

November 1992 • NREL/TP-463-5118

A Comparison of Data from SOLMET/ERSATZ and the National Solar Radiation Data Base

W. Marion and D. Myers



National Renewable Energy Laboratory
A Division of Midwest Research Institute
Operated for the U.S. Department of Energy
Under Contract No. DE-AC02-83CH10093

A Comparison of Data from SOLMET/ERSATZ and the National Solar Radiation Data Base

W. Marion and D. Myers



National Renewable Energy Laboratory
(formerly the Solar Energy Research Institute)
1617 Cole Boulevard
Golden, Colorado 80401-3393
A Division of Midwest Research Institute
Operated for the U.S. Department of Energy
under Contract No. DE-AC02-83CH10093

Prepared under Task Nos. RA210101, PV360501

November 1992

NOTICE

This report was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

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 A01
Printed Copy A03

Codes are used for pricing all publications. The code is determined by the number of pages in the publication. Information pertaining to the pricing codes can be found in the current issue of the following publications which are generally available in most libraries: *Energy Research Abstracts (ERA)*; *Government Reports Announcements and Index (GRA and I)*; *Scientific and Technical Abstract Reports (STAR)*; and publication NTIS-PR-360 available from NTIS at the above address.

Preface

This work was performed under the National Renewable Energy Laboratory's (NREL's) Solar Radiation Research Assessment Project Task No. RA210101 and Photovoltaic Solar Radiation Research Task No. PV360501. We would like to acknowledge Dave Menicucci (Sandia), Gobind Atmaram (Florida Solar Energy Center), and NREL staff members Roland Hulstrom, Carol Riordan, Dave Renné, Gene Maxwell, and Martin Rymes for their contributions to the report and their review. We would also like to thank Mary Anne Dunlap for technical editing and Terrie Webb for proofreading the appendices.

Summary

This report compares data from the new National Solar Radiation Data Base (NSRDB) with data from the earlier SOLMET/ERSATZ data base. It compares the two data bases, station-by-station, with respect to their long-term average daily values of global horizontal and direct normal solar radiation.

We conclude that on an annual basis, NSRDB values for global horizontal radiation are within $\pm 5\%$ of SOLMET/ERSATZ values for 60% of the stations, more than 5% greater than the SOLMET/ERSATZ values for 30% of the stations, and more than 5% less than the SOLMET/ERSATZ values for 10% of the stations. On an annual basis for direct normal radiation, the NSRDB values are within $\pm 5\%$ of the SOLMET/ERSATZ data for only 40% of the stations, more than 5% greater than the SOLMET/ERSATZ values for 45% of the stations, and more than 5% less than the SOLMET/ERSATZ values for 15% of the stations.

In general, the NSRDB shows higher values of solar radiation for the eastern United States, particularly the Northeast, and lower values for some of the western states (Arizona, Colorado, Idaho, Nevada, New Mexico, Utah, and Wyoming). However, because some of the stations within a state show higher values of solar radiation while others show lower values, this generalization may be misleading when concerned with a particular station. Consequently, the appendices provide tables showing a station-by-station comparison of the NSRDB and SOLMET/ERSATZ data. In addition to comparing annual values, the tables compare the two data bases for the months of August and December. This comparison shows larger differences between the two data bases for December.

Table of Contents

	<u>Page</u>
1.0 Introduction	1
2.0 Station Locations	3
3.0 Comparison of NSRDB and SOLMET/ERSATZ Data	5
3.1 Annual Solar Radiation	5
3.2 August and December Solar Radiation	7
3.3 Daily Solar Radiation Profiles	7
4.0 NSRDB Products	10
5.0 Conclusions	11
6.0 References	13
Appendix A Comparison of Annual Average Daily Radiation of SOLMET/ERSATZ and NSRDB Data Bases	A-1
Appendix B Comparison of Monthly Average Daily Radiation of SOLMET/ERSATZ and NSRDB Data Bases	B-1

List of Figures

		<u>Page</u>
2-1	SOLMET/ERSATZ station locations	3
2-2	NSRDB station locations	4
3-1	Percentage of change in profile of average global horizontal radiation in 1968 for Nashville when comparing NSRDB data to SOLMET data	8
3-2	December percentage of change in profile of average global horizontal radiation during 1961-1975 for Nashville when comparing NSRDB data to SOLMET data	9
5-1	Percentage of stations that have NSRDB data less than, approximately equal to, or greater than SOLMET/ERSATZ data	11

List of Tables

		<u>Page</u>
3-1	NSRDB Solar Radiation Source Flags	6
3-2	NSRDB Solar Radiation Uncertainty Flags	6
4-1	NSRDB Solar Radiation and Meteorological Elements	10
5-1	Range of Changes in Long-Term Averages When NSRDB Data Are Compared with SOLMET/ERSATZ Data	12
A-1	Comparison of Annual Average Daily Radiation (kWh/m ²) of SOLMET/ERSATZ and NSRDB Data Bases	A-1
B-1	Comparison of Monthly Average Daily Radiation (kWh/m ²) of SOLMET/ERSATZ and NSRDB Data Bases	B-1

1.0 Introduction

The National Renewable Energy Laboratory (NREL) recently completed the National Solar Radiation Data Base (NSRDB). This new data base consists of hourly values of solar radiation and meteorological data for 239 stations for the period from 1961 to 1990. A 30-year period of data collection was chosen to establish averages and extremes of solar radiation parameters, and it coincides with the same 30-year period used for the National Oceanic and Atmospheric Administration's (NOAA's) latest update of climate statistics. A 30-year period with updates every 10 years is a standard meteorological practice.

For the NSRDB, all of the meteorological data were provided by the National Climatic Data Center (NCDC), which is a part of NOAA. The majority of the measured solar radiation data was collected by NOAA's National Weather Service and was also provided to NREL by NCDC. Solar radiation data were also obtained from the University of Oregon; WEST Associates (a consortium of southwestern utilities); the University of New York at Albany; Trinity University, Texas; Georgia Institute of Technology; Bethune-Cookman College, Florida; and Savannah State College, Georgia (NSRDB-Vol. 1 1992).

The NSRDB is the successor to the 1952-1975 SOLMET/ERSATZ data base. In addition to accounting for the more recent climate, the NSRDB provides more accurate values of solar radiation because:

- More measured data were available during 1961 through 1990. For the SOLMET/ERSATZ data base, there was only one measured parameter: global horizontal solar radiation at 26 stations. The new data base has measured data for 56 of the 239 stations (however, some of these stations only made measurements for a few years). For a majority of these 56 stations, two parameters were measured: global horizontal solar radiation and direct normal solar radiation. Diffuse solar radiation was also measured for several years at nine stations. The greater availability of measured data enhanced model development and testing.
- A meteorological statistical model (METSTAT) provided better estimates of solar radiation for sites and times where no measurements were available (Maxwell 1991). Because 93% of the solar radiation data in the NSRDB is modeled, much emphasis was placed on model development.
- The accuracy of the measured data is improved. From 1977 to 1990, a radiometer calibration facility, operated by NOAA in Boulder, Colorado, performed routine calibrations to ensure the accuracy of instruments used to measure solar radiation by the National Weather Service. Universities and other agencies that provided solar radiation data also performed routine instrument calibrations.
- An improved synthetic calibration procedure (SYNCAL) corrected global horizontal solar radiation data for solar zenith and azimuth angles. Calibration corrections were determined for 10° by 20° zenith angle-azimuth angle cells for each instrument. The corrections were largest for data collected prior to 1976, when measurements were made using older style pyranometers.
- Procedures and software were devised for performing postmeasurement quality assessment of data. Each solar radiation data value was assigned a quality flag consisting of two characters that provide information on the source and uncertainty of the data.

The NSRDB represents the more recent climate and has an improved accuracy, but designers and engineers might ask the questions: Compared with SOLMET/ERSATZ data, how will NSRDB data impact analysis and design? Have the averages and extremes for the stations changed? Will we estimate more energy produced or less? Will the collector be sized larger or smaller?

Although this report does not answer these questions for specific applications, it does provide initial insight by comparing the two data bases with respect to their long-term averages of global horizontal and direct normal solar radiation on a station-by-station basis. The objective is to inform potential users about the magnitude of the differences between the two data bases for long-term averages of global horizontal and direct normal solar radiation.

Also, the information presented in this report is not intended for energy analysis and system design purposes. Analysis and design information will result from FY 1993 activities of NREL's Solar Radiation Research Assessment Project. The FY 1993 work includes using the data for the 239 NSRDB stations to develop typical meteorological year (TMY) data sets and to generate tabular data giving information on the monthly averages of solar radiation, the extremes, and the variability for various fixed and tracking collectors. FY1993 work will also include a detailed analysis explaining the reasons for the differences between the two data bases shown in this report. The contribution of improved measurements and models and the effects of climate change, such as changes in the amount of cloud cover, will be evaluated and presented.

This report begins by identifying the station locations for the two data bases. Next, annual and monthly long-term averages for global horizontal and direct normal solar radiation are compared, and daily solar radiation profiles are discussed. Last, information is provided on the NSRDB and its derived products, and the results are summarized.

2.0 Station Locations

The 248 station locations in the SOLMET/ERSATZ data base are shown in Figure 2-1. These stations were operated by the National Weather Service of NOAA. Data from 1952 to 1975 were included in this data base. Hourly values of global horizontal radiation were measured at 26 SOLMET stations during this period, and researchers modeled hourly values of direct normal radiation for these stations. In Figure 2-1, the SOLMET stations are identified by the use of the asterisk (*) symbol. No solar radiation measurements were made at the 222 ERSATZ stations. Rather, global horizontal radiation was modeled based on observed meteorological data such as cloudiness and minutes of sunshine. The ERSATZ data do not include direct normal radiation data, but this information is available in data sets derived from the ERSATZ data, such as ERSATZ TMY data sets and tabular data sets (SERI 1990) that modeled direct normal radiation for most of the ERSATZ sites.

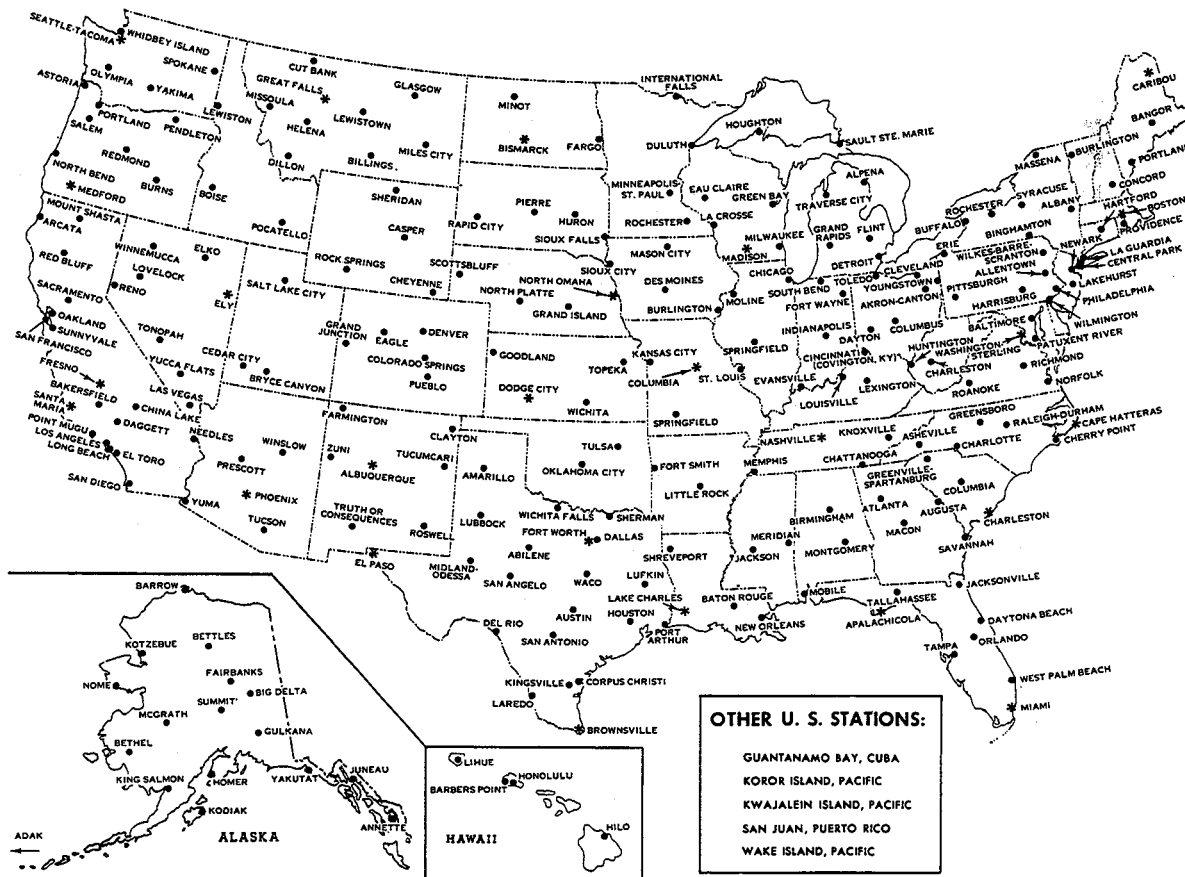


Figure 2-1. SOLMET/ERSATZ station locations

The 239 station locations in the NSRDB are shown in Figure 2-2. Because of the criteria for selecting stations, there are nine fewer stations than for the SOLMET/ERSATZ data base. Stations were selected only if they were National Weather Service stations that had meteorological data for the entire period from 1961 to 1990. The meteorological data were used to model solar radiation for times and locations where it was not measured. Measured solar radiation data in the NSRDB provided by universities and other agencies were incorporated by assigning them to the nearest NSRDB station. Although most of the stations in the NSRDB and the SOLMET/ERSATZ data base are the same, the selection criteria for the NSRDB caused some states to gain stations while other states lost stations. The NSRDB includes 37 new stations, but 46 previous SOLMET/ERSATZ stations were not included.

For the NSRDB, the 56 stations that measured solar radiation data, for at least a part if not the entire 30 years, are designated primary stations. The remaining 183 stations that have only modeled solar radiation data are designated secondary stations. The word *secondary* was deemed preferable to the word *ersatz*, which means an inferior substitute.

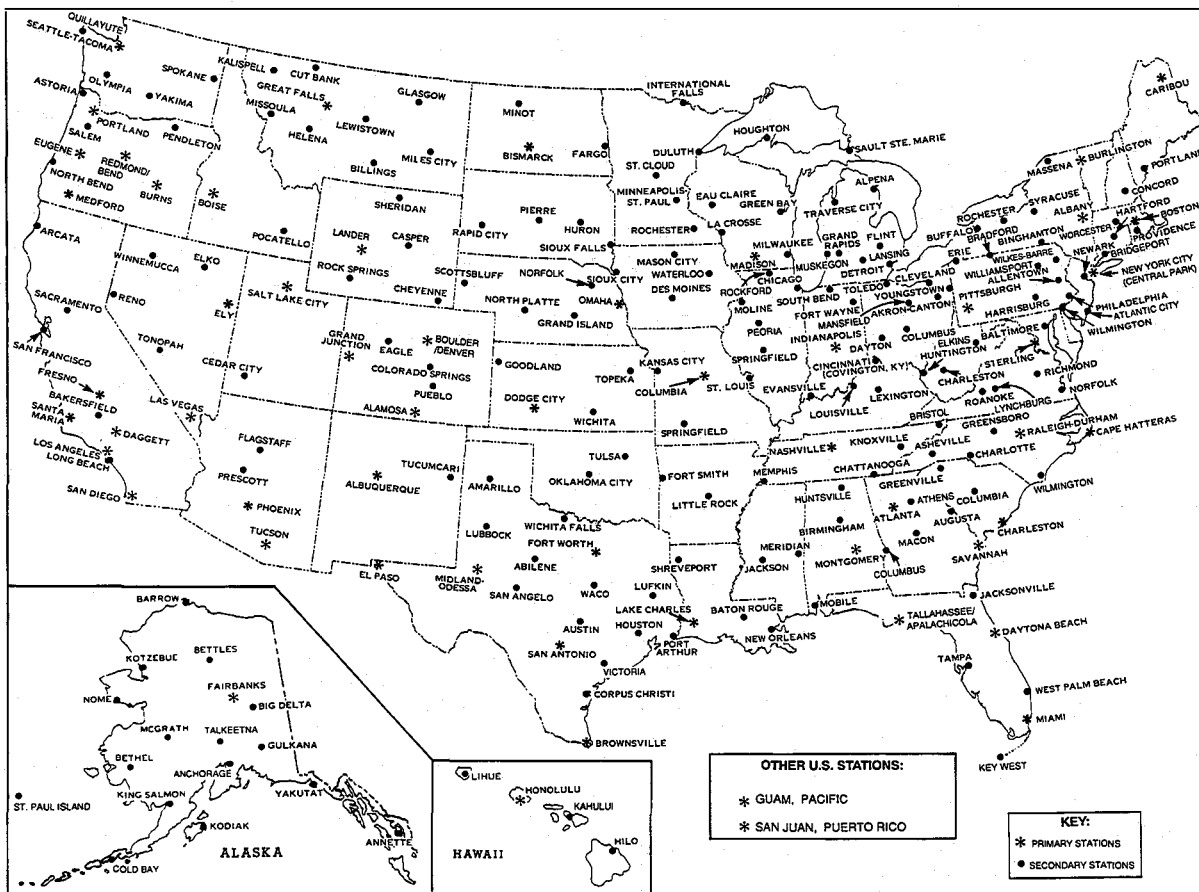


Figure 2-2. NSRDB station locations

3.0 Comparison of NSRDB and SOLMET/ERSATZ Data

Long-term averages of global horizontal and direct normal solar radiation for each of the two data bases were compared on an annual basis and for the months of August and December. For the comparison, the long-term averages of solar radiation used for the NSRDB stations were those presented in the daily statistic files for each station. Daily statistic files are one of the NSRDB products (NSRDB-Vol. 1 1992). For the SOLMET/ERSATZ long-term averages, tabular data were taken from the *Insolation Data Manual and Direct Normal Solar Radiation Data Manual*, (SERI 1990). Differences in long-term averages for the two data bases are due to differences in the measurement instruments, solar radiation models, and time periods. The SOLMET/ERSATZ data base spans 23-1/2 years, from 1952 to 1975, and the NSRDB spans 30 years, from 1961 to 1990.

3.1 Annual Solar Radiation

Appendix A contains tables that compare the average annual global horizontal and direct normal solar radiation of the two data bases. All 239 NSRDB stations are listed in the tables along with their Weather Bureau Army Navy (WBAN) number and other station identification information such as latitude, longitude, and elevation. The SOLMET/ERSATZ stations not in the NSRDB (46 total) are not listed in the tables. SOLMET stations are identified in the tables by the use of the asterisk (*) symbol, and the pound (#) symbol is used to identify NSRDB primary stations. The absence of a station identifying symbol means the station is an ERSATZ station and/or a NSRDB secondary station.

Although not available for the SOLMET/ERSATZ data, quality flags accompany the NSRDB data in the tables. The quality flags consist of two characters and provide information on the source and uncertainty of the NSRDB data. The solar radiation source and uncertainty flags are defined in Tables 3-1 and 3-2 (NSRDB-Vol. 1 1992). Most of the NSRDB data listed in the tables in Appendix A are assigned an uncertainty flag of 4, meaning the uncertainty of the data is from 6% to 9% of the solar radiation value.

The percentage of change listed in the tables indicates the percentage increase or decrease in solar radiation when comparing NSRDB and SOLMET/ERSATZ data. A value greater than zero means that the NSRDB data are greater than the SOLMET/ERSATZ data; a value below zero means the reverse is true. For NSRDB stations that have no corresponding SOLMET/ERSATZ station, no percentage change is indicated. Also, some ERSATZ stations have no direct normal radiation data; consequently, a comparison cannot be made for this situation either.

For global horizontal radiation, the NSRDB values are within $\pm 5\%$ of the SOLMET/ERSATZ values for 60% of the stations, more than 5% greater than the SOLMET/ERSATZ values for 30% of the stations, and more than 5% less than the SOLMET/ERSATZ values for 10% of the stations. For direct normal radiation, the NSRDB values are within $\pm 5\%$ of the SOLMET/ERSATZ values for only 40% of the stations, more than 5% greater than the SOLMET/ERSATZ values for 45% of the stations, and more than 5% less than the SOLMET/ERSATZ values for 15% of the stations.

In general, the NSRDB data show higher values for solar radiation for the eastern United States, particularly the northeast, and lower values for some of the western states (Arizona, Colorado, Idaho, Nevada, New Mexico, Utah, and Wyoming). Examples of much higher values are stations in New York that show increases in global horizontal radiation of up to 17% and increases in direct normal radiation of up to 24%. Portland, Maine, shows the largest increase for a single station, 18% for global horizontal and 33% for direct normal. Nevada stations show

Table 3-1. NSRDB Solar Radiation Source Flags

Flag	Definition
A	Post-1976 measured solar radiation data as received from NCDC or other sources
B	Same as 'A' except the global horizontal data underwent a calibration correction
C	Pre-1976 measured global horizontal data (direct and diffuse were not measured before 1976)
D	Data derived from the other two elements of solar radiation using the relation: $K_t=K_n+K_d$, where K_t = global horizontal transmittance, K_n = direct normal transmittance, and K_d = diffuse horizontal transmittance.
E	Modeled solar radiation data using inputs of <i>observed</i> sky cover (cloud amount) and aerosol optical depths derived from direct normal data collected at the same location
F	Modeled solar radiation data using inputs of <i>interpolated</i> sky cover and aerosol optical depths derived from direct normal data collected at the same location
G	Modeled solar radiation data using <i>observed</i> sky cover and aerosol optical depths estimated from geographical relationships
H	Modeled solar radiation data using <i>interpolated</i> sky cover and <i>estimated</i> aerosol optical depths
?	Source does not fit any of the above categories. Used for nighttime values, calculated extraterrestrial values, and missing data

Table 3-2. NSRDB Solar Radiation Uncertainty Flags

Flag	Uncertainty Range (%)
1	0 - 2
2	2 - 4
3	4 - 6
4	6 - 9
5	9 - 13
6	13 - 18
7	18 - 25
8	25 - 35
9	35 - 50
0	Not applicable

the largest decreases, from -4% to -10% for global horizontal radiation, and from -5% to -24% for direct normal radiation. Within a state, some of the stations may show higher values for solar radiation while others show lower values; consequently, generalizations about a change in solar radiation for a state may prove inaccurate. The tables in Appendix A may be used to evaluate changes for each station within a state.

3.2 August and December Solar Radiation

Appendix B contains tables that compare the average global horizontal and direct normal solar radiation of the two data bases for two months of the year, August and December. These two months were chosen because they have special significance for solar energy systems. For many stand-alone PV systems, designers size the PV system based on the amount of solar radiation for the month of December (assuming that December is the month with the smallest ratio of solar-radiation-to-electric-load demand). Therefore, a change in the solar resource for December can impact system size and cost. August was chosen because utilities analyze whether or not a solar electric power plant can help meet summertime electric demand. Consequently, a change in the solar resource for the month of August could favorably or unfavorably change the results of their analysis. The tables in Appendix B are similar to those in Appendix A, except they do not include the station identification information and the source and uncertainty flags for the NSRDB data. The tables in Appendix A provide this information.

For global horizontal radiation for August, the NSRDB values are within $\pm 5\%$ of the SOLMET/ERSATZ values for 70% of the stations, more than 5% greater than the SOLMET/ERSATZ values for 20% of the stations, and more than 5% less than the SOLMET/ERSATZ values for 10% of the stations. For direct normal radiation for August, the NSRDB values are within $\pm 5\%$ of the SOLMET/ERSATZ values for 55% of the stations, more than 5% greater than the SOLMET/ERSATZ values for 20% of the stations, and more than 5% less than the SOLMET/ERSATZ values for 25% of the stations. Overall, the results of the comparison for August were similar to the results of the annual comparison, but not necessarily with respect to individual stations.

For global horizontal radiation for December, the NSRDB values are within $\pm 5\%$ of the SOLMET/ERSATZ values for 25% of the stations, more than 5% greater than the SOLMET/ERSATZ values for 70% of the stations, and more than 5% less than the SOLMET/ERSATZ values for 5% of the stations. For direct normal radiation for December, the NSRDB values are within $\pm 5\%$ of the SOLMET/ERSATZ values for 30% of the stations, more than 5% greater than the SOLMET/ERSATZ values for 50% of the stations, and more than 5% less than the SOLMET/ERSATZ values for 20% of the stations. December shows larger differences between the two data bases than does the annual or August comparison. Changes in global horizontal radiation ranged from -8% to +51%, and changes in direct normal radiation ranged from -32% to +56% (not including Alaskan stations where small values yielded larger percentage changes).

3.3 Daily Solar Radiation Profiles

For solar energy systems that have desired output requirements for specific times of the day, knowing how the solar radiation varies throughout the day permits evaluating different design options with respect to their load-matching ability. The daily solar radiation profile also influences the optimum orientation of fixed-tilt collectors and the performance benefit of tracking collectors when compared with fixed-tilt collectors. Evaluating the daily solar radiation profiles for each station is beyond the scope of this report, but the comparison and discussion for a single station can, as a minimum, demonstrate and provide insight into how SOLMET/ERSATZ and NSRDB daily solar radiation profiles may differ.

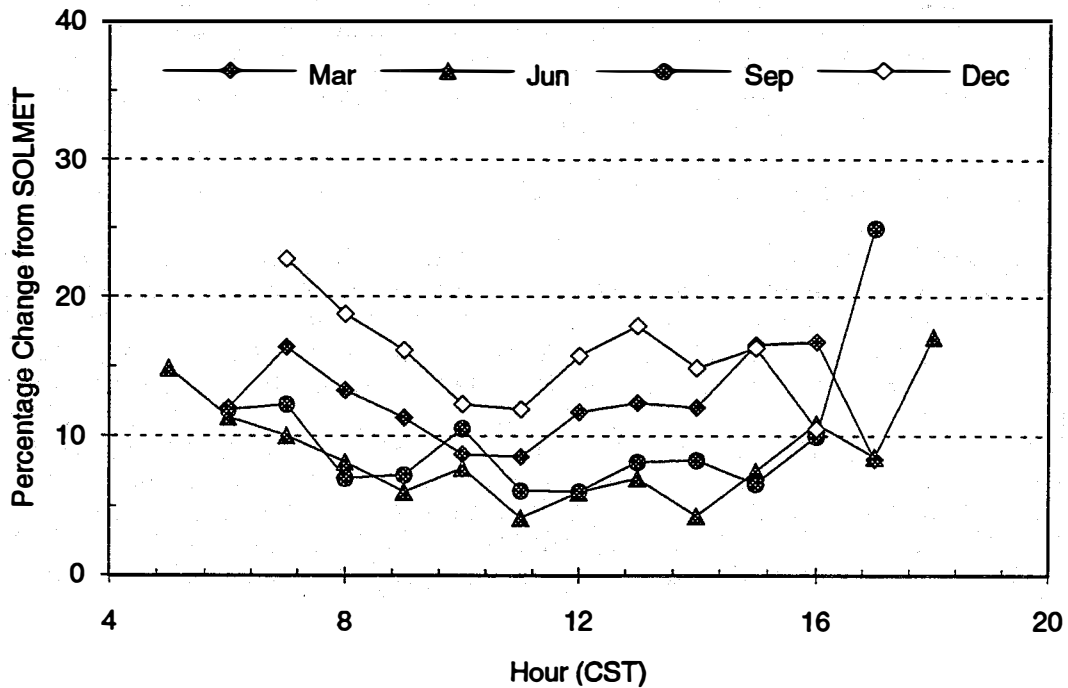


Figure 3-1. Percentage of change in profile of average global horizontal radiation in 1968 for Nashville when comparing NSRDB data to SOLMET data

Figure 3-1 compares the average daily profile for different months of the year for global horizontal radiation measured during 1968 at Nashville, Tennessee. For clarity, four months of the year are shown that represent different seasons and sun positions. For this station and year, the NSRDB data show an increase for all months when compared with the SOLMET data. Because both the SOLMET and NSRDB data are based on the same raw data measurements (1968 is a common year for both data bases), the difference between the two data bases results from using different synthetic calibration procedures. For NSRDB data, the synthetic calibration procedure also included correcting for solar zenith and azimuth angle. Each instrument was characterized for cosine and azimuth angle response, and then correction factors were applied to the data. The effect of this correction, shown in Figure 3-1, resulted in a greater difference between the SOLMET and NSRDB data for early morning and late afternoon hours and for the month of December. These times correspond to larger solar zenith angles that required larger correction factors to account for the imperfect cosine response of the instrument.

Corrections of NSRDB data were dependent on the zenith and azimuth angle response of the station's pyranometer. Each pyranometer had distinct characteristics. Some showed solar zenith and azimuth angle responses requiring different corrections for morning and afternoon and months of the year. Consequently, different corrections were required for all stations. In addition, when pyranometers were replaced at individual stations, different correction factors were applied to match the instrument being used. This is shown in Figure 3-2 in which the average daily profiles of global horizontal radiation from 1961 to 1975 for December at Nashville are illustrated. Notice how the different synthetic calibration procedures for the NSRDB caused the daily profiles to change from year to year when compared with the SOLMET profiles. Changes due to replacing instruments are also evident. (The profiles in Figure 3-2 are plotted against the hour of day, not the year, as indicated by the x-axis. The profile for December 1968 is the same as the December 1968 profile shown in Figure 3-1, but different scales are used.)

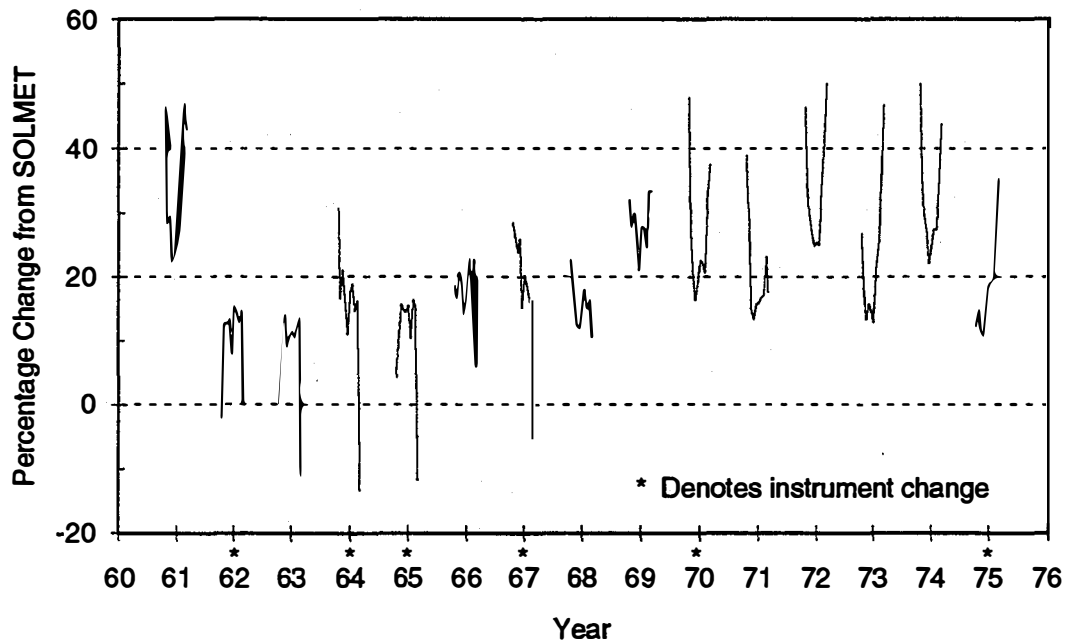


Figure 3-2. December percentage of change in profile of average global horizontal radiation during 1961-1975 for Nashville when comparing NSRDB data to SOLMET data

Although daily profiles were not evaluated for each station, the daily profiles for the NSRDB can be expected to be different than those for the SOLMET/ERSATZ data base. Therefore, analyses performed concerning such things as load matching, optimum azimuth orientation of fixed collectors, and benefits of tracking collectors would be affected.

For NSRDB secondary stations and partly cloudy skies, the individual hourly model estimates can be different from the actual solar radiation received. Input parameters to the METSTAT model describe only the percentage of the sky dome covered by clouds and not the position of the clouds with respect to the sun. Consequently, for the same amount of cloud cover, the actual solar radiation can vary a large amount depending on the time during the hour that clouds are actually positioned in front of the sun. But for monthly and annual data, which have numerous hourly data values, the METSTAT model successfully simulates their statistical and stochastic characteristics (NSRDB-Vol. 1 1992).

4.0 NSRDB Products

Products available from the NSRDB include (1) serial hourly data in either a synoptic or TD-3282 format, (2) hourly, daily, and quality statistics for solar radiation elements, (3) daily statistics for meteorological elements, and (4) persistence statistics for daily total solar radiation.

The synoptic format is similar to the SOLMET format. Each line of data contains all solar radiation and meteorological elements for 1 hour. The next line of data contains data for the next hour. The synoptic format includes quality flags for global horizontal, direct normal, and diffuse horizontal radiation. Table 4-1 lists the solar radiation and meteorological data available in both the synoptic and TD-3282 format.

For the TD-3282 format, each line of data contains a day (24 hourly values) of data for one element. The next line of data contains a day of data for the next element. This format offers flexibility because only the solar radiation and meteorological elements requested need to be included in the data file. The TD-3282 format includes quality flags for all elements.

Both the synoptic and TD-3282 formats use local civil time for the hour of the day. For most applications, this is more useful than the solar time used for the SOLMET/ERSATZ data. *When using the new NSRDB data to evaluate the performance of a solar energy system, analysis software and programs need to make the distinction between local civil time and solar time.* Otherwise, the sun position and the amount of solar radiation for the collector will not be correctly calculated.

Statistical summaries computed from the hourly data include hourly, monthly, annual, and 30-year averages and their standard deviations. The statistical products, as well as the synoptic and TD-3282 formats, are completely described in the user's manual (NSRDB-Vol. 1 1992) available from the National Climatic Data Center (NCDC). The NSRDB data and statistical products may also be ordered from NCDC. Please use the following address for correspondence:

User Services
 National Climatic Data Center
 Federal Building
 Asheville, NC 28801-2696
 Phone (704)259-0682
 Fax (704)259-0876

Table 4-1. NSRDB Solar Radiation and Meteorological Elements

Global horizontal radiation	Atmospheric pressure
Direct normal radiation	Wind direction
Diffuse horizontal radiation	Wind speed
Extraterrestrial radiation	Horizontal visibility
Direct normal extraterrestrial radiation	Ceiling height
Total sky cover	Present weather
Opaque sky cover	Total precipitable water
Dry-bulb temperature	Aerosol optical depth
Dew-point temperature	Snow depth
Relative humidity	Number of days since last snowfall

5.0 Conclusions

The NSRDB is the successor to the SOLMET/ERSATZ data base. Its data better represents the solar resource because improved equipment measured solar radiation at more sites and better models estimated solar radiation for sites and times where no measurements were available. By comparing the two data bases with respect to their long-term averages of global horizontal and direct normal radiation, differences between the two data bases are evident. Appendices A and B present the results of this comparison, station-by-station, for annual and monthly (August and December) values of solar radiation.

Even though the two data bases compare within $\pm 5\%$ for many stations, the NSRDB data for others show changes in annual global horizontal radiation from -10% to +18% and changes in annual direct normal radiation from -24% to +33%. For the two months compared, the percentage of change was greater for December than for August. For December, the NSRDB data show changes in global horizontal radiation from -8% to +51% and show changes in direct normal radiation from -32% to +56% (not including Alaskan stations). Figure 5-1 and Table 5-1 present summary information on the comparisons made using SOLMET/ERSATZ and NSRDB data.

Because of the differences in solar radiation values for the two data bases, the performance and economic analyses performed for some stations will show large changes when NSRDB data are used instead of SOLMET/ERSATZ data. For all stations, the credibility of performance and economic analyses is increased because the methods used during the development of the NSRDB had the advantage of more high quality measured data for developing better models (Maxwell et al, 1991).

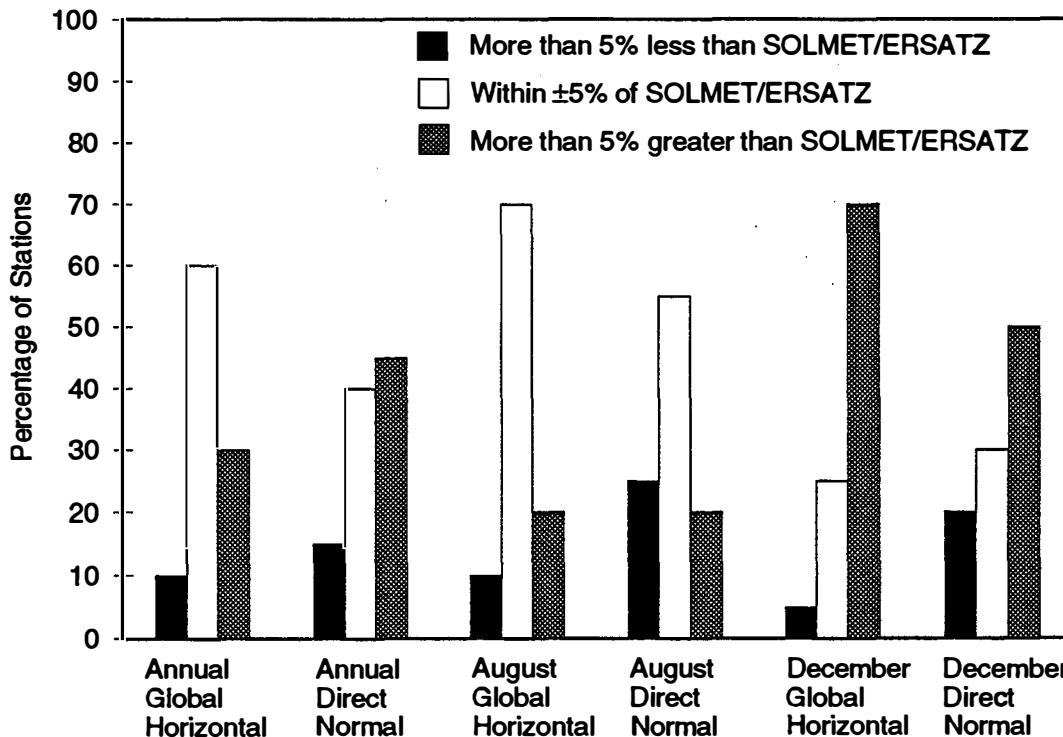


Figure 5-1. Percentage of stations that have NSRDB data less than, approximately equal to, or greater than SOLMET/ERSATZ data

Table 5-1. Range of Changes in Long-Term Averages When NSRDB Data Are Compared with SOLMET/ERSATZ Data

Period	Global Horizontal	Direct Normal
Annual	-10% to +18%	-24% to +33%
August	-11% to +16%	-20% to +31%
December	-8% to +51%	-32% to +56%

Future work includes developing products from the NSRDB such as TMY data sets and tabular data for various fixed and tracking collectors. A detailed analysis explaining the reasons for differences between SOLMET/ERSATZ and NSRDB data is also under way. We also encourage others to evaluate the NSRDB. Of particular interest is how modeled solar radiation data for NSRDB secondary stations compare with measured data from nearby solar radiation monitoring stations operated by independent organizations and regional networks.

6.0 References

- Maxwell, E.L. (1991). "Simulating Solar Radiation Data Sets." *Proceedings of the Biennial Congress of the International Solar Energy Society; August 19-23, 1991, Denver, Colorado*, pp. 975-980.
- Maxwell, E.L.; Myers, D.R.; Rymes, M.D.; Stoffel, T.L.; Wilcox, S.M. (1991). "Producing a National Solar Radiation Data Base." *Proceedings of the Biennial Congress of the International Solar Energy Society; August 19-23, 1991, Denver, Colorado*, pp. 1007-1012.
- NSRDB-Vol. 1 (1992). *User's Manual - National Solar Radiation Data Base (1961-1990)*. Version 1.0. Asheville, NC: National Climatic Data Center.
- SERI (1990). *Insolation Data Manual and Direct Normal Solar Radiation Data Manual*, SERI/TP-220-3880, Golden, CO: Solar Energy Research Institute.

Appendix A

Comparison of Annual Average Daily Radiation of SOLMET/ERSATZ and NSRDB Data Bases

Table A-1. Comparison of Annual Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases

State	City	WBAN Number	Latitude		Longitude		Elev (m)	Global Horizontal Radiation				Direct Normal Radiation			
			Deg	Min	Deg	Min		SOLMET ERSATZ	NSRDB	Flag	% Chg	SOLMET ERSATZ	NSRDB	Flag	% Chg
Alabama	Birmingham	13876	N33	34	W 86	45	192	4.24	4.45	H4	5	3.80	3.96	H4	4
	Huntsville	03856	N34	39	W 86	46	190		4.37	H4			3.99	H4	
	Mobile	13894	N30	41	W 88	15	67	4.37	4.44	H4	2	3.46	3.87	H4	12
	Montgomery #	13895	N32	18	W 86	24	62	4.38	4.61	F4	5	3.95	4.04	F4	2
Alaska	Anchorage	26451	N61	10	W150	1	35		2.40	G4			2.34	G4	
	Annette	25308	N55	2	W131	34	34	2.51	2.62	H4	4	2.09	2.34	H4	12
	Barrow	27502	N71	18	W156	47	4	1.88	2.01	H4	7		1.90	H4	
	Bethel	26615	N60	47	W161	48	46	2.31	2.40	H4	4	2.05	2.40	H4	17
	Bettles	26533	N66	55	W151	31	205	2.41	2.44	H4	1		3.03	H4	
	Big Delta	26415	N64	0	W145	44	388	2.56	2.56	H4	0	2.77	3.14	H4	13
	Cold Bay	25624	N55	12	W162	43	29		2.18	H4			1.22	H4	
	Fairbanks #	26411	N64	49	W147	52	138	2.42	2.55	H4	5	2.55	2.90	H4	14
	Gulkana	26425	N62	9	W145	27	481	2.62	2.70	H4	3	2.75	3.21	H4	17
	King Salmon	25503	N58	41	W156	39	15	2.50	2.42	H4	-3	2.34	2.23	H4	-5
	Kodiak	25501	N57	45	W152	20	34	2.51	2.48	H4	-1	2.32	2.49	H4	7
	Kotzebue	26616	N66	52	W162	38	5	2.35	2.42	H4	3		2.98	H4	
	Mcgrath	26510	N62	58	W155	37	103	2.31	2.47	H4	7	2.19	2.71	H4	24
	Nome	26617	N64	30	W165	26	7	2.33	2.48	H4	6	2.46	3.02	H4	23
	St Paul Island	25713	N57	9	W170	13	7		2.20	H4			1.16	H4	
Talkeetna	26528	N62	18	W150	6	105		2.49	H4			2.77	H4		
Yakutat	25339	N59	31	W139	40	9	2.09	2.28	H4	9	1.63	1.85	H4	13	
Arizona	Flagstaff	03103	N35	8	W111	40	2135		5.14	H4			6.43	H4	
	* Phoenix #	23183	N33	26	W112	1	339	5.89	5.73	F4	-3	6.90	6.79	F4	-2
	Prescott	23184	N34	39	W112	26	1531	5.72	5.33	H4	-7	7.25	6.78	H4	-6
	Tucson #	23160	N32	7	W110	56	779	5.90	5.70	F4	-3	7.12	7.02	F4	-1
Arkansas	Fort Smith	13964	N35	20	W 94	22	141	4.43	4.56	H4	3	4.40	4.50	H4	2
	Little Rock	13963	N34	44	W 92	14	81	4.43	4.51	H4	2	4.34	4.30	H4	-1
California	Arcata	24283	N40	59	W124	6	69	3.83	3.90	H4	2	3.33	3.54	H4	6
	Bakersfield	23155	N35	25	W119	3	150	5.51	5.20	H4	-6	6.21	5.74	H4	-8
	Daggett #	23161	N34	52	W116	47	588	5.81	5.78	F4	-1	7.07	7.47	F4	6
	* Fresno #	93193	N36	46	W119	43	100	5.39	5.17	F4	-4	6.09	5.63	F4	-8

* Denotes SOLMET station

Denotes NSRDB primary station

Table A-1. Comparison of Annual Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases (Continued)

State	City	WBAN Number	Latitude		Longitude		Elev (m)	Global Horizontal Radiation				Direct Normal Radiation				
			Deg	Min	Deg	Min		SOLMET ERSATZ	NSRDB	Flag	% Chg	SOLMET ERSATZ	NSRDB	Flag	% Chg	
California	Long Beach	23129	N33	49	W118	9	17	5.04	4.96	H4	-2	5.25	4.97	H4	-5	
	Los Angeles #	23174	N33	56	W118	24	32	5.02	4.95	E4	-1	5.25	4.83	E4		
	Sacramento	23232	N38	31	W121	30	8	5.18	4.93	H4	-5	5.82	5.51	H4	-5	
	San Diego #	23188	N32	44	W117	10	9	5.04	5.03	F4	0	5.17	5.25	F4	2	
	San Francisco	23234	N37	37	W122	23	5	4.90	4.72	H4	-4	5.23	5.02	H4	-4	
	* Santa Maria #	23273	N34	54	W120	27	72	5.07	5.17	H4	2	5.49	5.72	H4	4	
	Colorado	Alamosa #	23061	N37	27	W105	52	2297		5.26	F4			6.83	F4	
		Boulder #	94018	N40	1	W105	15	1634		4.58	F4			5.41	F4	
		Colorado Springs	93037	N38	49	W104	43	1881	5.03	4.69	H4	-7	6.53	5.65	H4	-13
		Eagle	23063	N39	39	W106	55	1985	5.03	4.67	H4	-7	6.27	5.43	H4	-13
Grand Junction #		23066	N39	7	W108	32	1475	5.23	4.98	F4	-5	6.50	5.86	F4	-10	
Pueblo		93058	N38	17	W104	31	1439	5.12	4.98	H4	-3	6.47	6.08	H4	-6	
Connecticut	Bridgeport	94702	N41	10	W 73	8	2		3.84	H4			3.54	H5		
	Hartford	14740	N41	56	W 72	41	55	3.34	3.81	H4	14	2.77	3.33	H5	20	
Delaware	Wilmington	13781	N39	40	W 75	36	24	3.81	4.07	H4	7	3.41	3.78	H5	11	
Florida	Daytona Beach #	12834	N29	11	W 81	3	12	4.60	4.82	F4	5	3.84	4.29	F4	12	
	Jacksonville	13889	N30	30	W 81	42	9	4.53	4.59	H4	1	3.84	4.18	H4	9	
	Key West	12836	N24	33	W 81	45	1		5.12	H4			4.81	H4		
	* Miami #	12839	N25	48	W 80	16	2	4.64	4.83	F4	4	3.88	3.96	F4	2	
	Tallahassee #	93805	N30	23	W 84	22	21	4.52	4.69	F4	4	3.77	4.13	F4	10	
	Tampa	12842	N27	58	W 82	32	3	4.70	4.85	H4	3	4.01	4.50	H4	12	
	West Palm Beach	12844	N26	41	W 80	6	6	4.53	4.74	H4	5	3.71	4.09	H4	10	
Georgia	Athens	13873	N33	57	W 83	19	244		4.54	H4			4.27	H4		
	Atlanta #	13874	N33	39	W 84	26	315	4.24	4.58	E4	8	3.88	4.19	E4	8	
	Augusta	03820	N33	22	W 81	58	45	4.29	4.57	H4	7	3.92	4.26	H4	9	
	Columbus	93842	N32	31	W 84	57	136		4.63	H4			4.26	H4		
	Macon	03813	N32	42	W 83	39	110	4.35	4.60	H4	6	4.01	4.24	H4	6	
	Savannah #	03822	N32	8	W 81	12	16	4.30	4.61	F4	7	3.84	4.16	F4	8	

* Denotes SOLMET station

Denotes NSRDB primary station

Table A-1. Comparison of Annual Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases (Continued)

State	City	WBAN Number	Latitude		Longitude		Elev (m)	Global Horizontal Radiation				Direct Normal Radiation			
			Deg	Min	Deg	Min		SOLMET	NSRDB	Flag	% Chg	SOLMET	NSRDB	Flag	% Chg
Hawaii	Hilo	21504	N19	43	W155	4	11	4.37	4.58	H4	5	3.10	3.62	H4	17
	Honolulu #	22521	N21	20	W157	55	5	5.17	5.39	H4	4	4.44	5.16	H4	16
	Kahului	22516	N20	54	W156	26	15		5.48	H4		5.84	H4		
	Lihue	22536	N21	59	W159	21	45	4.81	4.96	H4	3	3.82	4.48	H4	17
Idaho	Boise #	24131	N43	34	W116	13	874	4.71	4.42	F4	-6	5.53	5.20	F4	-6
	Pocatello	24156	N42	55	W112	36	1365	4.82	4.33	H4	-10	5.84	4.91	H4	-16
Illinois	Chicago	94846	N41	47	W 87	45	190	3.83	3.87	H4	1	3.71	3.44	H4	-7
	Moline	14923	N41	27	W 90	31	181	3.86	4.00	H4	4	3.72	3.86	H4	4
	Peoria	14842	N40	40	W 89	41	199		4.04	H4		3.84	H4		
	Rockford	94822	N42	12	W 89	6	221		3.90	H4		3.64	H4		
	Springfield	93822	N39	50	W 89	40	187	4.10	4.19	H4	2	4.10	4.13	H4	1
Indiana	Evansville	93817	N38	3	W 87	32	118	3.98	4.21	H4	6	3.60	3.96	H4	10
	Fort Wayne	14827	N41	0	W 85	12	252	3.54	3.86	H4	9	2.88	3.31	H4	15
	Indianapolis #	93819	N39	44	W 86	17	246	3.67	4.10	H4	12	3.05	3.59	H4	18
	South Bend	14848	N41	42	W 86	19	236	3.59	3.80	H4	6	3.17	3.14	H4	-1
Iowa	Des Moines	14933	N41	32	W 93	39	294	4.14	4.12	H4	0	4.36	4.22	H4	-3
	Mason City	14940	N43	9	W 93	20	373	4.06	3.97	H4	-2	4.39	3.93	H4	-10
	Sioux City	14943	N42	24	W 96	23	336	4.13	4.11	H4	0	4.38	4.30	H4	-2
	Waterloo	94910	N42	33	W 92	24	265		3.96	H4		3.84	H4		
Kansas	* Dodge City #	13985	N37	46	W 99	58	787	4.92	4.86	F4	-1	5.79	5.43	F4	-6
	Goodland	23065	N39	22	W101	42	1124	4.82	4.74	H4	-2	5.88	5.59	H4	-5
	Topeka	13996	N39	4	W 95	38	270	4.37	4.30	H4	-2	4.61	4.41	H4	-4
	Wichita	03928	N37	39	W 97	25	408	4.74	4.55	H4	-4	5.29	4.82	H4	-9
Kentucky	Covington	93814	N39	4	W 84	40	271	3.65	4.00	H4	10		3.52	H4	
	Lexington	93820	N38	2	W 84	36	301	3.84	4.06	H4	6	3.37	3.56	H4	6
	Louisville	93821	N38	11	W 85	44	149	3.83	4.12	H4	8	3.32	3.67	H4	11

* Denotes SOLMET station

Denotes NSRDB primary station

Table A-1. Comparison of Annual Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases (Continued)

State	City	WBAN Number	Latitude		Longitude		Elev (m)	Global Horizontal Radiation				Direct Normal Radiation			
			Deg	Min	Deg	Min		SOLMET ERSATZ	NSRDB	Flag	% Chg	SOLMET ERSATZ	NSRDB	Flag	% Chg
Louisiana	Baton Rouge	13970	N30	32	W 91	9	23	4.35	4.47	H4	3	3.70	3.93	H4	6
	* Lake Charles #	03937	N30	7	W 93	13	3	4.30	4.61	F4	7	3.68	3.94	F4	7
	New Orleans	12916	N29	59	W 90	15	3	4.53	4.55	H4	0	4.02	3.98	H4	-1
	Shreveport	13957	N32	28	W 93	49	79	4.50	4.61	H4	2	4.27	4.24	H4	-1
Maine	* Caribou #	14607	N46	52	W 68	1	190	3.35	3.55	F4	6	3.25	3.27	F4	1
	Portland	14764	N43	39	W 70	19	19	3.31	3.90	H4	18	2.95	3.93	H5	33
Maryland	Baltimore	93721	N39	11	W 76	40	47	3.83	4.05	H4	6	3.44	3.88	H4	13
Massachusetts	* Boston #	14739	N42	22	W 71	2	5	3.48	3.91	H4	12	3.24	3.72	H4	15
	Worcester	94746	N42	16	W 71	52	301		3.86	H4			3.48	H5	
Michigan	Alpena	94849	N45	4	W 83	34	210	3.42	3.72	H4	9	3.08	3.54	H4	15
	Detroit	94847	N42	25	W 83	1	191	3.53	3.78	H4	7	2.98	3.29	H4	10
	Flint	14826	N42	58	W 83	44	233	3.39	3.72	H4	10	2.77	3.18	H4	15
	Grand Rapids	94860	N42	53	W 85	31	245	3.58	3.80	H4	6	3.26	3.28	H4	1
	Houghton	94814	N47	10	W 88	30	329		3.56	H4			3.38	H4	
	Lansing	14836	N42	47	W 84	36	256		3.76	H4			3.22	H4	
	Muskegon	14840	N43	10	W 86	15	191		3.84	H4			3.30	H4	
	Sault Ste. Marie	14847	N46	28	W 84	22	221	3.28	3.67	H4	12	3.01	3.49	H4	16
	Traverse City	14850	N44	44	W 85	35	192	3.41	3.65	H4	7	2.98	3.15	H4	6
Minnesota	Duluth	14913	N46	50	W 92	11	432	3.36	3.71	H4	10	3.26	3.66	H4	12
	International Falls	14918	N48	34	W 93	23	361	3.43	3.55	H4	3	3.56	3.55	H4	0
	Minneapolis	14922	N44	53	W 93	13	255	3.69	3.89	H4	5	3.68	3.99	H4	8
	Rochester	14925	N43	55	W 92	30	402	3.65	3.84	H4	5	3.61	3.71	H4	3
	Saint Cloud	14926	N45	33	W 94	4	313		3.85	H4			3.98	H4	
Mississippi	Jackson	03940	N32	19	W 90	5	101	4.44	4.60	H4	4	4.07	4.21	H4	3
	Meridian	13865	N32	20	W 88	45	94	4.32	4.47	H4	3	3.80	3.87	H4	2

* Denotes SOLMET station

Denotes NSRDB primary station

Table A-1. Comparison of Annual Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases (Continued)

State	City	WBAN Number	Latitude		Longitude		Elev (m)	Global Horizontal Radiation				Direct Normal Radiation			
			Deg	Min	Deg	Min		SOLMET ERSATZ	NSRDB	Flag	% Chg	SOLMET ERSATZ	NSRDB	Flag	% Chg
Missouri	* Columbia #	03945	N38	49	W 92	13	270	4.19	4.33	F4	3	4.26	4.23	F4	-1
	Kansas City	03947	N39	18	W 94	43	315	4.22	4.28	H4	1	4.26	4.41	H4	4
	Springfield	13995	N37	14	W 93	23	387	4.29	4.36	H4	2	4.39	4.33	H4	-1
	St. Louis	13994	N38	45	W 90	23	172	4.18	4.22	H4	1	4.11	4.06	H4	-1
Montana	Billings	24033	N45	48	W108	32	1088	4.18	4.14	H4	-1	4.85	4.80	H4	-1
	Cut Bank	24137	N48	36	W112	22	1170	3.90	3.91	H4	0	4.58	4.60	H4	0
	Glasgow	94008	N48	13	W106	37	700	3.84	3.86	H4	1	4.34	4.38	H4	1
	* Great Falls #	24143	N47	29	W111	22	1116	3.98	3.99	F4	0	4.56	4.46	F4	-2
	Helena	24144	N46	36	W112	0	1188	3.98	3.96	H4	-1	4.45	4.52	H4	2
	Kalispell	24146	N48	18	W114	16	904		3.62	H4			3.68	H4	
	Lewistown	24036	N47	3	W109	27	1264	3.91	3.92	H4	0	4.42	4.43	H4	0
	Miles City	24037	N46	26	W105	52	803	4.10	4.11	H4	0	4.77	4.78	H4	0
Missoula	24153	N46	55	W114	5	972	3.68	3.76	H4	2	3.73	3.95	H4	6	
Nebraska	Grand Island	14935	N40	58	W 98	19	566	4.43	4.41	H4	0	5.10	4.92	H4	-4
	Norfolk	14941	N41	59	W 97	26	471		4.25	H4			4.55	H4	
	North Platte	24023	N41	8	W100	41	849	4.55	4.43	H4	-3	5.38	4.99	H4	-7
	* Omaha #	94918	N41	22	W 96	31	404	4.16	4.20	F4	1	4.45	4.24	F4	-5
	Scottsbluff	24028	N41	52	W103	36	1206	4.49	4.43	H4	-1	5.38	5.12	H4	-5
Nevada	Elko	24121	N40	50	W115	47	1547	5.12	4.61	H4	-10	6.42	5.52	H4	-14
	* Ely #	23154	N39	17	W114	51	1906	5.27	4.90	F4	-7	7.85	5.99	F4	-24
	Las Vegas #	23169	N36	5	W115	10	664	5.88	5.65	F4	-4	7.43	7.05	F4	-5
	Reno	23185	N39	30	W119	47	1341	5.55	5.00	H4	-10	7.22	6.16	H4	-15
	Tonopah	23153	N38	4	W117	8	1653	5.82	5.22	H4	-10	7.77	6.67	H4	-14
	Winnemucca	24128	N40	54	W117	48	1323	5.19	4.72	H4	-9	6.49	5.63	H4	-13
New Hampshire	Concord	14745	N43	12	W 71	30	105	3.32	3.90	H4	17	2.92	3.78	H5	29
New Jersey	Atlantic City	93730	N39	27	W 74	34	20		4.03	H4			3.83	H4	
	Newark	14734	N40	42	W 74	10	9	3.67	3.90	H4	6	3.29	3.49	H5	6
New Mexico	* Albuquerque #	23050	N35	3	W106	37	1619	5.76	5.57	F4	-3	7.20	6.69	F4	-7
	Tucumcari	23048	N35	11	W103	36	1231	5.43	5.21	H4	-4	6.75	6.15	H4	-9

* Denotes SOLMET station

Denotes NSRDB primary station

Table A-1. Comparison of Annual Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases (Continued)

State	City	WBAN Number	Latitude		Longitude		Elev (m)	Global Horizontal Radiation				Direct Normal Radiation			
			Deg	Min	Deg	Min		SOLMET ERSATZ	NSRDB	Flag	% Chg	SOLMET ERSATZ	NSRDB	Flag	% Chg
New York	Albany #	14735	N42	45	W 73	48	89	3.36	3.79	F4	13	3.65	3.28	F4	-10
	Binghamton	04725	N42	13	W 75	59	499	3.14	3.66	H4	17	2.38	2.96	H5	24
	Buffalo	14733	N42	56	W 78	44	215	3.26	3.68	H4	13	2.54	3.11	H4	22
	Massena	94725	N44	56	W 74	51	63	3.28	3.72	H4	13	3.67	3.56	H4	-3
	* New York City #	94728	N40	47	W 73	58	57	3.46	3.99	F4	15	3.03	3.45	F4	14
	Rochester	14768	N43	7	W 77	40	169	3.29	3.69	H4	12	2.60	3.17	H4	22
	Syracuse	14771	N43	7	W 76	7	124	3.26	3.72	H4	14	2.60	3.23	H4	24
North Carolina	Asheville	03812	N35	26	W 82	32	661	4.14	4.29	H4	4	3.86	4.10	H4	6
	* Cape Hatteras #	93729	N35	16	W 75	33	2	4.34	4.47	H4	3	4.21	4.33	H4	3
	Charlotte	13881	N35	13	W 80	56	234	4.24	4.44	H4	5	3.98	4.21	H4	6
	Greensboro	13723	N36	5	W 79	57	270	4.24	4.37	H4	3	4.06	4.18	H4	3
	Raleigh #	13722	N35	52	W 78	47	134	4.08	4.39	F4	8	3.35	4.03	F4	20
	Wilmington	13748	N34	16	W 77	54	9		4.49	H4			4.21	H4	
North Dakota	* Bismarck #	24011	N46	46	W100	45	502	3.94	4.03	F4	2	4.46	4.45	F4	0
	Fargo	14914	N46	54	W 96	48	274	3.79	3.83	H4	1	4.02	4.08	H4	1
	Minot	24013	N48	16	W101	17	522	3.71	3.86	H4	4	4.11	4.39	H4	7
Ohio	Akron	14895	N40	55	W 81	26	377	3.50	3.76	H4	7	2.87	3.02	H4	5
	Cleveland	14820	N41	24	W 81	51	245	3.44	3.75	H4	9	2.78	3.04	H4	9
	Columbus	14821	N40	0	W 82	53	254	3.54	3.83	H4	8	2.83	3.16	H4	12
	Dayton	93815	N39	54	W 84	13	306	3.66	3.94	H4	8	3.08	3.46	H4	12
	Mansfield	14891	N40	49	W 82	31	395		3.79	H4			3.11	H4	
	Toledo	94830	N41	36	W 83	48	211	3.57	3.89	H4	9	3.01	3.40	H4	13
	Youngstown	14852	N41	16	W 80	40	361	3.30	3.63	H4	10	2.60	2.78	H4	7
Oklahoma	Oklahoma City	13967	N35	24	W 97	36	397	4.61	4.76	H4	3	4.82	5.04	H4	5
	Tulsa	13968	N36	12	W 95	54	206	4.33	4.50	H4	4	4.20	4.52	H4	8

* Denotes SOLMET station

Denotes NSRDB primary station

Table A-1. Comparison of Annual Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases (Continued)

State	City	WBAN Number	Latitude		Longitude		Elev (m)	Global Horizontal Radiation				Direct Normal Radiation			
			Deg	Min	Deg	Min		SOLMET ERSATZ	NSRDB	Flag	% Chg	SOLMET ERSATZ	NSRDB	Flag	% Chg
Oregon	Astoria	94224	N46	9	W123	53	7	3.15	3.22	H4	2	2.40	2.70	H4	13
	Burns #	94185	N43	35	W119	3	1271		4.41	F4			5.01	F4	
	Eugene #	24221	N44	7	W123	13	109		3.73	F4			3.53	F4	
	* Medford #	24225	N42	22	W122	52	396	4.27	4.37	F4	2	4.29	4.70	F4	10
	North Bend	24284	N43	25	W124	15	5	3.84	3.87	H4	1	3.48	3.69	H4	6
	Pendleton	24155	N45	41	W118	51	456	3.97	4.10	H4	3		4.49	H4	
	Portland #	24229	N45	36	W122	36	12	3.36	3.52	F4	5	2.83	3.08	F4	9
	Redmond #	24230	N44	16	W121	9	940	4.36	4.40	H4	1	4.91	4.95	H4	1
	Salem	24232	N44	55	W123	1	61	3.55	3.69	H4	4	3.10	3.38	H4	9
Pacific Islands	Guam #	41415	N13	33	E144	50	110		4.98	F4			3.59	F4	
Pennsylvania	Allentown	14737	N40	39	W 75	26	117	3.59	3.86	H4	8	3.06	3.35	H5	9
	Bradford	04751	N41	48	W 78	38	600		3.72	H4			2.95	H4	
	Erie	14860	N42	5	W 80	11	225	3.34	3.77	H4	13	2.71	3.12	H4	15
	Harrisburg	14751	N40	13	W 76	51	106	3.63	3.94	H4	9	3.13	3.49	H4	12
	Philadelphia	13739	N39	53	W 75	15	9	3.68	3.99	G4	8	3.21	3.67	G5	14
	Pittsburgh #	94823	N40	30	W 80	13	373	3.37	3.80	F4	13	2.64	2.91	F4	10
	Wilkes-Barre	14777	N41	20	W 75	44	289	3.42	3.76	H4	10	2.75	3.10	H5	13
	Williamsport	14778	N41	16	W 77	3	243		3.77	H4			3.10	H5	
Puerto Rico	San Juan #	11641	N18	26	W 66	0	19	5.17	5.30	H4	3	4.34	4.41	H4	2
Rhode Island	Providence	14765	N41	44	W 71	26	19	3.51	3.88	H4	11	3.21	3.59	H5	12
South Carolina *	Charleston #	13880	N32	54	W 80	2	12	4.24	4.60	H4	8	3.78	4.22	H4	12
	Columbia	13883	N33	57	W 81	7	69	4.35	4.52	H4	4	4.12	4.25	H4	3
	Greenville	3870	N34	54	W 82	13	296	4.25	4.45	H4	5	3.98	4.39	H4	10
South Dakota	Huron	14936	N44	23	W 98	13	393	4.02	4.06	H4	1	4.38	4.35	H4	-1
	Pierre	24025	N44	23	W100	17	526	4.25	4.16	H4	-2	4.89	4.63	H4	-5
	Rapid City	24090	N44	3	W103	4	966	4.23	4.26	H4	1	4.95	5.00	H4	1
	Sioux Falls	14944	N43	34	W 96	44	435	4.07	4.06	H4	0	4.48	4.32	H4	-4

* Denotes SOLMET station

Denotes NSRDB primary station

Table A-1. Comparison of Annual Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases (Continued)

State	City	WBAN Number	Latitude		Longitude		Elev (m)	Global Horizontal Radiation				Direct Normal Radiation			
			Deg	Min	Deg	Min		SOLMET ERSATZ	NSRDB	Flag	% Chg	SOLMET ERSATZ	NSRDB	Flag	% Chg
Tennessee	Bristol	13877	N36	29	W 82	24	459		4.14	H4			3.74	H4	
	Chattanooga	13882	N35	2	W 85	12	210	3.93	4.27	H4	9	3.34	3.73	H4	12
	Knoxville	13891	N35	49	W 83	59	299	4.01	4.23	H4	5	3.51	3.71	H4	6
	Memphis	13893	N35	3	W 89	59	87	4.31	4.52	H4	5	4.02	4.33	H4	8
	* Nashville #	13897	N36	7	W 86	41	180	4.00	4.37	F4	9	3.62	3.88	F4	7
Texas	Abilene	13962	N32	26	W 99	41	534	4.90	5.08	H4	4	5.22	5.48	H4	5
	Amarillo	23047	N35	14	W101	42	1098	5.23	5.03	H4	-4	6.35	5.81	H4	-9
	Austin	13958	N30	18	W 97	42	189	4.65	4.86	H4	5	4.38	4.63	H4	6
	* Brownsville #	12919	N25	54	W 97	26	6	4.88	4.75	F4	-3	4.45	3.95	F4	-11
	Corpus Christi	12924	N27	46	W 97	30	13	4.79	4.57	H4	-5	4.39	3.98	H4	-9
	* El Paso #	23044	N31	48	W106	24	1194	5.99	5.73	F4	-4	7.29	6.69	F4	-8
	* Fort Worth #	03927	N32	50	W 97	3	164	4.65	4.89	H4	5	4.67	4.84	H4	4
	Houston	12960	N29	59	W 95	22	33	4.26	4.43	H4	4	3.51	3.81	H4	9
	Lubbock	23042	N33	39	W101	49	988	5.57	5.11	H4	-8	6.57	5.75	H4	-12
	Lufkin	93987	N31	14	W 94	45	96	4.54	4.65	H4	2	4.27	4.19	H4	-2
	Midland #	23023	N31	56	W102	12	871	5.68	5.33	F4	-6	6.61	5.91	F4	-11
	Port Arthur	12917	N29	57	W 94	1	7	4.43	4.55	H4	3	3.81	4.00	H4	5
	San Angelo	23034	N31	22	W100	30	582	4.94	5.13	H4	4	5.22	5.47	H4	5
	San Antonio #	12921	N29	32	W 98	28	242	4.73	4.95	F4	5	4.44	4.54	F4	2
	Victoria	12912	N28	51	W 96	55	32		4.61	H4			3.85	H4	
	Waco	13959	N31	37	W 97	13	155	4.63	4.87	H4	5	4.51	4.83	H4	7
	Wichita Falls	13966	N33	58	W 98	29	314	4.79	4.90	H4	2	4.96	5.18	H4	4
Utah	Cedar City	93129	N37	42	W113	6	1712	5.49	5.05	H4	-8	7.02	6.19	H4	-12
	Salt Lake City #	24127	N40	46	W111	58	1288	5.05	4.58	E4	-9	6.19	5.11	E4	-17
Vermont	Burlington #	14742	N44	28	W 73	9	104	3.22	3.72	F4	16	3.48	3.34	F4	-4
Virginia	Lynchburg	13733	N37	20	W 79	12	279		4.39	H4			4.32	H4	
	Norfolk	13737	N36	54	W 76	12	9	4.18	4.19	H4	0	3.91	3.98	H4	2
	Richmond	13740	N37	30	W 77	20	50	3.93	4.22	H4	7	3.49	3.92	H4	12
	Roanoke	13741	N37	19	W 79	58	358	4.00	4.24	H4	6	3.75	3.98	H4	6
	* Sterling #	93738	N38	57	W 77	27	82	3.81	4.12	F4	8	3.48	3.70	F4	6

* Denotes SOLMET station

Denotes NSRDB primary station

Table A-1. Comparison of Annual Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases (Continued)

State	City	WBAN Number	Latitude		Longitude		Elev (m)	Global Horizontal Radiation				Direct Normal Radiation			
			Deg	Min	Deg	Min		SOLMET	NSRDB	Flag	% Chg	ERSATZ	NSRDB	Flag	% Chg
Washington	Olympia	24227	N46	58	W122	54	61	3.16	3.26	H4	3	2.53	2.67	H4	6
	Quillayute	94240	N47	57	W124	33	55		3.02	H4		2.60	H4		
	* Seattle #	24233	N47	27	W122	18	122	3.32	3.33	F4	0	2.80	2.94	F4	5
	Spokane	24157	N47	38	W117	32	721	3.86	3.84	H4	-1	4.12	4.22	H4	2
	Yakima	24243	N46	34	W120	32	325	4.04	4.10	H4	1	4.22	4.68	H4	11
West Virginia	Charleston	13866	N38	22	W 81	36	290	3.54	3.95	H4	12	2.80	3.28	H4	17
	Elkins	13729	N38	53	W 79	51	594		3.77	H4		2.89	H4		
	Huntington	3860	N38	22	W 82	33	255	3.71	3.93	H4	6	3.29	H4		
Wisconsin	Eau Claire	14991	N44	52	W 91	29	273	3.57	3.78	H4	6	3.45	3.67	H4	6
	Green Bay	14898	N44	29	W 88	8	214	3.60	3.81	H4	6	3.45	3.68	H4	7
	La Crosse	14920	N43	52	W 91	15	205	3.66	3.87	H4	6	3.52	3.79	H4	8
	* Madison #	14837	N43	8	W 89	20	262	3.75	3.91	F4	4	3.72	3.54	F4	-5
	Milwaukee	14839	N42	57	W 87	54	211	3.76	3.89	H4	3	3.65	3.65	H4	0
Wyoming	Casper	24089	N42	55	W106	28	1612	4.93	4.40	H4	-11	6.44	5.32	H4	-17
	Cheyenne	24018	N41	9	W104	49	1872	4.70	4.43	H4	-6	6.08	5.21	H4	-14
	Lander #	24021	N42	49	W108	44	1696		4.58	F4		5.47	F4		
	Rock Springs	24027	N41	36	W109	4	2056	5.15	4.60	H4	-11	6.90	5.43	H4	-21
	Sheridan	24029	N44	46	W106	58	1209	4.19	4.18	H4	0	4.83	4.74	H4	-2

* Denotes SOLMET station

Denotes NSRDB primary station

Appendix B

Comparison of Monthly Average Daily Radiation of SOLMET/ERSATZ and NSRDB Data Bases

Table B-1. Comparison of Monthly Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases

State	City	August Solar Radiation						December Solar Radiation					
		Global Horizontal			Direct Normal			Global Horizontal			Direct Normal		
		SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg
Alabama	Birmingham	5.43	5.61	3	4.44	4.14	-7	2.09	2.33	11	2.77	2.99	8
	Huntsville		5.70			4.60			2.14			2.68	
	Mobile	5.18	5.24	1	3.68	3.66	-1	2.39	2.53	6	2.63	3.04	16
	Montgomery #	5.50	5.71	4	4.48	3.98	-11	2.27	2.50	10	3.04	3.24	7
Alaska	Anchorage		3.52			2.99			0.17			0.40	
	Annette	3.66	3.97	8	2.86	3.39	19	0.39	0.45	15	0.51	0.72	41
	Barrow	2.70	2.63	-3		1.59		0.00	0.00	0		0.00	
	Bethel	2.90	3.17	9	1.80	2.01	12	0.15	0.22	47	0.19	0.79	316
	Bettles	3.39	3.49	3		3.43		0.00	0.00	0		0.12	
	Big Delta	3.87	3.88	0	3.91	4.00	2	0.03	0.08	167	0.01	0.55	5400
	Cold Bay		2.99			1.09			0.45			0.61	
	Fairbanks #	3.52	3.73	6	3.26	3.49	7	0.01	0.05	400	0.00	0.29	
	Gulkana	3.95	4.12	4	3.95	4.39	11	0.09	0.16	78	0.08	0.58	625
	King Salmon	3.30	3.38	2	2.39	2.16	-10	0.29	0.32	10	0.56	0.93	66
	Kodiak	3.67	3.77	3	3.09	3.28	6	0.31	0.34	10	0.51	0.93	82
	Kotzebue	3.29	3.32	1		3.21		0.00	0.01			0.11	
	Mcgrath	3.21	3.45	7	2.48	3.03	22	0.06	0.12	100	0.04	0.54	1250
	Nome	3.13	3.27	4	2.57	2.82	10	0.01	0.06	500	0.00	0.51	
	St Paul Is.		2.87			0.84			0.35			0.43	
Talkeetna		3.57			3.25			0.16			0.69		
Yakutat	2.97	3.39	14	2.02	2.50	24	0.16	0.26	63	0.17	0.53	212	
Arizona	Flagstaff		5.91			6.10			2.80			5.15	
	* Phoenix #	7.23	7.06	-2	7.49	7.23	-3	2.94	2.96	1	4.91	4.84	-1
	Prescott	6.59	6.28	-5	6.94	6.60	-5	2.92	2.82	-3	5.59	5.22	-7
	Tucson #	6.88	6.68	-3	7.00	6.80	-3	3.14	3.15	0	5.38	5.37	0
Arkansas	Fort Smith	5.92	5.98	1	5.46	5.46	0	2.15	2.31	7	3.18	3.25	2
	Little Rock	5.87	5.92	1	5.31	5.13	-3	2.12	2.23	5	3.04	2.97	-2

* Denotes SOLMET station

Denotes NSRDB primary station

Table B-1. Comparison of Monthly Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases (Continued)

State	City	August Solar Radiation						December Solar Radiation					
		Global Horizontal			Direct Normal			Global Horizontal			Direct Normal		
		SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg
California	Arcata	4.98	5.03	1	3.94	3.86	-2	1.48	1.61	9	1.94	2.30	19
	Bakersfield	7.63	7.21	-6	8.44	8.20	-3	2.14	2.10	-2	2.79	2.35	-16
	Daggett #	7.51	7.34	-2	8.32	8.66	4	2.76	2.94	7	4.83	5.39	12
	* Fresno #	7.64	7.18	-6	8.45	8.13	-4	1.81	1.87	3	2.36	1.92	-19
	Long Beach	6.62	6.67	1	6.44	6.36	-1	2.67	2.58	-3	4.16	3.70	-11
	Los Angeles #	6.56	6.54	0		5.91		2.68	2.61	-3		3.76	
	Sacramento	7.47	7.03	-6	8.37	8.10	-3	1.70	1.74	2	2.22	1.95	-12
	San Diego #	6.49	6.52	0	6.09	6.27	3	2.85	2.85	0	4.42	4.48	1
	San Francisco	6.67	6.51	-2	6.84	6.57	-4	2.03	1.97	-3	3.07	2.90	-6
* Santa Maria #	6.64	6.78	2	6.57	6.79	3	2.53	2.65	5	4.09	4.39	7	
Colorado	Alamosa #		6.47			7.02			2.72			5.41	
	Boulder #		5.97			6.29			2.13			3.95	
	Colorado Springs	6.39	6.02	-6	6.94	6.25	-10	2.47	2.30	-7	5.45	4.41	-19
	Eagle	6.57	6.13	-7	7.23	6.51	-10	2.18	2.11	-3	4.52	3.53	-22
	Grand Junction #	6.88	6.60	-4	7.57	7.07	-7	2.31	2.22	-4	4.71	3.88	-18
	Pueblo	6.63	6.48	-2	7.22	6.94	-4	2.47	2.41	-2	5.19	4.58	-12
Connecticut	Bridgeport		5.18			4.22			1.55			2.20	
	Hartford	4.48	5.13	15	3.42	3.99	17	1.21	1.51	25	1.50	1.99	33
Delaware	Wilmington	5.09	5.45	7	4.22	4.46	6	1.54	1.74	13	2.10	2.44	16
Florida	Daytona Beach #	5.30	5.66	7	3.92	4.12	5	2.74	2.88	5	3.34	3.58	7
	Jacksonville	5.34	5.41	1	4.03	3.96	-2	2.58	2.68	4	3.16	3.44	9
	Key West		5.83			4.39			3.44			4.41	
	* Miami #	5.14	5.59	9	3.56	3.63	2	3.21	3.30	3	4.01	3.88	-3
	Tallahassee #	5.28	5.48	4	3.90	3.80	-3	2.56	2.74	7	3.07	3.41	11
	Tampa	5.21	5.46	5	3.73	3.94	6	2.95	3.06	4	3.70	4.00	8
	West Palm Beach	5.24	5.56	6	3.85	3.93	2	3.02	3.11	3	3.71	3.78	2

* Denotes SOLMET station

Denotes NSRDB primary station

Table B-1. Comparison of Monthly Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases (Continued)

State	City	August Solar Radiation						December Solar Radiation					
		Global Horizontal			Direct Normal			Global Horizontal			Direct Normal		
		SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg
Georgia	Athens		5.63			4.30			2.35			3.26	
	Atlanta #	5.39	5.72	6	4.45	4.22	-5	2.13	2.39	12	2.94	3.20	9
	Augusta	5.26	5.53	5	4.15	4.14	0	2.27	2.45	8	3.27	3.40	4
	Columbus		5.64			4.18			2.52			3.37	
	Macon	5.42	5.63	4	4.41	4.20	-5	2.30	2.49	8	3.24	3.33	3
	Savannah #	5.11	5.49	7	3.93	3.84	-2	2.38	2.57	8	3.23	3.41	6
Hawaii	Hilo	5.02	5.30	6	3.45	4.00	16	3.21	3.49	9	3.12	3.54	13
	Honolulu #	6.20	6.44	4	5.32	6.02	13	3.57	3.74	5	4.09	4.30	5
	Kahului		6.52			6.76			3.87			4.95	
	Lihue	5.73	5.89	3	4.47	5.11	14	3.32	3.47	5	3.57	3.88	9
Idaho	Boise #	6.92	6.55	-5	8.01	7.96	-1	1.38	1.42	3	2.11	1.97	-7
	Pocatello	7.06	6.33	-10	8.28	7.43	-10	1.50	1.49	-1	2.53	1.90	-25
Illinois	Chicago	5.42	5.36	-1	5.01	4.48	-11	1.26	1.45	15	1.75	1.73	-1
	Moline	5.41	5.51	2	4.93	5.00	1	1.36	1.58	16	1.96	2.11	8
	Peoria		5.54			4.94			1.62			2.08	
	Rockford		5.38			4.68			1.51			1.97	
	Springfield	5.69	5.70	0	5.42	5.29	-2	1.55	1.73	12	2.29	2.31	1
Indiana	Evansville	5.47	5.72	5	4.75	5.04	6	1.57	1.80	15	2.01	2.23	11
	Fort Wayne	5.03	5.35	6	4.12	4.44	8	1.16	1.42	22	1.25	1.39	11
	Indianapolis #	5.18	5.63	9	4.33	4.71	9	1.31	1.62	24	1.50	1.82	21
	South Bend	5.25	5.30	1	4.67	4.37	-6	1.07	1.36	27	1.21	1.11	-8
Iowa	Des Moines	5.76	5.66	-2	5.67	5.44	-4	1.54	1.66	8	2.48	2.43	-2
	Mason City	5.78	5.48	-5	5.85	5.06	-14	1.40	1.52	9	2.41	2.13	-12
	Sioux City	5.82	5.67	-3	5.83	5.55	-5	1.48	1.61	9	2.42	2.45	1
	Waterloo		5.48			5.01			1.55			2.14	

* Denotes SOLMET station

Denotes NSRDB primary station

Table B-1. Comparison of Monthly Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases (Continued)

State	City	August Solar Radiation						December Solar Radiation					
		Global Horizontal			Direct Normal			Global Horizontal			Direct Normal		
		SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg
Kansas	* Dodge City #	6.48	6.31	-3	6.84	6.24	-9	2.31	2.35	2	4.28	4.01	-6
	Goodland	6.45	6.28	-3	6.96	6.77	-3	2.19	2.20	0	4.40	4.01	-9
	Topeka	6.02	5.80	-4	5.96	5.50	-8	1.84	1.92	4	2.91	2.93	1
	Wichita	6.41	6.07	-5	6.55	5.97	-9	2.18	2.17	0	3.76	3.45	-8
Kentucky	Covington	5.15	5.50	7		4.61		1.36	1.62	19		1.80	
	Lexington	5.31	5.47	3	4.50	4.51	0	1.53	1.74	14	1.91	2.01	5
	Louisville	5.30	5.60	6	4.45	4.65	4	1.54	1.74	13	1.90	2.02	6
Louisiana	Baton Rouge	5.29	5.44	3	4.09	4.05	-1	2.32	2.51	8	2.78	3.02	9
	* Lake Charles #	5.23	5.65	8	4.09	4.06	-1	2.22	2.59	17	2.71	3.04	12
	New Orleans	5.41	5.46	1	4.30	3.94	-8	2.46	2.58	5	3.01	3.02	0
	Shreveport	5.92	6.02	2	5.26	5.01	-5	2.30	2.45	7	3.19	3.14	-2
Maine	* Caribou #	4.73	4.80	1	4.28	4.09	-4	0.98	1.23	26	1.43	1.82	27
	Portland	4.61	5.36	16	3.77	4.93	31	1.14	1.51	32	1.62	2.43	50
Maryland	Baltimore	5.04	5.32	6	4.16	4.37	5	1.57	1.77	13	2.10	2.57	22
Massachusetts	* Boston #	4.69	5.35	14	3.86	4.47	16	1.27	1.52	20	1.82	2.34	29
	Worcester		5.23			4.22			1.53			2.13	
Michigan	Alpena	4.99	5.11	2	4.49	4.88	9	0.85	1.22	44	0.91	1.12	23
	Detroit	4.97	5.28	6	4.12	4.46	8	1.08	1.30	20	1.17	1.28	9
	Flint	4.90	5.22	7	4.08	4.42	8	0.97	1.28	32	0.97	1.16	20
	Grand Rapids	5.28	5.32	1	4.82	4.65	-4	0.98	1.29	32	1.11	1.02	-8
	Houghton		5.02			4.88			1.07			0.93	
	Lansing		5.24			4.45			1.30			1.13	
	Muskegon		5.45			4.97			1.24			0.76	
	Sault Ste. Marie	4.80	4.99	4	4.24	4.74	12	0.80	1.21	51	1.04	1.23	18
	Traverse City	5.07	5.05	0	4.50	4.48	0	0.81	1.17	44	0.76	0.74	-3

* Denotes SOLMET station

Denotes NSRDB primary station

Table B-1. Comparison of Monthly Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases (Continued)

State	City	August Solar Radiation						December Solar Radiation					
		Global Horizontal			Direct Normal			Global Horizontal			Direct Normal		
		SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg
Minnesota	Duluth	4.88	5.08	4	4.45	4.76	7	0.92	1.25	36	1.50	1.83	22
	International Falls	5.10	4.93	-3	4.99	4.68	-6	0.86	1.11	29	1.49	1.74	17
	Minneapolis	5.32	5.41	2	4.98	5.22	5	1.11	1.38	24	1.73	2.01	16
	Rochester	5.24	5.31	1	4.88	4.86	0	1.17	1.43	22	1.83	1.91	4
	Saint Cloud		5.37			5.26			1.32			1.99	
Mississippi	Jackson	5.61	5.79	3	4.68	4.59	-2	2.23	2.43	9	2.97	3.08	4
	Meridian	5.48	5.57	2	4.43	4.02	-9	2.21	2.40	9	2.84	2.91	2
Missouri	* Columbia #	5.92	5.87	-1	5.71	5.21	-9	1.65	1.88	14	2.52	2.67	6
	Kansas City	5.87	5.79	-1	5.63	5.51	-2	1.77	1.88	6	2.74	2.85	4
	Springfield	5.91	5.90	0	5.64	5.49	-3	1.90	2.01	6	2.92	2.79	-4
	St. Louis	5.73	5.67	-1	5.34	5.08	-5	1.67	1.84	10	2.39	2.43	2
Montana	Billings	6.38	6.10	-4	7.23	7.17	-1	1.33	1.44	8	2.61	2.54	-3
	Cut Bank	5.98	5.79	-3	6.83	6.57	-4	1.05	1.14	9	2.13	2.32	9
	Glasgow	5.87	5.70	-3	6.53	6.43	-2	1.05	1.17	11	2.02	2.04	1
	* Great Falls #	6.09	5.90	-3	6.83	6.57	-4	1.06	1.21	14	1.89	2.13	13
	Helena	6.09	5.91	-3	6.84	6.91	1	1.15	1.24	8	2.03	1.98	-2
	Kalispell		5.60			6.36			0.99			0.84	
	Lewistown	5.99	5.81	-3	6.68	6.61	-1	1.14	1.23	8	2.16	2.11	-2
	Miles City	6.23	6.05	-3	7.03	7.07	1	1.26	1.37	9	2.46	2.40	-2
Missoula	5.93	5.82	-2	6.58	6.81	3	0.84	1.07	27	1.00	1.09	9	
Nebraska	Grand Island	6.11	5.97	-2	6.40	6.14	-4	1.80	1.89	5	3.37	3.25	-4
	Norfolk		5.80			5.78			1.72			2.77	
	North Platte	6.27	5.98	-5	6.62	6.20	-6	1.91	1.94	2	3.80	3.43	-10
	* Omaha #	5.86	5.72	-2	5.84	5.22	-11	1.61	1.71	6	2.64	2.62	-1
	Scottsbluff	6.30	6.18	-2	6.79	6.79	0	1.81	1.89	4	3.76	3.41	-9

* Denotes SOLMET station

Denotes NSRDB primary station

Table B-1. Comparison of Monthly Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases (Continued)

State	City	August Solar Radiation						December Solar Radiation					
		Global Horizontal			Direct Normal			Global Horizontal			Direct Normal		
		SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg
Nevada	Elko	7.30	6.56	-10	8.64	7.66	-11	1.95	1.89	-3	3.73	3.27	-12
	* Ely #	7.03	6.48	-8	9.19	7.38	-20	2.28	2.24	-2	5.94	4.11	-31
	Las Vegas #	7.42	7.18	-3	8.24	8.06	-2	2.78	2.76	-1	5.22	5.02	-4
	Reno	7.58	6.94	-8	9.00	8.27	-8	2.22	2.07	-7	4.42	3.60	-19
	Tonopah	7.69	6.95	-10	9.12	8.14	-11	2.61	2.40	-8	5.41	4.62	-15
	Winnemucca	7.40	6.74	-9	8.78	7.95	-9	1.95	1.86	-5	3.69	3.16	-14
New Hampshire	Concord	4.59	5.30	15	3.72	4.73	27	1.14	1.51	32	1.55	2.19	41
New Jersey	Atlantic City		5.33			4.37			1.77			2.63	
	Newark	4.93	5.23	6	4.06	4.05	0	1.43	1.60	12	1.98	2.19	11
New Mexico *	Albuquerque #	7.22	6.89	-5	7.81	6.98	-11	2.92	2.89	-1	5.72	5.18	-9
	Tucumcari	6.82	6.52	-4	7.27	6.56	-10	2.87	2.73	-5	5.72	4.83	-16
New York	Albany #	4.73	5.19	10	4.94	4.20	-15	1.12	1.40	25	1.73	1.57	-9
	Binghamton	4.49	5.02	12	3.42	3.99	17	0.94	1.39	48	0.86	1.17	36
	Buffalo	4.77	5.18	9	3.81	4.42	16	0.89	1.27	43	0.77	1.01	31
	Massena	4.68	5.07	8	5.02	4.54	-10	0.93	1.30	40	1.45	1.57	8
	* New York City #	4.68	5.38	15	3.72	4.05	9	1.27	1.61	27	1.69	2.14	27
	Rochester	4.79	5.15	8	3.87	4.48	16	0.89	1.29	45	0.77	1.03	34
	Syracuse	4.74	5.17	9	3.79	4.49	18	0.90	1.31	46	0.81	1.09	35
North Carolina	Asheville	5.13	5.27	3	4.08	3.94	-3	2.07	2.22	7	3.09	3.29	6
	* Cape Hatteras #	5.38	5.63	5	4.54	4.49	-1	2.08	2.24	8	3.09	3.27	6
	Charlotte	5.34	5.57	4	4.44	4.37	-2	2.12	2.25	6	3.14	3.24	3
	Greensboro	5.35	5.53	3	4.55	4.38	-4	2.08	2.17	4	3.17	3.18	0
	Raleigh #	5.08	5.48	8	3.91	3.94	1	2.00	2.20	10	2.16	3.12	44
	Wilmington		5.44			4.01			2.38			3.37	

* Denotes SOLMET station

Denotes NSRDB primary station

Table B-1. Comparison of Monthly Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases (Continued)

State	City	August Solar Radiation						December Solar Radiation					
		Global Horizontal			Direct Normal			Global Horizontal			Direct Normal		
		SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg
North Dakota *	Bismarck #	5.92	5.78	-2	6.49	6.16	-5	1.18	1.36	15	2.08	2.32	12
	Fargo	5.75	5.52	-4	6.00	5.76	-4	1.06	1.28	21	1.83	2.04	11
	Minot	5.68	5.59	-2	6.16	6.20	1	0.98	1.20	22	1.84	2.26	23
Ohio	Akron	5.03	5.24	4	4.21	4.16	-1	1.11	1.37	23	1.14	1.12	1
	Cleveland	4.99	5.26	5	4.15	4.30	4	1.00	1.30	30	0.92	0.97	5
	Columbus	5.17	5.27	2	4.01	4.21	5	1.22	1.47	20	1.31	1.41	8
	Dayton	5.19	5.45	5	4.34	4.61	6	1.28	1.53	20	1.47	1.61	10
	Mansfield		5.28			4.27			1.40			1.25	
	Toledo	5.09	5.43	7	4.29	4.60	7	1.12	1.38	23	1.24	1.36	10
	Youngstown	4.75	5.01	5	3.78	3.76	-1	0.99	1.31	32	0.94	0.94	0
Oklahoma	Oklahoma City	6.15	6.25	2	5.88	6.12	4	2.29	2.45	7	3.74	3.79	1
	Tulsa	5.88	6.01	2	5.38	5.67	5	2.08	2.24	8	3.07	3.28	7
Oregon	Astoria	4.73	4.77	1	3.87	3.96	2	0.82	0.98	20	0.73	1.14	56
	Burns #		6.49			7.79			1.49			2.02	
	Eugene #		5.82			6.19			1.04			0.89	
	* Medford #	6.69	6.67	0	7.24	7.80	8	1.06	1.23	16	1.00	1.14	14
	North Bend	5.63	5.61	0	5.28	5.27	0	1.20	1.34	12	1.40	1.8	29
	Pendleton	6.29	6.30	0		7.52		0.92	1.14	24		1.15	
	Portland #	5.28	5.42	3	4.96	5.18	4	0.82	0.98	20	0.69	0.94	36
	Redmond #	6.52	6.56	1	7.49	7.72	3	1.34	1.42	6	2.13	2.07	-3
	Salem	5.60	5.74	3	5.51	5.77	5	0.87	1.05	21	0.73	0.95	30
Pacific Islands	Guam #		4.87			2.72		4.21			3.62		
Pennsylvania	Allentown	4.87	5.22	7	3.95	4.11	4	1.36	1.56	15	1.71	1.96	15
	Bradford		5.05			3.91			1.40			1.05	
	Erie	4.59	5.30	15	4.09	4.51	10	0.88	1.28	45	0.70	0.73	4
	Harrisburg	4.89	5.26	8	3.97	4.16	5	1.41	1.63	16	1.80	2.06	14

* Denotes SOLMET station

Denotes NSRDB primary station

Table B-1. Comparison of Monthly Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases (Continued)

State	City	August Solar Radiation						December Solar Radiation					
		Global Horizontal			Direct Normal			Global Horizontal			Direct Normal		
		SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg
	Philadelphia	4.96	5.39	9	4.04	4.41	9	1.48	1.69	14	1.95	2.36	21
	Pittsburgh #	4.76	5.24	10	3.74	3.86	3	1.09	1.41	29	1.05	1.17	11
	Wilkes-Barre	4.77	5.18	9	3.77	4.11	9	1.16	1.42	22	1.21	1.43	18
	Williamsport		5.14			3.92			1.43			1.49	
Puerto Rico	San Juan #	5.80	5.96	3	4.63	4.61	0	3.90	3.95	1	4.39	3.82	-13
Rhode Island	Providence	4.72	5.22	11	3.92	4.17	6	1.32	1.56	18	1.90	2.33	23
South Carolina	* Charleston #	5.00	5.47	9	3.70	3.84	4	2.27	2.53	11	3.11	3.48	12
	Columbia	5.37	5.50	2	4.41	4.16	-6	2.28	2.40	5	3.42	3.40	-1
	Greenville	5.36	5.54	3	4.42	4.47	1	2.11	2.29	9	3.11	3.40	9
South Dakota	Huron	5.97	5.82	-3	6.27	6.12	-2	1.28	1.47	15	2.16	2.40	11
	Pierre	6.28	5.97	-5	6.89	6.51	-6	1.39	1.51	9	2.54	2.53	0
	Rapid City	6.19	6.07	-2	6.86	6.87	0	1.50	1.63	9	2.94	3.04	3
	Sioux Falls	5.82	5.66	-3	6.02	5.68	-6	1.39	1.53	10	2.49	2.43	-2
Tennessee	Bristol		5.39			4.25			1.94			2.51	
	Chattanooga	5.14	5.49	7	4.09	4.15	1	1.83	2.12	16	2.26	2.61	15
	Knoxville	5.25	5.50	5	4.27	4.23	-1	1.80	2.03	13	2.26	2.49	10
	Memphis	5.75	5.97	4	5.02	5.18	3	1.98	2.17	10	2.70	2.87	6
	* Nashville #	5.48	5.73	5	4.61	4.35	-6	1.64	2.00	22	2.19	2.59	18
Texas	Abilene	6.17	6.32	2	5.75	6.06	5	2.72	2.86	5	4.47	4.40	-2
	Amarillo	6.63	6.29	-5	6.96	6.33	-9	2.75	2.67	-3	5.31	4.63	-13
	Austin	6.09	6.33	4	5.34	5.75	8	2.60	2.79	7	3.63	3.58	-1
	* Brownsville #	6.39	6.01	-6	5.87	4.90	-17	2.72	2.74	1	3.15	2.71	-14
	Corpus Christi	6.28	5.84	-7	5.71	4.87	-15	2.66	2.66	0	3.21	2.84	-12
	* El Paso #	7.20	6.76	-6	7.59	6.51	-14	3.25	3.20	-2	5.82	5.24	-10
	* Fort Worth #	6.25	6.36	2	5.89	5.77	-2	2.41	2.66	10	3.61	3.80	5

* Denotes SOLMET station

Denotes NSRDB primary station

Table B-1. Comparison of Monthly Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases (Continued)

State	City	August Solar Radiation						December Solar Radiation					
		Global Horizontal			Direct Normal			Global Horizontal			Direct Normal		
		SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg
	Houston	5.32	5.61	5	4.08	4.39	8	2.30	2.49	8	2.60	2.76	6
	Lubbock	6.96	6.33	-9	7.26	6.25	-14	2.95	2.81	-5	5.17	4.62	-11
	Lufkin	5.88	6.01	2	5.07	5.00	-1	2.42	2.55	5	3.28	3.13	-5
	Midland #	6.97	6.46	-7	7.13	6.16	-14	3.15	3.05	-3	5.36	4.85	-10
	Port Arthur	5.47	5.72	5	4.36	4.50	3	2.38	2.56	8	2.84	2.99	5
	San Angelo	6.20	6.38	3	5.77	6.15	7	2.82	2.97	5	4.56	4.45	-2
	San Antonio #	6.14	6.42	5	5.39	5.47	1	2.67	2.85	7	3.65	3.52	-4
	Victoria		5.83			4.55			2.66			2.81	
	Waco	6.17	6.36	3	5.59	6.04	8	2.53	2.73	8	3.69	3.77	2
	Wichita Falls	6.21	6.30	1	5.84	6.12	5	2.52	2.61	4	4.00	3.95	-1
Utah	Cedar City	7.07	6.53	-8	7.95	7.19	-10	2.48	2.39	-4	4.82	4.37	-9
	Salt Lake City #	7.11	6.51	-8	8.20	7.31	-11	1.80	1.68	-7	3.18	2.16	-32
Vermont	Burlington #	4.65	5.19	12	4.93	4.48	-9	0.89	1.25	40	1.26	1.31	4
Virginia	Lynchburg		5.63			4.62			2.09			3.16	
	Norfolk	5.30	5.39	2	4.37	4.32	-1	1.97	2.01	2	2.86	2.93	2
	Richmond	5.05	5.43	8	4.07	4.22	4	1.79	2.00	12	2.44	2.83	16
	Roanoke	5.11	5.45	7	4.25	4.32	2	1.86	2.03	9	2.75	2.89	5
	* Sterling #	5.10	5.40	6	4.23	3.99	-6	1.52	1.82	20	2.07	2.50	21
Washington	Olympia	4.88	5.06	4	4.42	4.57	3	0.70	0.86	23	0.51	0.71	39
	Quillayute		4.53			3.82			0.83			1.04	
	* Seattle #	5.10	5.15	1	4.74	4.83	2	0.67	0.80	19	0.57	0.85	49
	Spokane	6.12	5.94	-3	6.90	7.01	2	0.80	1.07	34	1.00	1.15	15
	Yakima	6.23	6.18	-1	6.82	7.37	8	0.93	1.15	24	1.15	1.49	30
West Virginia	Charleston	4.77	5.28	11	3.57	4.01	12	1.39	1.68	21	1.51	1.79	19
	Elkins		5.02			3.51			1.63			1.56	
	Huntington	4.98	5.22	5		3.92		1.47	1.66	13		1.76	

* Denotes SOLMET station

Denotes NSRDB primary station

Table B-1. Comparison of Monthly Average Daily Radiation (kWh/m²) of SOLMET/ERSATZ and NSRDB Data Bases (Continued)

State	City	August Solar Radiation						December Solar Radiation					
		Global Horizontal			Direct Normal			Global Horizontal			Direct Normal		
		SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg	SOLMET ERSATZ	NSRDB	% Chg
Wisconsin	Eau Claire	5.11	5.20	2	4.64	4.76	3	1.07	1.37	28	1.61	1.88	17
	Green Bay	5.11	5.22	2	4.58	4.70	3	1.10	1.38	25	1.64	1.91	16
	La Crosse	5.25	5.37	2	4.80	4.91	2	1.16	1.43	23	1.69	1.99	18
	* Madison #	5.39	5.39	0	5.05	4.32	-14	1.23	1.46	19	1.79	1.96	9
	Milwaukee	5.42	5.40	0	5.03	4.86	-3	1.19	1.42	19	1.68	1.83	9
Wyoming	Casper	7.02	6.26	-11	8.32	7.20	-13	1.87	1.74	-7	4.20	3.33	-21
	Cheyenne	6.20	5.95	-4	6.83	6.31	-8	2.12	1.95	-8	4.78	3.71	-22
	Lander #		6.23			7.01			1.87			3.62	
	Rock Springs	7.06	6.39	-9	8.46	7.11	-16	2.05	1.88	-8	4.64	3.33	-28
	Sheridan	6.32	6.03	-5	7.14	6.88	-4	1.39	1.57	13	2.67	2.62	-2

* Denotes SOLMET station

Denotes NSRDB primary station