# Development of Hourly Data for Weather Year for Energy Calculations (WYEC)

LOREN W. CROW Fellow ASHRAE

Sets of hourly data, representing the long term mean of both temperature and solar radiation, have been prepared for 21 U.S. metropolitan areas. The 8,760 sequential hourly values for all weather elements, including solar data, have been placed on magnetic tape for use in computer calculations of energy requirements.

A NY energy use calculations for planned commercial (nonresidential) buildings require some sets of weather data which can be considered as representative for the location of that building. For several years the Energy Calculations Committee of ASHRAE has recommended the use of a full set of 8,760 hours which contains real weather sequences that truly represent the long-term climatic means of the several semi-independent weather parameters.

Research Project 239 covers the development of hourly data sets for 21 stations which are each identified as a "Weather Year for Energy Calculations (WYEC)". Each set includes hourly solar radiation data representing the long-term mean for such observations. The locations of these 21 stations are shown in Fig. 1. A 22nd representative set of hourly weather data for Chicago, IL, which included solar data measured at the Argonne National Laboratories, was prepared by this same author in 1969-70 under ASHRAE Research Project RP 100.

The hourly solar data included in the WYEC data sets contain the rehabilitated solar data for most of the 21 stations as developed by the United States Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), Environmental Data and Information Service, National Climatic Center, Asheville, NC. That rehabilitation work was carried out for the Department of Energy, (A detailed explanation of procedures used and reasons for the rehabilitation effort are presented in SOLMET, Vol. I, Users Manual, August, 1978, and SOLMET, Vol. II, Final Report, February, 1979.1)

#### Mean monthly temperature values

The long period average dry-bulb temperature for any city has historically been represented by the arithmetic mean of the daily maximum and

Loren W. Crow, Consulting Meteorologist, President, Loren W. Crow Consultants, Inc., Denver, CO.

ASHRAE JOURNAL October 1981

minimum temperatures. Monthly average temperature values for 30-day months are obtained by averaging 30 maximum 30 and minimum measurements. Each annual up-date of Local Climatological Data<sup>2</sup> carries forward a table indicating monthly and annual average temperatures as recorded at the "official" observing stations. The Annual Summaries through 1978 for most cities throughout the United States carried a 40-yr. history of monthly temperature average values beginning in 1939 and continuing through 1978. In that same publication under the heading "Normals, Means and Extremes", monthly "normal" temperatures are shown as derived from temperature measurements during the 30-yr. period 1941 through 1970.

Most of the data collected from 1939 through 1978 have been collected at airports. In that same period there have been some changes in thermometer exposure locations. Aspirating equipment, consisting of a suction fan used to provide good ventilation for the thermometers, was generally added when temperature measuring equipment was placed near the runways at most airports in the early 1960's.

To accommodate some of the changes in temperature exposure locations, the evolution in instrument development, and possibly some gradual change in climate, the National Oceanic and Atmospheric Administration (NOAA) follows a policy of updating the 30-yr. "normal" tempera-ture values every 10 hrs. The monthly normal temperatures based on the 30yr. time span from 1941 through 1970 have been quoted since 1971. The 10yr. period 1941 through 1950 will be dropped and an additional 10 years will be added when historical records become available through the full year of 1980.

In this report the initial selection of representative historical months for dry-bulb temperature values focused on the one or two historical months having the closest proximity to the published 30-yr. normal for the period 1941 through 1970. After the initial selection, individual days and hours were adjusted by replacement from the same month in other years to bring the final result into very close proximity to or exactly on the published 30 yr. dry-bulb temperature normal for each month at each station. A summary of the final adjusted monthly temperature values. following careful adjustment for each of 21 stations, is presented in Table I.

The difference between the final adjusted monthly average temperature value and the 30-yr. normal temperature (1941-1970) is presented for



Figure 1: Locations of 22 cities where WYEC data sets have been developed.

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov .	Dec.
Los Angeles, CA	54.6 .1	55.6	56.5	58.8	61.8 1	64.6 .1	68.6 .1	69.4 1	68.7	65.3 .1	60.5	57.0
Washington, D.C.	35.4 2	37.2 1	45.1	56.3 1	66.2	74.5 1	78.6 1	77.3 .2	70.6	59.7 1	48.1 1	37.2 2
Miami, FL	67.2	67.6 2	71.3	75.0	78.0	81.0	82.3	82.9	81.9 .1	77.8	72.3	68.3
Tallahassee, FL	52.5 1	55.0 .2	60.1 1	67.9	75.0 .2	80.1 .1	81.0 -,1	81.0 1	78.2 .1	69.3	58,9	53.1 1
Boise, ID	29.1 .1	35.6 .1	41,3 ,2	49.0	57.4	65.0 .2	74.6 .1	72.1 1	63.0 1	52.1	40.0 2	32.0 1
Lake Charles, LA	52.2 1	55.0 1	60.2 1	69.1 .2	75.0 2	80.7	82.5 .1	82.2	78.3 1	70.1 .1	60.2	54.3
Omaha, NB	22.5 .1	28.1	37.1	52.3	63.0	72.2	77.2	75.6	66.3	56.0 .1	40.0	28.0
Las Vegas, NV	44.2	49.0 1	55.0 .2	63.7 1	73.2 1	82.3	89.6	87.4	80.1	67.1	53.3	45,1 1
Albuquerque, NM	35.3 .1	40.1 .1	45,9 .1	56.0 .2	65.4 .1	74.6	78,7	76.6	70.1	58.2	44.7 .2	36.1 1
New York, NY	32.1	33.2 .1	40.6	51.8	61.8	71.5	76.7 ~	75.0 .1	68.2 .1	58.1	47.3	35.6 ,
Bismarck, ND	8.4 .2	13.5	24.8 3	43.2 .2	54.4	63.6 2	70.9	69.1 1	57.7 .2	46.8	28.9	15.6
Cleveland, OH	27.1 .2	27.9	36.0 1	48.4	58.2 1	67.9	71.4	70.1 .1	63.9	53.9 .1	41.6	30.2 1
Dayton, OH	28.0	30.5 .1	39.2 .2	51.5 .1	61.6	71.3	74.6	73.0	66.2 1	55.5	41.8	30.9
Medford, OR	36.8 .2	41.3	44.6 2	50.3 .1	57.4	64.2 1	71.7	70.4	64.3 1	53.3 1	<b>43.6</b> .1	37.8 .1
Charleston, NC	48.5 1	50.3 2	56.5	64.6	72.0 1	77.9	80.2	79.6	75.2	65.9 2	56.3	49.2 1
Nashville, TN	38.3 .1	40.8 2	48.6 1	60.1	68.4 1	76.7 .1	79.6	78.7 .2	72.0	60.8 1	48.4	40.4
Brownsville, TX	60.3	63.4	67.6 1	74.9	79.3	82.9 .1	84.4	84.4	81.4 2	75.5 2	68.3 .2	62.7 1
Dallas-Ft. Worth, TX	44.9 .1	48.7	55.0	65.2	72.6 .1	80.6	84.7 1	85.0 .1	77.6 1	67.4 2	55.9 .1	47.8 1
El Paso, TX	43.4 2	48.3 1	54.5 -,1	63.8 1	72.4 .2	80.4 .1	82,4 .1	80.5	74.3	63.9 1	51.6	44.4
Seattle-Tacoma, WA	38.3 .1	42.3	44.1	48.7	54.9	59.8	64.7 .2	63.9 .1	59.6	52.1 1	44.6	40.6 .1
Madison, WI	16.9 .1	20.2	30.2	45.4 .1	55.8 2	65.8	69.9 2	68.6 1	59.9 .2	49.7 2	34.7	21.9

Table 1: Monthly mean temperature values (Fahrenheit) which make up the 12-month series of hourly data for the weather year for energy calculations.

all occasions when the final product differed from the 30-yr, normal. When no number is shown, the final adjusted value exactly matches the 30 yr. normal. For instance, at Los Angeles, 6 of the 12 months have a final monthly average temperature, as adjusted, exactly matching the 30-yr, normal, During the months of May and August, the final adjusted average monthly temperature is 0.1 deg cooler than the 30 yr. normal. (See the two -0.1 anomalies.) For the 4 months of January, June, July and October, the final product is 0.1 warmer (shown as 0.1 without a prefix). To eliminate completely these small abnormalities is not justified. The changes generally range from 0.2 from one 30- yr. period to the next.

## 40-year historical arrays

Selection of a comparatively short historical period of recorded temperatures cannot represent long term climatic periods. Any 10-yr. period, whether running in series or selected as every third year out of a 30-yr. period, will almost always compare poorly with long term climatic average conditions. The "normal" values based on a 30-yr. record are conservatively stable and change very little as old 10-yr. periods are dropped and new 10- yr. periods are added. The selec-1941-70 tion of the normal temperature values as the most representative published climatic mean for temperatures will mean that the final adjusted WYEC tapes will have a climatic mean for continuing usefulness for at least an additional 20 years. Small changes in thermometer exposure or effects of surrounding terrain, such as mountain valley relationships, produce notably different minimum and maximum temperatures. The "heat islands" which develop over large fractions of all major cities due to local heat sources and differences in radiation receptor surfaces, can produce temperature differences of several degrees.

Individual arrays of the historical monthly temperature record from 1939 through 1978 were prepared to portray both monthly and annual ranges. In each of those arrays, the final adjusted monthly average dry bulk temperature is shown and placed in its relative position in the arrays for individual months

ASHRAE JOURNAL October 1981

for each of the 21 cities. The total climatological range for dry-buib temperatures, both within individual months and for annual periods, varies considerably with geographic location throughout the United States. Coastal locations such as Los Angeles, Miami and Seattle, have only limited annual ranges. In some months the total range of historical anomalies is limited to only one or two degrees.

In several temperature arrays there are large anomalies from the long-term normal monthly temperature values. Although these extreme anomalies affect the long-term average value, the arrays clearly show the very high frequency of values are near the long-term mean. Within the arrays double or triple dots instead of bars have been used when duplicate values occurred within the 40 yr. period. For stations that are great distances from the ocean, the degree of variability for the same month from year to year can be quite extreme. The city with the largest monthly and annual temperature range in this group of 21 cities is Bismarck, ND.

Considerable adjustment was required to alter several of the initially selected months to bring them within close proximity to the 1941-70 normal values.

A typical example of the adjustment sequence will illustrate the procedure used. The selection of the initial historical month having an average monthly temperature nearest the 1941-70 normal also needed to be a month which had historical hourly weather data available. Following the initial selection of a month having its average dry-bulb temperature somewhat near the long-term normal, a determination was made as to whether or not that same month also had near normal solar radiation measurements and whether or not the precipitation amount was considerably above or below the long-term mean. In many instances the initial pre-adjustment month selected would require a greater substitute effort for temperature anomalies but very little adjustment for solar data. Perhaps four substitute days would have been required for adjusting the solar values to match long-term averages if the initial closest temperature month in 1962 had been used, whereas only two substitute days would be needed to adjust the monthly temperature anomaly and no substitute days required for solar if the best fit solar month in 1964 was selected. After the final choice of initial pre-adjusted month was made, two days-perhaps March 14-15. 1962-would be substituted into the final March, 1964 data set to produce a final adjusted month having only 0.1 temperature anomaly and a 6 B/ft<sup>2</sup> **ASHRAE JOURNAL** October 1981

anomaly in the average monthly solar data.

The hourly sequences at the edges of the new substitute days required some additional adjustment for various individual measured weather parameters such as station pressure, dew point, and relative humidity. These "edge" hours were carefully adjusted to avoid abrupt changes which would not be typical of nighttime weather in that particular city.

When a final selected and adjusted month of one year followed the final selected and adjusted month of another year, care had to be taken to adjust the meteorological parameters within the hours at the edges to prevent abrupt changes. In some instances errors in the original sets of hourly observations were detected and missing data were filled in to make the sets complete.

### WYEC monthly solar data

With the development of concern for more efficient use of solar radiation there has been a corresponding awareness of the limited set of solar radiation measurements within the United States. A careful examination of all records available prior to 1976 indicated that some corrections would be needed to develop directly comparable solar data for even the limited number of measuring stations. Subsequently, personnel at the National Climatic Center, as supported by the Department of Energy, prepared a corrected set of data for 26 locations throughout the United States where previous solar measurements had been made.

In addition to the rehabilitated solar data work mentioned above, two other reports presented detailed cata related to historical solar measurements. A report by Randall and Whitson<sup>3</sup> presents hourly and monthly insolation values. Table 5.2 of that report presents a nearly full set of data, either as measured or estimated, for the period 1952 through 1975 at 26 cities. Mean and standard deviation values are presented for the data set covering that period-the most complete and carefully estimated set of historical solar data available within the United States. A separate report published in November, 1978 by the Department of Commerce, NOAA, at Asheville presented tables of "Input Data for Systems".4 Solar Tables were prepared showing the derived mean values for solar radiation in each month at 222 U.S. stations. For these stations the "solar" data were derived from cloud cover and time of day data. Only at 26 stations are the data based on historical hourly measured values. Monthly mean solar values are presented in separate columns for

amounts in B's/ft<sup>2</sup>, Kilojoules/metre<sup>2</sup>, and Langleys. Examples of the direct comparison between the adjusted WYEC solar data and the long-term average solar data identified as SOLMET are presented in Table 2 for two stations with high annual rates of solar radiation-El Paso and Las Vegas-and for two comparatively low stations-New York and Seattle/ Tacoma. Similar comparative sets were prepared for each of the 21 WYEC citles to assure direct comparison with long- term solar radiation mean values. The WYEC solar data have a projected long- term use with equal consistent reliability to the adjusted dry-bulb values discussed above.

#### Hourly and daily solar profiles

Estimates of the hourly global measurements of solar radiation when clear skies prevail can be made with relative ease. Cloud cover and the many possible combinations of cloud cover show highly variable patterns of hourly solar radiation measurements.

In some WYEC cities, such as Las Vegas and Albuquerque, it is extremely difficult to find days having extensive cloud cover throughout the entire day. By contrast, it is easy to find cloudy days in the northeastern United States cities. Many times they occur in sequential periods of two to three days.

#### Interpolation procedures

When sets of carefully adjusted and truly representative hourly weather data tapes have been developed for 50 to 60 cities throughout the U.S., it will be possible to use interpolation procedures to make some corrections and derive almost equally valid energy use estimates for any place in the country. Within this study, reference data from Dayton and Cleveland, OH, have been used to develop recommended interpolation procedures.

Let us imagine that a particular building is being planned for Columbus, OH, where no carefully adjusted WYEC weather tape has been developed. An approximate energy use estimate for that building and its planned heating and cooling equipment can first be determined using the WYEC weather tape for Dayton. A second interpolation step would improve the approximate estimate. Both Columbus and Dayton have similar winter weather and similar summer weather. The recommended interpolation procedure for estimating heating requirements is primarily concerned with the variation in dry-bulb temperatures between Dayton and Columbus during the winter months. During summer months moisture content of the air is a very important factor estimates made for a city having a seasonal degree day total to the base 50 F within  $\pm$  degree days of the seasonal total at a WYEC city should be considered reliable using this interpolation procedure.

The original measurements of heating requirements using degree day values to any base are highly sensitive to thermometer exposure. If a winter heating season is assumed to last for six 30-day months, a difference of one degree will cause a seasonal total to change by 180 degree days. Thus, a seasonal difference of  $\pm$  100 degree days would be produced by a difference of only slightly more than one-half degree (0.5 F) per day. During a period of 180 days 0.5 F would produce 90 degree days.

Estimates of the amount of energy needed to cool a commercial building during summer should not rely solely on calculations that use dry-bulb temperature values. Moisture content is a major factor. On any psychrometric chart the wet-bulb values are directly comparable to enthalpy values. For northern latitude stations a representative value which can be used for comparative calculations is the median wet-bulb value for the four summer months, June through September. Such values were determined and published by Fluor Products Company<sup>6</sup> in 1958 for approximately 434 geographic locations throughout the United States, Canada and Mexico. Within the state of Ohio, summer median wet-bulb values were developed from hourly weather data at 10 airport locations. At that point in time the availability of hourly weather data in computer compatible format was quite limited. Only five of the 10 Ohio stations had 10 yrs. or more of hourly data on punched cards. However, wetbuilb temperatures are a conservative weather parameter and have a much smeller climatic range than dry-bulb temperatures.

The 50th percentile level (median) summer wet-bulb temperature values for six stations are shown in the summer map in Fig. 2 The respective summer median wet-bulb temperatures for the period June through September at the 6 cities are: Cleveland—64.4 F; Findlay—64.9 F; Mansfield—64.0 F; Akron/Canton—64.1 F; Columbus— 65.6 F; Dayton—65.2 F.

The relative positions of combined summer median wet-bulb and summer dry-bulb temperatures for Cleveland and Dayton are located very near each other on a psychrometric chart. The combined coordinates of Cleveland are 64.4 F for wet-bulb and 68.3 F for dry-bulb. For Dayton they are 65.2 F wet-bulb and 71.3 F drybulb.

The recommended interpolation ASHRAE JOURNAL October 1981



procedure for comparative energy use for cooling would require a ratio relationship involving only the median summer wet-buib. Step one would involve making calculations for energy requirements for summer cooling using a WYEC weather data tape from either Dayton or Cleveland to derive a energy use and/or cost reliable estimate. The second step would use the appropriate ratio to find an equally valid estimate for the city in which the commercial building is to be built. If you were to assume that summer cooling of a commercial building would reguire a cost of \$25,000 per year's operation in Cleveland, it would cost \$24,844 for the same building in Mansfield (\$25,000 × 64.0/64.4 = \$24,844).

The set of 21 new WYEC data tapes, plus one more at Chicago, for which reliable hourly data sets have been developed is not considered to have sufficient proximity distance for reliable interpolation procedures throughout the entire country. It is this author's opinion that with equally valid WYEC tapes for approximately 30 more stations, chosen for geographic and climatic representativeness, a high quality interpolation procedure could be developed for the entire United States.

#### **Data format**

The data format of the individual sets of 8760 h of weather data is available through the ASHRAE headquarters office. Those data will show the sequential format developed initially for the Test Reference Year (TRY) tapes by NOAA in September, 1976.<sup>7</sup> The new WYEC data tapes include the carefully adjusted solar data in field 24. Each logical hourly record (observations) is 80 bytes long. The 80-byte hourly records are blocked in groups of 24 (one day). The initial basic tape is in 9tape EBCDIC character code with odd parity. The 80th column, which was originally left blank, has now been used to indicate snow cover conditions. If the ground is covered with snow, the number 1 (one) appears. If there is no snow cover, a 0 (zero) appears. For each of the 21 cities care was taken to confirm that the ground was covered with snow when the number 1 (one) appeared. Much higher reflectivity of solar radiation would take place when the ground is snow covered.

For convenience in reading individual values for each hour, a single microfiche sheet covers the data for a full year (8760 h) for each station.

#### REFERENCES

1. SOLMET, Vol. I., User's Manual, Department of Energy Contract No. E(49-26)-1041, U.S. Department of Commerce, 1977, Asheville, NC, 44 pp.

SOLMET, Vol. II, Final Report, Department of Energy Contract No. E(49-26)-1041, U.S. Department of Commerce, 1979, Asheville, NC, 184 pp.

2. "Local Climatological Data" for 147 Selected Cities, U.S. Department of Commerce, National Climatic Center, Federal Building, Asheville, NC.

3. Randall, C.M., M.E. Whitson, Jr., "Final Report Hourly Insolation and Meteorological Data Bases Including Improved Direct Isolation Estimates", Sandla Laboratories, Albuquerque, NM, December, 1977.

4. Cinquemani, V., J.R. Owenby, Jr., R.G. Baldwin, "Input Data for Solar Systems", U.S. Department of Energy, November, 1978, 912 pp.

5. Nail, D.H., E.A. Arens, "The Influence of Degree Day Base Temperature on Residential Building Energy Prediction", ASHRAE Transactions 1979, Vol. 85, Part 1; pp. 722-735.

6. "Evaluated Weather Data for Cooling Equipment Design", Fluor Products Company, 1958.

7. The Tape Reference Manual "Test Reference Year", National Climatic Center, NOAA, Ashevilie, NC, September, 1976.

41

to be considered in estimating energy requirements for cooling.

Most commercial buildings currently being built can expect sizeable internal heating sources. It is not unusual for heating not to be required in moderate to large commercial buildings until average dally outdoor temperatures drop below 50 F. On a particular day when the minimum temperature might reach 60 F with a minimum temperature of 40 F, the dally average temperature would be 50 F. Nall and Arens<sup>5</sup> have shown that a base 65 F for determining degree day deficiency amounts is notably higher than the true threshold value for heating requirements in residential buildings. A threshold value of 56.5 F was found to be more appropriate for test houses which had good insulation in walls and ceilings.

For commercial buildings it is the author's recommendation that interpolation between locations be based on the variability found in dry-bulb temperature degree day values using the base of 50 F rather than 65 F.

The comparative degree day data have been developed primarily from the daily maximum and minimum temperatures at airport stations. Generally such stations are outside any major heat island. Heat islands generally develop over the central part of the city and extend outward toward the downslope dimensions of the city.

The degree day values to the base 50 F are as follows: Cleveland—2876; Findlay—2950; Mansfield—2679; Akron/Canton—2936; Columbus—2597; Dayton—2600. The 2597 degree day total at Columbus is almost exactly the same as the 2,600 at Dayton. Therefore, any commercial building for which energy requirements for heating are estimated during Dayton WYEC sets of weather data can be applied directly to Columbus.

The comparatively higher number of degree days to the base 50 F at Mansfield would mean somewhat higher energy requirements for heating at Mansfield than at Dayton. To illustrate the magnitude of this difference, an assumption might be made that a particular building planned for Mansfield would have a ratio of increased energy requirement proportional to the greater number of degree days to the base 50 F as compared with Dayton. If the energy requirements for heating a particular commercial building planned for Mansfield are calculated by using the WYEC weather data for Dayton giving a resultant current cost of energy value of \$25,000 per "normal" winter, the energy cost for the same building at Mansfield would be \$25,760.00 (\$25,000 × 2679/2600 = \$25,760).

Although degree day relationships to the base 50 F are recommended, there is little difference in the ratio of degree day values to the base 60 F as compared to 50 F. The relationship using degree days to the base 60 F would have been \$25,000 x 4618/4483 = \$25,753. A similar ratio relationship can be developed by using WYEC weather data at Cleveland. However, the interpolation factor would use degree day values to the base 50 F which are 2679 at Mansfield and 2876 at Cleveland. Heating costs at Mansfield would be lower than in Cleveland. If an energy current cost estimate for a commercial building planned for Mansfield turned out to be \$27,500 using the WYEC weather tape for Cleveland, the interpolated value for heating that building in Mansfield would be \$25,616 2679/2876 = \$25,616). (\$27,500 X

Generally speaking, energy

Table 2: Comparison monthly mean solar data in WYEC set and similar monthly data from "Input Data for Solar System" (SOLMET) report for two highest and two lowest stations.

		BF <sup>2</sup>				
Station	Month	WYEC*	SOLMET**	Station	WYEC *	SOLMET*
El Paso	JAN	1127	1125	New York	505	500
#23044	FEB	1506	1480	Central.	722	721
	MAR	1898	1909	Park	1038	1037
	APR	2382	2364	Weather-	1338	1364
	MAY	2650	2601	#14732	1617	1636
	JUN	2643	2683	Solar-	1710	1710
	JUL	2461	2450	#94728	1661	1688
	AUG	2261	2285		1470	1483
	SEP	1971	1987		1227	1214
	OCT	1651	1639		890	895
	NOV	1.254	1244		533	533
· · ·	DEC	1023	1031		404	404
	ANN	1902	1900		1093	1099
Las Vegas+	JAN	988	978	Seattle-	262	262
#23169	FEB	1328	1340	Tacoma	500	494
	MAR	1817	1824	#24233	848	849
	APR	2358	2319		1299	1294
	MAY	2639	2646		1704	1714
	JUN	2770	2778		1821	1802
۰.	JUL	2553	2588		2243	2248
	AUG	2341	2355		1594	1616
	SEP	2072	2037		1141	1148
<i>*</i>	OCT	1523	1540		650	656
	NOV	1083	1086		333	337
	DEC	878	881		210	211
	ANN	1863	1864		1050	1053

KJ/M<sup>2</sup>: Kilojoules/square metre

B/M<sup>2</sup>: British thermal units/sq. ft. and equals KJ/M<sup>2</sup> times 0.088114. Langleys: One langley equals one gram calorie/s . centimeter and equals KJ/M<sup>2</sup> times 0.023901.

\*Weather Year for Energy Calculations as developed by ASHRAE contract RP 239. \*\*Thput Data for Solar Systems, Nov. 1978, by V. Cinquemani, J.R. Owenby, Jr., R.G. Baldwin; a report prepared by NOAA, Environmental Data and Information Service for the Department of Energy under Inter-Agency Agreement No. #(49-26)-1041. +Mean solar data as derived according to NOAA SOLMET procedures.