris@fsec.ucf.edu
Bill Marion .... bill_marion@nrel.gov
Ken Miller .... ecskamil@aol.com
Ross McCluney.. RMcCluney@fsec.ucf.edu
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Helen Powers..... power@udel.edu
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Martin Rymes......... mrymes@nrel.nrel.gov
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Frank Vignola .... fev@oregon.uoregon.edu
Gary Vliet............... gvliet@mail.utexas.edu
Cecile Warner .... cecile@nrel.nrel.gov

DQMS™ now with DataView!

The Data Quality Management System™

by Jim Augustyn

DQMS 2.20 Release Fixes More Than a y2K Bug!

Just in case you thought that there were no actual y2K bugs found or eradicated anywhere on earth after expenditure of hundreds of millions of dollars worldwide – get this: DQMS, the Data Quality Management System, actually had a y2K bug! However, the recently released Version 2.2 lacks this bug. Here's the story:

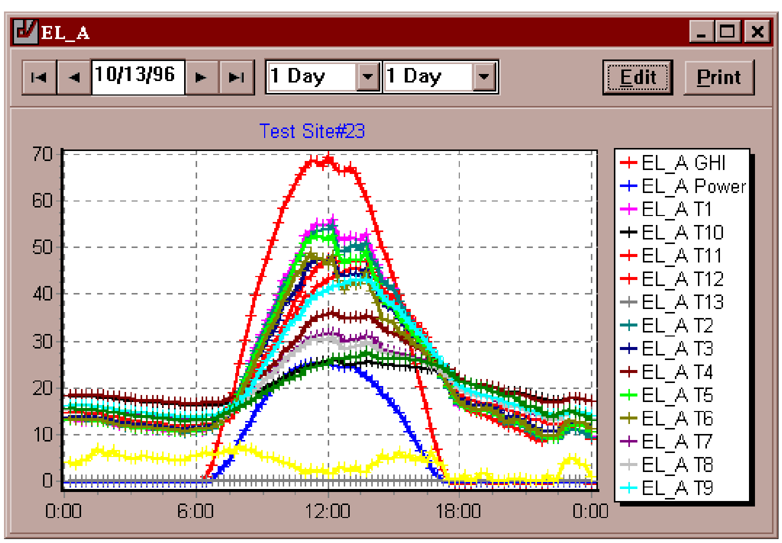
DQMS is database management software designed to manage data flow in monitoring networks. It has several features unique to solar radiation data quality assessment and analysis. It is used by over 50 organizations worldwide most notably NREL in its work for DOE's Atmospheric Radiation Measurement program. It is available from Augustyn + Company in Berkley, California (ACI). You can learn more about it at www.dqms.com.

DQMS incorporates NREL's SERI_QC solar radiation data quality assessment tool, as well as a set of solar position algorithms assembled by NREL called SOLPOS. SOLPOS is where that annoying little y2K bug was found. SOLPOS was oblivious that 2000 is a leap year. The resulting SOLPOS and SERI_QC (which uses SOLPOS in it's calculations), output would have been slightly incorrect between the dated of 2000-02-29 and 2000-12-31.

In the process of fixing this bug, NREL and ACI decided this was an opportune time to improve SOLPOS and SERI_QC since both routines will be incorporated into the next version of DQMS now under development. The improvements to SOLPOS were fairly extensive, since the old (Spencer) position algorithms were discarded in favor of the more accurate position algorithms developed by Joe Michalsky at SUNY Albany. The changes to SERI_QC were very minor, dealing primarily with error coding and comments.

DQMS itself was also changed in a few places to allow complete display of dates and date time fields containing four digit year values. Previously, such dates were oked and were internally stored correctly, you just could see them completely. In the process of doing this, all date and date time fields in the program were changed to adhere to the ISO 1988 standard of expressing dates in the format YYYY-MM-DD.

As mentioned above, an new version of DQMS is now being written primarily to serve NREL's needs as the solar radiation instrument experts serving the ARM program. This new version DQMS3 is scheduled to be completed early in 2001, incorporating many improvements which we will describe in a future article.



One of the many types of plots now available with DQMS.

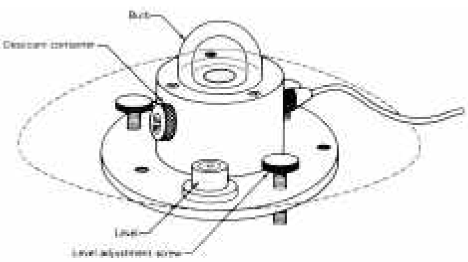
Radiometric Instrumentation - a Look Ahead

by Tom Kirk

Reliable and accurate measurements of Solar and Atmospheric Radiation at the Earth's surface are needed to better understand greenhouse effects, climatological trends, agricultural requirements, solar energy efficiency and many other areas of studies. In addition, reliable earth based and airborne measurements are used to validate satellite derived data and modeling used to determine the Earth's radiation budget.

The Eppley Laboratory, Inc. has been involved with precision solar and atmospheric radiation measurement instrumentation since the mid 1920s. The "lightbulb" pyranometers and normal incidence pyrheliometers for the measurement of direct and global shortwave radiation were the most accurate instruments of their generation. In the late sixties, Eppley developed modern day pyranometers with the wire-wound thermopile detector replacing the slower responding and less durable Coblentz type detectors. Today, the science community demands even more precise instruments, stricter measurement and calibration procedures and higher data quality controls than ever before. Extensive and accurate models employing satellite derived data are being developed and the need for reliable data to test and fine tune these models is greater than ever.

Several large programs such as the Atmospheric Radiation Measurement (ARM) Network, the Baseline Surface Radiation Network (BSRN) and the Global Atmospheric Watch (GAW) and numerous local stations and networks have been developed to ensure continuous long-term accurate measurements.



Pyranometer — Global Sensor

Self calibrating cavity pyrheliometers are constructed and characterized to yield absolute radiation values in Standard International (SI) units. A select group of these instruments is known as the World Standard Group (WSG) which is maintained at the World Radiation Center (WRC) in Davos, Switzerland. Using this group of reference instruments, the World Radiation Reference is determined every five years at the International Pyrheliometric Comparison (IPC). All other solar instruments are referenced to the WRR by intercomparison. The Eppley version of the self-calibrating pyrheliometer is the Absolute Cavity Pyrheliometer, Model AHF. On going developments have led to the new Model 409 Control Box for automatic operation.

Eppley continues to work with researchers to modify or test its standard equipment to allow for continual improvements to the instruments and calibration procedures. The latest example is the development of the "All-Weather" Cavity Radiometer being tested for the BSRN which allows for the Cavity Radiometer to measure direct beam radiation continuously using a window filter to protect the sensing element. Of course, valid window factors and careful maintenance of these windows now becomes the critical issue in the measurement and additional work is being done by the National Oceanic & Atmospheric Administration/Climate Monitoring and Diagnostics Laboratory (NOAA/CMDL) to test the reliability of certain filters (calcium fluoride, suprisil, etc.) over time.

The Normal Incidence Pyrheliometer, Model NIP and Precision Spectral Pyranometer, Model PSP are classified as Secondary Standards used for the measurement of Direct, Global and Diffuse Radiation. Their standard designs allow for very accurate measurements of better than 1% and withstand the test of time. Instruments that were built over 15-20 years ago are still being used for everyday measurements and continue to produce the highest quality results due to solid design and construction. In addition to standard designs, developments have been made for specific requirements such as aircraft or balloon use, marine buoy and shipboard applications and arctic conditions. Aircraft and High Altitude Balloons measurements allow for further validation of satellite data and outgoing (reflected) radiation measurements.

The Precision Infrared Radiometer, Model PIR is the only commercial pyrgeometer that can produce reliable long wave (terrestrial) radiation values of better than 3-5%. Work is being done to further improve the accuracy of the data through calibration procedures and careful monitoring of instrument temperatures. Recent improvements in the dome's interference filter have greatly reduced shortwave radiation leaks and better consistency in filter transmittance.

The Eppley Laboratory is proud of its prominent history of over 80 years of manufacturing precision

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Looking Back and Forward

Solar 1999 in Maine was a lot of fun as well as a successful conference. The pictures shown on this page are from the lobster fest that took the attendees on a ferry to one of the many islands dotting the Portland Harbor.

We are looking forward to another successful conference, SOLAR 2000 in Madison, Wisconsin. Hope to see you there.

At Solar 2000, the Resource Assessment Division will host a forum on the uses of and needs for solar radiation data. The forum will consist of four panelists talking about their use of solar radiation data and what additional data and in what formats could the data be presented to facilitate their work.

These three RAD division members (Frank, Daryl, and Gary) were found wandering around an island off the Maine coast. There is no truth to the rumor that they got lost once the sun when down.

Sandi Klein from the University of Wisconsin, Madison will talk about how data are used for the calculation of thermal processes. Over the years, Sandi has developed and tested the standard models that estimate the performance of solar thermal systems and should be able to let the resource assessment community know what aspects of solar data are a key for accurate assessment of the system performance.

Doug Balcomb, from NREL, is a leading expert and pioneer in the analysis of passive solar buildings. He knows what data are important and what data are needed to help those who are making passive building designs.

Bob Cable, from Kramer Junction Operating Company, is the vice chair of the RAD division and has been using solar radiation data to evaluate the performance and to manage the Kramer Junction facility. This on the job use of solar radiation data gives Bob the unique perspective on what data are useful and the importance of accurate data for the operation of a solar electric facility.

The fourth panelist (TBA) will be an expert on the use of solar radiation data for estimating the performance photovoltaic systems. First choice would be someone with experience in using solar radiation data to size systems outside the United States. One problem with sizing a system outside the United States is the lack of solar data. Many international systems are designed without the use of solar radiation data. Is this because there is a lack of data or that accurate data are not needed to size most of the systems installed? It is likely that both statements are valid.

Come, join in the forum. Let us hear your views and learn what other are doing.

While some people had difficulty opening a lobster, others shared their expertise and all had a good time..

Uncertainty of Diffuse Irradiance Calculated from Beam and Global Irradiance

by Frank Vignola

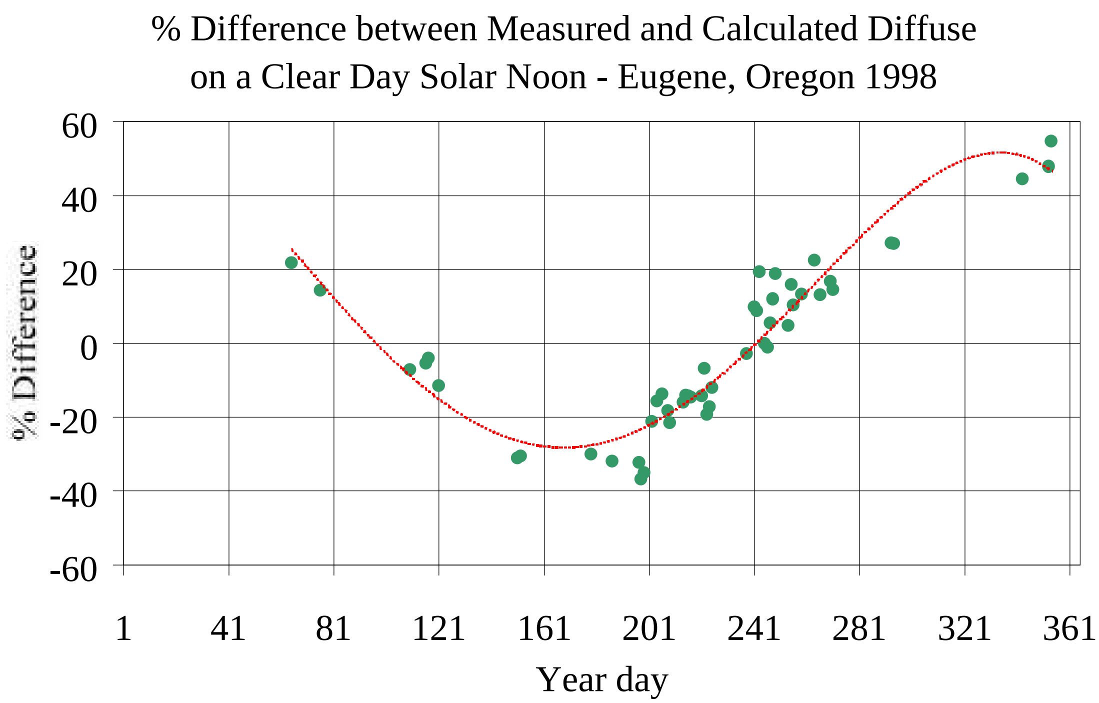

Fig. 1 The % difference between diffuse irradiance calculated from global minus beam measurements and diffuse irradiance measured utilizing a shade disk. Measurements were made on clear days at solar noon during 1998 at Eugene, Oregon.

Accurate diffuse data are difficult to obtain. For a long time, many people have tried to correct the errors in diffuse data measured with a shadow band. With the availability of beam measurements came the opportunity to calculate diffuse values from beam and global data. These calculated diffuse values are treated as superior to the diffuse values measured utilizing a shadow band.

At present there is a limited amount of data available that measure diffuse values with a shade disk. Diffuse data measured with a shade disk has an advantage that no shadow band corrections have to be made because only the disk shades the pyranometer.

With the direct beam, global, and diffuse irradiance being measured, it is fairly straight forward to compare the diffuse measured with a shade disk and diffuse calculated from global and beam data. To calculate the diffuse value, all one has to do is subtract the beam data multiplied by the cosine of the zenith angle from the global value.

There are two main sources of error that occur. First, as reported by Joe Michalsky, the cosine response of the pyranometer is know to deviate systematically from a true cosine response (See Fig. 2). Second, there is an uncertainty in the absolute calibration constant of the instruments. This is complicated by the fact that the relative calibration constants between the two instruments change with temperature and other factors.

In Fig. 1 the value of the diffuse irradiance calculated from beam and global data is compared to the measured diffuse values on clear days at solar noon. The beam data were obtained from an Eppley NIP and the global and diffuse data were obtained with Eppley PSPs. The calibration factor for the PSP was obtained by averaging the responsivity when the zenith angle was between 45 and 55 degrees. With the calibration factor determined in this manner, the systematic deviation from a true cosine response for Eppley PSPs results in the global measurements overestimating the incident solar radiation in the summer and underestimating the solar radiation in the winter.

Fig. 2 shows the relative responsivity of the PSP used in this study. If the difference between the diffuse calculation was solely due to the dependence on the zenith angle, then the solar noon values should follow the same

Uncertainty of Diffuse Irradiance Calculated from Beam and Global Irradiance

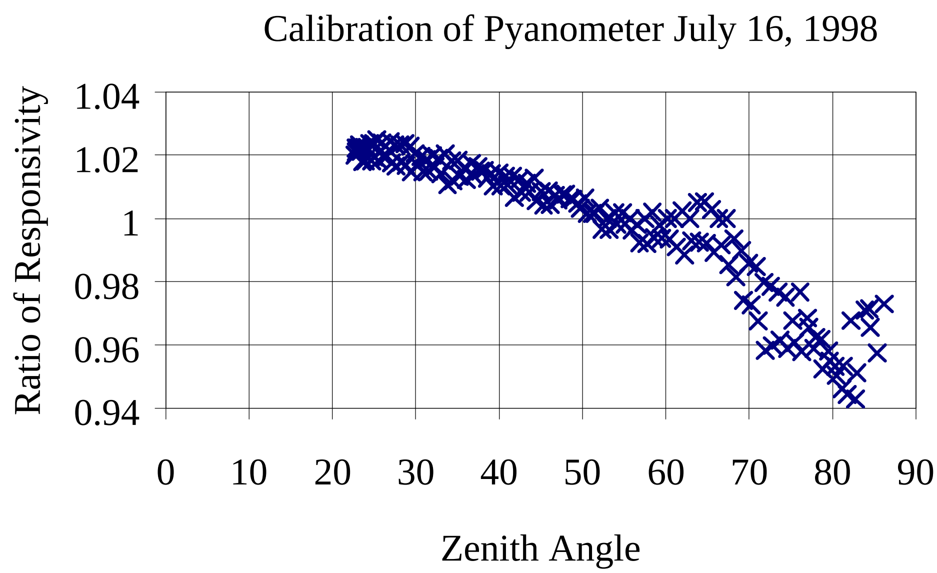

Fig. 2. Relative responsivity of the PSP as a function of Zenith Angle on July 16, 1998 (year day 197). Note that a 2% difference in the global responsivity at solar noon leads to about a 30% difference in the calculated diffuse value as shown in Fig. 1.

zenith angle curve as the responsivity. In December when the solar noon zenith angle is about 68 degrees, the responsivity curve suggests that the global reading would be 2% low. At solar noon this would account for 7.5 W/m^2 or about 20% of the difference between the calculated and measured diffuse. Around yearday 274, the solar noon zenith angle is about 48 degrees. If the deviation from true cosine response were the sole cause of the difference between the calculated and measured diffuse, then the calculated and the measured diffuse should match. This is not the case, as Fig. 1 shows. The measured diffuse is about 20% above the calculated diffuse. There are many potential factors that can cause this difference from an azimuthal dependence in the pyranometer to temperature and calibration differences. Even differences in reradiation from the sensor surface may be the cause of the problem.

While a lot has been learned about the systematic errors in pyranometers, more remains to be learned. Comparing the measured diffuse against calculated diffuse is a good way to start unraveling these problems because even small deviations have large consequences.

Radiometric Instrumentation - a Look Ahead

(Continued from page 4)
measurement instrumentation and looks forward to continuing it's fine tradition. The new millennium promises to bring greater challenges as the science community continues to strive for near-perfect measurements through better instrumentation and techniques and EPLAB invites all ideas, comments, suggestions, etc. for improving the current instrumentation or developing new instruments. Whether the project is an extensive long-term worldwide network of sites or a single instrument on a research building roof, the Eppley Laboratory is interested in hearing from you. You may contact us at:

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In This Issue... | *Radiometric Instrumentation—A Look Ahead*

Solar Position Calculator Now a Click Away

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the zenith angle is calculated both with and without the refraction correction that bends the solar radiation as it passes through the atmosphere. Except for sunrise and sunset, the difference caused by the atmospheric refraction is small.

Having two possible zenith angles does lead to a conundrum. What is the correct extraterrestrial radiation? Since extraterrestrial means outside the earth's atmosphere, the zenith angle without the refraction correction was chosen. This leads to a problem during the sunrise and sunset period when the extraterrestrial irradiance is zero and there is measurable solar radiation.

The sunrise and sunset times are also determined when the zenith angle goes to zero. In the case of the solar calculator, that is when the zenith angle without the refraction correction goes to zero. Most models calculate extraterrestrial solar radiation using these values.

Actual sunrise and sunset times reported in the daily newspaper use the refraction correction to determine the time when the sun appears above the horizon. The refraction changes sunrise and sunset times by about 5 minutes.

The daily extraterrestrial values are obtained using the declination determined by the time used in the calculation. Since the declination changes over the day, this will lead to small changes in the daily extraterrestrial values depending on the time of day input for the calculations. The most accurate estimates of the extraterrestrial radiation are made about solar noon. While this is unlikely to affect the results of many calculations, one will get different values depending on the time of day.

There is at least one bug in the program. Under specific circumstances the Equation of Time will produce values close to 24 hours instead of 5 to 10 minutes. This sometimes occurs when the input is near midnight. The solar day is used instead of the local day, hence the 24 hour difference. The correct value can be obtained by adjusting the Equation of Time by 24 hours.

This calculator is one component of a contract with Bonneville Power Administration to write a solar resource assessment education web site. The goal is to provide a well maintained web site that utility staff and decision makers can access to learn how to use the solar resource data and to get explanations of solar resource terminology.

It is also hoped that others in the resource assessment community can use the web site to make quick, back of the envelop, estimates while at the same time providing enough details so that those interested in solar resource assessment can pick up some of the fundamentals.