

Steven A. Bluhm

5105-42
Solar Thermal Power Systems Project
Parabolic Dish Power Systems
Module Development

Average Daily and Annual Direct Normal Insolation Estimates for the United States

J. H. Smith



August 15, 1980

Prepared for
U.S. Department of Energy
Through an agreement with
National Aeronautics and Space Administration
by
Jet Propulsion Laboratory
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ABSTRACT

This document provides average direct normal insolation estimates for 232 locations in the United States. An average day value for each month is presented with the annual totals and the average daily amount on an annual basis. The estimates were generated using a modified Liu and Jordan procedure and input data compiled from the SOLMET data base. A computer simulation program was used to estimate average hourly values which were aggregated to the average day totals.

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FOREWORD

The intent of this document is to provide initial estimates of the direct normal insolation resources for a wide variety of U.S. locations. In situations where the level of accuracy requires more detailed hourly estimates, the user is referred to the SOLMET tape data base of the National Climatic Center or other hourly recorded data. However, the estimates presented here provide a reasonable first approximation for solar resource comparisons, in a relative sense, to the average daily direct normal insolation characteristics of numerous (232) U.S. locations.

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SECTION I

INTRODUCTION

The purpose of this document is to present direct normal insolation estimates for a wide variety of locations. The term "direct normal insolation" has specific meaning. Transmission through the Earth's atmosphere results in fractionation of the radiant beam into its two components--a direct beam component and a diffuse (scattered) component. The term "direct" refers to the direct component only. The term "normal" refers to the surface orientation on which the insolation falls--a surface perpendicular to the sun's rays.

Direct normal insolation estimates are of particular interest to designers of point-focusing thermal electric systems. Most of these systems track the position of the sun on two axes enabling the solar collector to maintain a perpendicular position relative to the sun's rays. The estimates presented herein provide a basis for relative comparisons of the aggregate direct normal insolation resources of numerous locations. However, the system designer should be aware that average-day estimates are not sufficient to represent the effective insolation at a site. Short-term data are required to capture random fluctuations in order to accurately model the transient behavior of the resource. The efficiency of solar thermal systems is dependent on insolation intensity. Averaging, which smooths the insolation profile, may understate energy output due to reduced calculated efficiency while overestimating energy output by including periods of low ineffective insolation. The effect of these errors is complicated by the existence of a minimum operating threshold for the system. Thus in low insolation areas, the effect of averaging is more significant since a greater portion of the insolation is below the threshold. In addition, microclimatic variations in insolation may be significantly different between the plant site and the nearest SOLMET* station. Where interpolations are made they should consider local meteorological conditions at the site and at the nearby station.

The method used here for estimating the direct normal insolation is based on an average-day model described in Reference 1. The model was originally developed for fixed surfaces, but one of the steps in the algorithm (Step 5) involves the computation of the hourly direct normal insolation. The estimates presented here do not represent the random fluctuations of the insolation process, but rather the long-term average. The approach used here is identical to that found in Reference 1.

The remainder of this document describes the model and presents input data and corresponding insolation estimates. The input data used to generate these estimates were derived from the latest available rehabilitated SOLMET data (Reference 2).

*The National Climatic Center's network for recording insolation and meteorological data.

SECTION II

THE MODEL

The approach used here was to estimate monthly, average-day insolation values. This necessitated calculation of hourly direct normal insolation values and their summation to obtain the daily estimate. Details of the procedure and the computer program that was modified to generate the estimates may be found in Reference 1. The relationship used and the definitions of the component variables are given below:

$$\bar{I}_{DN}(\omega) = (\bar{K}_T - \bar{K}_d)(H_o)(f)\exp(-B/\cos Z) \quad (\text{Equation 1})$$

where

$\bar{I}_{DN}(\omega)$ = average hourly direct normal insolation during hour ω . Time is measured in degrees (solar time) where ω is the angle between the sun's direct beam and a north-south vertical plane; the hour-angle correspondence is:

<u>solar hour</u>	<u>hour angle,</u>
10 a.m.	-30
11 a.m.	-15
12 noon	0
1 p.m.	15
2 p.m.	30
.	.
.	.
.	.

\bar{K}_T = the fraction of daily extraterrestrial radiation (H_o) that reaches the ground as total insolation ($\bar{K}_T = \bar{H}/H_o$, where \bar{H} = total insolation measured at ground level on a horizontal surface). The \bar{K}_T value is a measure of the solar climate of the location and is an input to the model (there are 12 values for each location--one for each month).

Table 2-1. Solar Declination (δ), the Ratio of Solar Radiation Intensity at Normal Incidence Outside Earth's Atmosphere to the Solar Constant (γ), and Atmospheric Absorption Coefficient (B) (Reference 5)

Month	Declination (Degrees . Minutes) δ	Ratio γ	Atmospheric Absorption Coefficient B
January	-19.51	1.0300	0.142
February	-10.28	1.0207	0.144
March	0.20	1.0057	0.156
April	11.56	0.9875	0.180
May	20.14	0.9727	0.196
June	23.27	0.9670	0.205
July	20.26	0.9692	0.207
August	12.03	0.9785	0.201
September	0.37	0.9945	0.177
October	-10.47	1.0133	0.160
November	-19.58	1.0267	0.149
December	-23.27	1.0327	0.142

Table 2-2. The Value of the m Factor (kWh/m²) (Reference 1)

LAT. DEG.	MONTH											
	1	2	3	4	5	6	7	8	9	10	11	12
0.	1.77	1.74	1.74	1.77	1.81	1.83	1.83	1.81	1.77	1.77	1.78	1.78
1.	1.77	1.74	1.74	1.77	1.80	1.83	1.83	1.81	1.77	1.77	1.78	1.78
2.	1.77	1.74	1.74	1.77	1.80	1.82	1.82	1.81	1.77	1.77	1.78	1.79
3.	1.77	1.74	1.74	1.77	1.80	1.82	1.82	1.80	1.77	1.77	1.79	1.79
4.	1.78	1.74	1.74	1.77	1.80	1.82	1.82	1.80	1.77	1.77	1.79	1.79
5.	1.78	1.75	1.74	1.77	1.79	1.81	1.82	1.80	1.77	1.77	1.79	1.80
6.	1.78	1.75	1.74	1.77	1.79	1.81	1.81	1.80	1.77	1.78	1.80	1.80
7.	1.79	1.75	1.74	1.77	1.79	1.81	1.81	1.80	1.77	1.78	1.80	1.80
8.	1.79	1.75	1.74	1.76	1.79	1.81	1.81	1.80	1.77	1.78	1.80	1.81
9.	1.79	1.75	1.74	1.76	1.79	1.80	1.81	1.80	1.77	1.78	1.81	1.81
10.	1.80	1.76	1.74	1.76	1.78	1.80	1.81	1.80	1.77	1.79	1.81	1.82
11.	1.80	1.76	1.74	1.76	1.78	1.80	1.80	1.80	1.78	1.79	1.82	1.82
12.	1.81	1.76	1.74	1.76	1.78	1.80	1.80	1.80	1.78	1.79	1.82	1.83
13.	1.81	1.76	1.75	1.76	1.78	1.80	1.80	1.80	1.78	1.80	1.83	1.83
14.	1.81	1.77	1.75	1.76	1.78	1.80	1.80	1.80	1.78	1.80	1.83	1.84
15.	1.82	1.77	1.75	1.76	1.78	1.79	1.80	1.80	1.78	1.80	1.84	1.84
16.	1.82	1.77	1.75	1.77	1.78	1.79	1.80	1.80	1.78	1.81	1.84	1.85
17.	1.83	1.78	1.75	1.77	1.78	1.79	1.80	1.80	1.79	1.81	1.85	1.86
18.	1.84	1.78	1.76	1.77	1.78	1.79	1.80	1.80	1.79	1.81	1.85	1.86
19.	1.84	1.78	1.76	1.77	1.78	1.79	1.80	1.80	1.79	1.82	1.86	1.87
20.	1.85	1.79	1.76	1.77	1.78	1.79	1.80	1.80	1.79	1.82	1.87	1.88
21.	1.86	1.79	1.76	1.77	1.78	1.79	1.80	1.81	1.80	1.83	1.87	1.89
22.	1.86	1.80	1.77	1.77	1.78	1.79	1.80	1.81	1.80	1.83	1.88	1.90
23.	1.87	1.80	1.77	1.77	1.78	1.79	1.80	1.81	1.80	1.84	1.89	1.91
24.	1.88	1.81	1.77	1.77	1.78	1.79	1.80	1.81	1.81	1.84	1.90	1.92
25.	1.89	1.81	1.78	1.78	1.78	1.79	1.80	1.81	1.81	1.85	1.91	1.93
26.	1.90	1.82	1.78	1.78	1.78	1.79	1.80	1.82	1.81	1.86	1.92	1.94
27.	1.91	1.82	1.78	1.78	1.78	1.79	1.80	1.82	1.82	1.86	1.93	1.95
28.	1.92	1.83	1.79	1.78	1.78	1.79	1.80	1.82	1.82	1.87	1.94	1.96
29.	1.93	1.84	1.79	1.79	1.79	1.79	1.81	1.82	1.83	1.88	1.95	1.98
30.	1.94	1.84	1.79	1.79	1.79	1.80	1.81	1.83	1.83	1.89	1.96	1.99
31.	1.95	1.85	1.80	1.79	1.79	1.80	1.81	1.83	1.84	1.89	1.97	2.01
32.	1.96	1.86	1.80	1.79	1.79	1.80	1.81	1.83	1.84	1.90	1.99	2.02
33.	1.98	1.87	1.81	1.80	1.79	1.80	1.81	1.84	1.85	1.91	2.00	2.04
34.	1.99	1.87	1.81	1.80	1.80	1.80	1.82	1.84	1.85	1.92	2.02	2.06
35.	2.01	1.88	1.82	1.80	1.80	1.80	1.82	1.84	1.86	1.93	2.03	2.08
36.	2.02	1.89	1.83	1.81	1.80	1.81	1.82	1.85	1.87	1.94	2.05	2.10
37.	2.04	1.90	1.83	1.81	1.80	1.81	1.83	1.85	1.87	1.95	2.07	2.12
38.	2.06	1.91	1.84	1.82	1.81	1.81	1.83	1.86	1.88	1.97	2.09	2.15
39.	2.08	1.92	1.84	1.82	1.81	1.82	1.83	1.86	1.89	1.98	2.11	2.18
40.	2.10	1.94	1.85	1.83	1.81	1.82	1.84	1.87	1.90	1.99	2.14	2.21
41.	2.13	1.95	1.86	1.83	1.82	1.82	1.84	1.87	1.91	2.01	2.16	2.24
42.	2.15	1.96	1.87	1.84	1.82	1.83	1.84	1.88	1.92	2.02	2.19	2.28
43.	2.18	1.98	1.88	1.84	1.83	1.83	1.85	1.89	1.93	2.04	2.22	2.32
44.	2.21	1.99	1.89	1.85	1.83	1.83	1.85	1.89	1.94	2.06	2.26	2.36
45.	2.25	2.01	1.89	1.85	1.83	1.84	1.86	1.90	1.95	2.08	2.29	2.41
46.	2.29	2.03	1.90	1.86	1.84	1.84	1.86	1.91	1.96	2.10	2.34	2.47
47.	2.33	2.05	1.92	1.87	1.84	1.85	1.87	1.92	1.97	2.12	2.38	2.53
48.	2.37	2.07	1.93	1.88	1.85	1.85	1.87	1.92	1.98	2.14	2.43	2.60
49.	2.43	2.09	1.94	1.88	1.86	1.86	1.88	1.93	2.00	2.17	2.49	2.68
50.	2.48	2.11	1.95	1.89	1.86	1.86	1.89	1.94	2.01	2.20	2.55	2.78

\bar{K}_d = the fraction of daily extraterrestrial radiation (H_o) that reaches the ground as diffuse (scattered) radiation. (It is assumed that most of the scattering is forward scattering). This value is interpolated from an empirical relationship originally described by Liu and Jordan (Reference 4). The following table illustrates the empirical relationship between \bar{K}_T and \bar{K}_d .

\bar{K}_T	\bar{K}_d	$(\bar{K}_T - \bar{K}_d)$
0.3	0.179	0.121
0.4	0.183	0.217
0.5	0.188	0.312
0.6	0.174	0.426
0.7	0.149	0.551
0.8	0.125	0.625

Note that the difference between the two fractions, $(\bar{K}_T - \bar{K}_d)$, is the fraction of daily extraterrestrial radiation that reaches the ground as direct radiation on a horizontal surface.

H_o = average daily extraterrestrial insolation on a horizontal surface ($\text{kWh/m}^2/\text{day}$),

$$= \frac{24}{\pi} \times I_c \times \gamma \times (\cos \phi \times \cos \delta \times \sin W_s + W_s \times \sin \phi \times \delta)$$

I_c = solar constant, 1.377 kW/m^2 ; varies by $\pm 3\%$ during the year due to Earth-sun distance variation

γ = adjustment to account for Earth-sun distance variation (see Table 2-1)

ϕ = latitude of the site (radians)*

δ = declination of the Earth--the angle between the Earth's equator and sun's equatorial plane through the Earth (see Table 2-1)

W_s = sunrise hour angle, $W_s = \cos^{-1}(-\tan \phi \times \tan \delta)$

f = adjustment to account for increased length of atmosphere that the sun beam must pass through at low sun elevation angles. The product $H_o \times f$ is a combined factor, m , which is given in Table 2-2 for latitudes from $0-50^\circ$ north.

B = effective solar extinction coefficient, averaged over the solar spectrum, that varies by time of year (see Table 2-1).

$\cos Z$ = cosine of the zenith angle, the angle between a vertical line perpendicular to the Earth's surface and the direct sun beam,

$$= \cos \phi \times \cos \delta \times \cos \omega + \sin \phi \times \sin \delta$$

*Degrees are converted to radians by multiplying by $\pi/180$. All the trigonometric functions used here require radian arguments.

The exponentiation, $\exp(-B/\cos Z)$, adjusts the insolation for the varying length of atmosphere and, with the f factor, converts the daily total to an hourly estimate.

The input data for locations used in this report are listed in Appendix A. The SOLINS program described in Reference 1 was modified to generate the values tabulated in Section III for 232 selected U.S. locations.

SECTION III
MONTHLY AND ANNUAL
AVERAGE DAILY DIRECT NORMAL INSOLATION ESTIMATES

The following data were estimated using a modified version of the SOLINS computer program (Reference 1) and the latest available input data derived from the SOLMET network (Reference 2).

The tables present the location (city and state); the average daily direct normal insolation for each month of the year; the annual total which is the weighted sum based on the number of days in each month, e.g., Tucson, Arizona:

$$5.26 \times 31 + 6.07 \times 28 + \dots + 5.32 \times 31 = 2709.6;$$

and the average daily amount, e.g., $2709.6/365 = 7.42$. It should be noted that microclimate variations are not considered in these estimates. (Most of the input data are from the local airport).

The locations are in alphabetical order by state and then city within state.

PFTEA PROJECT--AVERAGE DAILY AND ANNUAL DIRECT NORMAL INSOLATION ESTIMATES (KWH/SQ. M)

SITE		AVERAGE DAILY AMOUNTS BY MONTH												ANNUAL AMOUNT	AVERAGE DAY
		J	F	M	A	M	J	J	A	S	O	N	D		
ADAK	AK	1.18	1.67	2.30	2.83	2.81	2.54	2.51	2.38	2.55	2.54	2.15	1.34	815.9	2.24
JUNEAU	AK	1.17	1.77	2.27	3.41	3.69	3.96	3.60	3.02	2.44	1.64	1.36	0.80	886.2	2.43
KING SALMON	AK	1.37	2.26	3.75	4.38	4.72	4.61	4.16	3.41	3.53	3.38	2.45	1.30	1197.1	3.28
KODIAK	AK	1.20	1.85	3.47	4.30	4.09	4.50	4.23	4.02	3.51	3.32	2.22	1.14	1153.1	3.16
NOME	AK	0.37	1.55	3.41	5.03	5.77	6.19	4.81	3.71	3.70	2.83	1.37	0.0	1180.0	3.23
BIRMINGHAM	AL	2.69	3.29	3.98	4.93	5.31	5.43	5.06	5.19	4.77	4.79	3.72	2.90	1585.6	4.34
MOBILE	AL	3.12	3.77	4.32	5.04	5.37	5.19	4.62	4.63	4.50	5.00	3.94	3.17	1602.4	4.39
MONTGOMERY	AL	2.83	3.44	4.11	5.17	5.51	5.70	5.20	5.24	4.74	4.96	3.91	3.12	1642.1	4.50
FORT SMITH	AR	3.19	3.65	4.18	4.74	5.64	6.29	6.39	6.10	5.22	4.99	3.99	3.33	1757.9	4.82
LITTLE ROCK	AR	3.02	3.61	4.14	4.69	5.70	6.36	6.22	5.97	5.25	5.10	3.83	3.17	1737.9	4.76
PHOENIX	AZ	4.95	5.88	6.96	8.79	9.92	9.96	8.66	8.35	8.27	7.43	6.08	5.08	2749.4	7.53
PRESCOTT	AZ	5.19	5.79	6.88	8.39	9.63	10.10	7.70	7.27	8.01	7.42	6.32	5.37	2680.0	7.34
TUCSON	AZ	5.26	6.07	7.11	8.73	9.85	9.89	7.82	7.61	7.80	7.36	6.22	5.32	2709.6	7.42
WINSLOW	AZ	5.01	5.80	6.96	8.46	9.43	9.78	7.93	7.59	7.86	7.26	6.25	5.16	2661.6	7.29
YUMA	AZ	5.37	6.25	7.53	9.11	10.17	10.32	8.45	8.53	8.40	7.66	6.43	5.51	2852.1	7.81
ARCATA	CA	2.41	2.98	3.73	4.91	5.44	5.81	5.22	4.86	4.87	3.92	2.96	2.49	1510.3	4.14
BAKERSFIELD	CA	3.36	4.27	5.81	7.38	8.87	10.04	10.00	9.41	8.43	6.91	4.77	3.32	2516.4	6.89
CHINA LAKE	CA	4.53	5.22	6.74	8.22	9.14	10.03	9.54	10.39	8.38	7.08	5.65	4.82	2734.1	7.49
DAGGETT	CA	4.75	5.44	6.88	8.40	9.40	10.13	9.44	9.10	8.45	7.25	5.89	4.94	2743.0	7.52
EL TORO	CA	4.40	4.96	5.72	6.31	6.41	6.80	7.99	7.55	6.46	5.82	5.07	4.59	2195.0	6.01
FRESNO	CA	2.79	3.88	5.79	7.49	8.77	9.96	10.05	9.58	8.61	6.97	4.62	2.72	2475.9	6.78
LONG BEACH	CA	4.28	4.84	5.74	6.36	6.38	6.53	7.63	7.25	6.24	5.63	4.91	4.42	2137.9	5.86
LOS ANGELES	CA	4.29	4.85	5.80	6.43	6.36	6.44	7.68	7.14	6.14	5.58	4.95	4.47	2135.6	5.85

PFTEA PROJECT--AVERAGE DAILY AND ANNUAL DIRECT NORMAL INSOLATION ESTIMATES (KWH/SQ. M)

SITE		AVERAGE DAILY AMOUNTS BY MONTH												ANNUAL AMOUNT	AVERAGE DAY
		J	F	M	A	M	J	J	A	S	O	N	D		
MOUNT SHASTA	CA	2.73	3.44	4.38	5.90	7.28	8.37	9.58	8.63	7.56	5.68	3.56	2.86	2133.8	5.85
NEEDLES	CA	4.95	5.96	7.21	8.66	9.80	10.25	9.03	8.36	8.47	7.39	6.21	5.27	2787.3	7.64
OAKLAND	CA	3.30	4.03	5.25	6.54	7.27	7.73	7.86	7.28	6.76	5.45	4.27	3.48	2108.2	5.78
POINT MUGU	CA	4.33	4.91	5.92	6.45	6.15	6.11	6.64	6.32	5.72	5.46	5.00	4.57	2057.4	5.64
RED BLUFF	CA	2.63	3.52	4.89	6.67	8.30	9.24	10.13	9.20	8.17	6.05	3.74	2.72	2295.1	6.29
SACRAMENTO	CA	2.59	3.64	5.34	7.09	8.56	9.70	10.15	9.40	8.35	6.41	4.08	2.69	2378.4	6.52
SAN DIEGO	CA	4.44	5.03	5.76	6.29	6.05	6.15	6.97	6.93	6.23	5.78	5.15	4.66	2113.7	5.79
SAN FRANCISCO	CA	3.28	3.97	5.23	6.52	7.35	7.87	8.26	7.66	7.01	5.53	4.23	3.42	2142.6	5.87
SANTA MARIA	CA	3.90	4.47	5.68	6.35	6.79	7.66	7.88	7.37	6.56	6.02	4.91	4.29	2189.1	6.00
SUNNYVALE	CA	3.47	4.11	5.38	6.64	7.63	8.29	8.52	7.95	7.10	5.66	4.37	3.52	2213.2	6.06
COLORADO SPRINGS	CO	5.12	5.36	5.95	6.69	6.84	7.87	7.28	7.23	7.31	6.84	5.71	5.10	2352.2	6.44
DENVER	CO	4.89	5.13	5.96	6.47	6.90	7.82	7.65	7.42	7.23	6.57	5.37	4.82	2320.9	6.36
EAGLE	CO	4.06	4.74	5.76	6.76	7.59	8.69	8.30	7.65	7.50	6.61	5.18	4.36	2350.9	6.44
GRAND JUNCTION	CO	4.28	4.96	6.01	7.04	8.27	9.18	8.73	8.20	7.88	6.79	5.53	4.64	2482.4	6.80
PUEBLO	CO	5.02	5.21	5.97	6.79	7.00	8.21	7.81	7.64	7.36	6.73	5.64	4.95	2385.0	6.53
HARTFORD	CT	2.12	2.58	2.97	3.69	4.21	4.55	4.54	4.18	3.89	3.51	2.31	1.84	1230.0	3.37
GUANTANAMO BAY	CU	5.49	5.84	6.34	6.73	6.17	5.79	6.39	6.09	5.79	5.49	5.68	5.38	2164.6	5.93
WASHINGTON--STERLINDC		2.46	2.91	3.51	4.21	4.79	5.42	5.22	4.92	4.62	4.12	3.08	2.28	1447.4	3.97
WILMINGTON	DE	2.56	3.06	3.70	4.34	4.77	5.35	5.27	4.97	4.57	4.07	3.15	2.45	1469.1	4.02
APALACHICOLA	FL	3.17	3.83	4.57	5.83	6.45	5.83	5.04	4.82	4.91	5.34	4.41	3.42	1753.3	4.80
DAYTONA BEACH	FL	3.75	4.24	4.95	5.82	5.82	4.98	4.89	4.76	4.53	4.51	4.29	3.68	1710.9	4.69
JACKSONVILLE	FL	3.54	4.10	4.90	5.74	5.78	5.26	4.99	4.88	4.44	4.48	4.21	3.53	1699.5	4.66
MIAMI	FL	3.97	4.48	4.99	5.55	5.19	4.50	4.78	4.43	4.23	4.44	4.39	4.18	1677.2	4.60
ORLANDO	FL	3.92	4.35	5.09	5.88	5.93	5.02	4.97	4.70	4.60	4.77	4.62	3.96	1758.6	4.82

PFTEA PROJECT--AVERAGE DAILY AND ANNUAL DIRECT NORMAL INSOLATION ESTIMATES (KWH/SQ. M)

SITE		AVERAGE DAILY AMOUNTS BY MONTH												ANNUAL AMOUNT	AVERAGE DAY
		J	F	M	A	M	J	J	A	S	O	N	D		
TALLAHASSEE	FL	3.39	3.95	4.65	5.56	5.69	5.26	4.75	4.78	4.71	5.09	4.29	3.49	1691.8	4.64
TAMPA	FL	3.92	4.37	5.11	5.90	5.97	5.10	4.75	4.59	4.53	4.95	4.61	3.93	1756.5	4.81
WEST PALM BEACH	FL	3.73	4.12	4.81	5.36	5.19	4.49	4.86	4.58	4.10	4.09	4.10	3.88	1622.6	4.45
ATLANTA	GA	2.77	3.32	4.02	5.00	5.32	5.40	5.08	5.10	4.59	4.73	3.91	3.00	1590.7	4.36
AUGUSTA	GA	2.96	3.55	4.17	5.23	5.37	5.36	5.02	4.87	4.49	4.83	4.13	3.31	1622.0	4.44
MACON	GA	2.99	3.51	4.24	5.23	5.44	5.43	4.93	5.11	4.61	4.92	4.18	3.25	1639.3	4.49
SAVANNAH	GA	3.09	3.59	4.37	5.33	5.29	5.06	4.92	4.60	4.17	4.64	4.08	3.35	1597.6	4.38
BARBERS POINT	HI	4.39	4.77	4.93	5.30	5.83	6.06	6.05	5.96	5.82	5.47	5.00	4.57	1952.6	5.35
HILO	HI	3.75	3.66	3.50	3.51	3.93	4.37	4.21	4.15	4.36	4.28	3.67	3.51	1426.9	3.91
HONOLULU	HI	4.22	4.51	4.82	5.12	5.73	5.98	5.97	5.95	5.80	5.39	4.78	4.35	1905.5	5.22
LIHUE	HI	3.87	4.09	4.15	4.40	5.10	5.28	5.27	5.22	5.47	4.91	4.14	3.92	1698.9	4.65
BURLINGTON	IA	2.80	3.38	3.88	4.67	5.60	6.60	6.68	6.24	5.33	4.84	3.50	2.56	1708.1	4.68
DES MOINES	IA	2.93	3.49	4.03	4.81	5.59	6.66	6.76	6.30	5.54	5.03	3.60	2.74	1750.4	4.80
MASON CITY	IA	2.98	3.53	4.12	4.73	5.81	6.68	6.78	6.47	5.56	4.88	3.40	2.60	1752.8	4.80
SIoux CITY	IA	2.98	3.46	4.05	4.96	5.81	6.70	6.94	6.46	5.56	4.95	3.64	2.72	1774.3	4.86
BOISE	ID	2.44	3.60	5.01	6.50	7.96	8.67	10.00	8.82	8.02	6.05	3.76	2.60	2239.3	6.14
LEWISTON	ID	1.51	2.34	3.60	4.54	5.73	6.33	8.50	7.44	6.29	4.26	2.25	1.53	1657.4	4.54
POCATELLO	ID	2.81	3.80	5.36	6.42	7.93	8.73	9.86	9.04	8.15	6.48	4.24	2.88	2307.7	6.32
CHICAGO	IL	2.35	2.85	3.66	4.37	5.18	6.07	5.98	5.70	5.05	4.31	2.87	1.98	1534.5	4.20
MOLINE	IL	2.54	3.16	3.69	4.35	5.01	5.86	5.93	5.65	5.03	4.45	3.05	2.22	1551.3	4.25
SPRINGFIELD	IL	2.69	3.29	3.68	4.51	5.51	6.44	6.48	6.03	5.44	4.74	3.44	2.49	1666.9	4.57
EVANSVILLE	IN	2.35	2.87	3.57	4.35	5.03	5.80	5.72	5.52	4.92	4.59	3.18	2.29	1528.9	4.19
FORT WAYNE	IN	1.81	2.37	2.92	3.85	4.64	5.19	5.11	4.93	4.44	3.85	2.33	1.57	1310.0	3.59
INDIANAPOLIS	IN	1.97	2.55	3.12	3.97	4.68	5.28	5.18	5.12	4.62	4.04	2.65	1.82	1370.1	3.75

PFTEA PROJECT--AVERAGE DAILY AND ANNUAL DIRECT NORMAL INSOLATION ESTIMATES (KWH/SQ. M)

SITE		AVERAGE DAILY AMOUNTS BY MONTH												ANNUAL AMOUNT	AVERAGE DAY
		J	F	M	A	M	J	J	A	S	O	N	D		
SOUTH BEND	IN	1.57	2.18	3.03	4.02	4.88	5.62	5.49	5.40	4.63	3.84	2.28	1.39	1351.2	3.70
DODGE CITY	KS	4.28	4.77	5.38	6.34	6.61	7.77	7.72	7.30	6.67	6.15	4.91	4.29	2198.4	6.02
GOODLAND	KS	4.33	4.53	5.24	6.16	6.52	7.82	7.91	7.39	6.59	6.22	4.98	4.33	2192.9	6.01
TOPEKA	KS	3.32	3.70	4.21	5.10	5.75	6.58	6.83	6.54	5.74	5.19	4.12	3.18	1835.1	5.03
WICHITA	KS	3.88	4.29	4.92	5.77	6.33	7.25	7.39	7.16	6.18	5.72	4.68	3.85	2053.1	5.63
LEXINGTON	KY	2.13	2.60	3.31	4.25	4.88	5.37	5.36	5.24	4.66	4.28	2.99	2.17	1439.1	3.94
LOUISVILLE	KY	2.15	2.67	3.34	4.20	4.77	5.41	5.29	5.22	4.67	4.27	2.98	2.21	1437.8	3.94
BATON ROUGE	LA	2.84	3.51	4.18	4.83	5.35	5.48	4.74	4.80	4.56	4.99	3.68	2.99	1581.3	4.33
LAKE CHARLES	LA	2.44	3.23	3.83	4.32	5.25	5.69	4.91	4.68	4.64	5.45	3.61	2.72	1546.0	4.24
NEW ORLEANS	LA	3.08	3.77	4.30	5.33	5.84	5.87	5.05	4.98	4.81	5.14	3.94	3.20	1683.4	4.61
SHREVEPORT	LA	2.92	3.60	4.12	4.60	5.46	6.16	6.07	5.93	5.24	5.27	4.05	3.24	1725.4	4.73
BOSTON	MA	2.17	2.59	3.22	3.76	4.45	5.13	5.01	4.51	4.51	3.80	2.42	2.08	1329.5	3.64
BALTIMORE	MD	2.61	3.10	3.72	4.35	4.76	5.31	5.24	4.85	4.59	4.10	3.20	2.46	1470.2	4.03
PATUXENT RIVER	MD	2.64	3.14	3.75	4.53	4.96	5.35	5.18	4.95	4.66	4.14	3.40	2.65	1502.5	4.12
BANGOR	ME	2.37	2.98	3.87	4.46	5.05	5.40	5.69	5.34	4.80	3.80	2.53	2.24	1478.1	4.05
CARIBOU	ME	2.37	3.23	4.32	4.47	4.48	5.05	5.29	4.88	4.09	3.02	1.86	1.89	1368.9	3.75
PORTLAND	ME	2.14	2.54	3.06	3.72	4.27	4.72	4.66	4.46	4.08	3.52	2.24	1.88	1258.1	3.45
ALPENA	MI	1.55	2.24	3.53	4.31	5.03	5.53	5.84	5.20	4.21	3.17	1.74	1.69	1342.6	3.68
DETROIT	MI	1.68	2.39	3.12	4.12	4.88	5.36	5.44	4.93	4.48	3.72	2.21	1.52	1336.4	3.66
FLINT	MI	1.45	2.16	2.93	3.85	4.64	5.13	5.26	4.87	4.21	3.48	1.87	1.82	1271.0	3.48
GRAND RAPIDS	MI	1.94	2.22	3.24	4.20	5.09	5.85	5.87	5.54	4.59	3.66	2.00	1.83	1403.8	3.85
HOUGHTON	MI	1.22	1.52	3.18	4.25	4.86	5.41	5.73	5.02	3.60	2.94	1.72	1.09	1236.8	3.39
SAULT STE. MARIE	MI	1.37	2.32	3.67	4.29	4.95	5.27	5.66	4.95	3.75	2.86	1.46	1.71	1288.1	3.53
TRAVERSE CITY	MI	1.61	1.86	3.34	4.28	5.05	5.69	5.96	5.32	4.22	3.20	1.64	1.50	1332.5	3.65

PFTEA PROJECT--AVERAGE DAILY AND ANNUAL DIRECT NORMAL INSOLATION ESTIMATES (KWH/SQ. M)

SITE		AVERAGE DAILY AMOUNTS BY MONTH												ANNUAL AMOUNT	AVERAGE DAY
		J	F	M	A	M	J	J	A	S	O	N	D		
DULUTH	MN	2.05	2.87	3.74	4.26	4.77	5.08	5.79	5.14	4.05	3.29	2.00	1.68	1362.6	3.73
INTERNATIONAL FALL	MN	2.01	3.03	4.00	4.75	5.21	5.55	6.28	5.73	4.41	3.40	1.92	1.79	1465.3	4.01
MINNEAPOLIS-ST.PAUM	MN	2.47	3.25	3.94	4.48	5.09	5.78	6.29	5.79	4.81	3.97	2.63	1.99	1537.4	4.21
ROCHESTER	MN	2.43	3.06	3.72	4.26	4.86	5.60	5.91	5.56	4.65	3.88	2.60	2.00	1478.2	4.05
COLUMBIA	MO	2.75	3.27	3.79	4.51	5.56	6.38	6.75	6.36	5.29	4.82	3.47	2.61	1692.0	4.64
KANSAS CITY	MO	3.11	3.44	3.95	4.77	5.53	6.34	6.69	6.30	5.37	4.83	3.84	3.03	1742.3	4.77
SPRINGFIELD	MO	3.05	3.42	3.94	4.79	5.53	6.26	6.44	6.21	5.29	4.87	3.74	3.02	1722.6	4.72
ST. LOUIS	MO	2.86	3.33	3.91	4.69	5.50	6.39	6.40	6.01	5.34	4.79	3.57	2.66	1688.9	4.63
JACKSON	MS	2.84	3.51	4.24	5.05	5.73	5.96	5.55	5.41	4.96	5.04	3.82	3.05	1679.6	4.60
MERIDIAN	MS	2.78	3.44	4.05	4.81	5.31	5.65	5.11	5.20	4.66	4.95	3.78	3.00	1605.4	4.40
BILLINGS	MT	2.83	3.37	4.54	4.95	6.07	7.16	8.74	7.96	6.46	5.23	3.59	2.88	1944.7	5.33
CUT BANK	MT	2.50	3.23	4.51	4.97	6.12	6.61	8.42	7.49	6.07	4.87	3.36	2.57	1852.1	5.07
DILLON	MT	3.11	3.88	5.08	5.57	6.46	6.95	8.75	7.89	6.72	5.44	3.90	3.06	2035.9	5.58
GLASGOW	MT	2.29	3.05	4.32	4.95	5.77	6.59	7.82	7.23	5.92	4.83	3.24	2.48	1782.7	4.88
GREAT FALLS	MT	2.48	3.30	4.65	4.89	5.84	6.86	8.57	7.59	6.08	5.07	3.27	2.32	1857.4	5.09
HELENA	MT	2.32	3.09	4.36	4.82	5.84	6.48	8.51	7.45	6.17	4.89	3.33	2.44	1820.7	4.99
LEWISTOWN	MT	2.40	3.03	4.32	4.64	5.58	6.60	8.28	7.32	5.94	4.81	3.23	2.52	1790.0	4.90
MILES CITY	MT	2.66	3.33	4.59	5.09	6.02	7.03	8.25	7.74	6.36	5.15	3.64	2.78	1909.8	5.23
MISSOULA	MT	1.31	2.15	3.44	4.32	5.44	5.91	8.51	7.18	5.82	3.96	2.30	1.41	1579.5	4.33
ASHEVILLE	NC	3.05	3.50	4.17	5.01	5.09	5.12	4.93	4.77	4.40	4.62	4.00	3.16	1577.2	4.32
CAPE HATTERAS	NC	2.77	3.36	4.25	5.57	5.90	6.03	5.66	5.18	5.02	4.53	4.16	3.14	1692.2	4.64
CHARLOTTE	NC	3.00	3.48	4.20	5.15	5.35	5.45	5.20	5.13	4.70	4.78	4.09	3.24	1636.5	4.48
CHERRY POINT	NC	3.22	3.76	4.53	5.66	5.69	5.54	5.18	4.77	4.73	4.71	4.36	3.54	1694.4	4.64
GREENSBORO	NC	3.10	3.55	4.25	5.12	5.42	5.62	5.38	5.18	4.79	4.68	4.05	3.27	1656.7	4.54

PFTEA PROJECT--AVERAGE DAILY AND ANNUAL DIRECT NORMAL INSOLATION ESTIMATES (KWH/SQ. M)

SITE		AVERAGE DAILY AMOUNTS BY MONTH												ANNUAL AMOUNT	AVERAGE DAY
		J	F	M	A	M	J	J	A	S	O	N	D		
RALEIGH-DURHAM	NC	2.92	3.38	4.04	4.91	5.12	5.17	4.94	4.71	4.53	4.40	3.77	3.06	1550.6	4.25
BISMARCK	ND	2.82	3.60	4.52	4.69	5.79	6.58	7.63	7.14	5.77	4.76	3.23	2.57	1800.9	4.93
FARGO	ND	2.33	3.12	4.12	4.78	5.71	6.23	7.25	6.80	5.45	4.49	2.77	2.20	1684.0	4.61
MINOT	ND	2.25	2.94	3.96	4.81	5.89	6.21	7.25	6.81	5.47	4.59	2.83	2.19	1683.5	4.61
GRAND ISLAND	NE	3.49	3.79	4.43	5.52	6.12	7.25	7.39	6.90	5.94	5.47	4.25	3.39	1948.1	5.34
NORTH OMAHA	NE	3.35	3.66	4.25	4.81	5.60	6.65	6.81	6.46	5.12	4.86	3.44	2.93	1765.1	4.84
NORTH PLATTE	NE	3.80	4.07	4.87	5.70	6.20	7.41	7.76	7.22	6.34	5.83	4.50	3.81	2056.8	5.64
SCOTTSBLUFF	NE	3.81	4.13	4.80	5.44	5.96	7.26	7.84	7.37	6.69	5.72	4.32	3.66	2041.0	5.59
CONCORD	NH	2.16	2.51	3.05	3.76	4.32	4.67	4.70	4.40	3.93	3.43	2.20	1.81	1247.4	3.42
LAKEHURST	NJ	2.53	2.90	3.51	4.25	4.60	4.88	4.72	4.58	4.28	3.93	3.03	2.39	1388.4	3.80
NEWARK	NJ	2.56	2.95	3.56	4.25	4.70	4.98	5.00	4.76	4.41	3.98	2.93	2.30	1412.4	3.87
ALBUQUERQUE	NM	5.28	5.91	6.87	8.15	9.05	9.56	8.71	8.47	8.20	7.56	6.38	5.50	2728.8	7.48
CLAYTON	NM	5.15	5.41	6.30	7.13	7.28	8.06	7.60	7.44	7.25	6.93	5.82	5.23	2423.4	6.64
FARMINGTON	NM	5.08	5.76	6.61	7.72	8.59	9.52	8.70	8.39	8.21	7.36	6.08	5.07	2651.0	7.26
ROSWELL	NM	5.13	5.86	6.91	7.95	8.53	9.12	8.40	8.04	7.54	7.04	5.90	5.26	2608.3	7.15
TRUTH OR CONSEQUEN	NM	5.71	6.42	7.40	8.65	9.13	9.38	7.98	7.89	7.69	7.40	6.60	5.70	2736.0	7.50
TUCUMCARI	NM	5.25	5.60	6.52	7.39	7.78	8.40	7.93	7.74	7.25	6.75	5.86	5.36	2491.2	6.83
ZUNI	NM	5.03	5.59	6.36	7.78	8.66	9.06	7.47	7.22	7.66	7.14	5.99	5.17	2529.9	6.93
ELKO	NV	3.71	4.61	5.68	6.67	7.92	8.89	9.85	9.31	8.71	7.00	4.94	3.87	2472.4	6.77
ELY	NV	4.59	5.16	6.40	7.21	7.89	8.71	8.64	8.51	8.72	7.37	5.65	4.59	2540.5	6.96
LAS VEGAS	NV	5.20	6.08	7.39	8.81	9.80	10.23	9.38	9.02	8.89	7.77	6.24	5.33	2865.8	7.85
LOVELOCK	NV	4.64	5.48	6.86	8.24	9.38	10.23	10.67	10.19	9.39	8.03	5.94	4.71	2856.3	7.83
RENO	NV	4.46	5.26	6.72	8.13	9.14	9.87	10.21	9.75	9.14	7.67	5.59	4.47	2753.7	7.54
TONOPAH	NV	5.18	5.96	7.38	8.55	9.43	10.35	10.20	9.77	9.19	8.11	6.34	5.36	2918.1	7.99

PFTEA PROJECT--AVERAGE DAILY AND ANNUAL DIRECT NORMAL INSOLATION ESTIMATES (KWH/SQ. M)

SITE		AVERAGE DAILY AMOUNTS BY MONTH												ANNUAL AMOUNT	AVERAGE DAY
		J	F	M	A	M	J	J	A	S	O	N	D		
WINNEMUCCA	NV	3.73	4.57	5.74	7.10	8.27	9.11	10.24	9.56	8.84	7.01	4.93	3.90	2529.3	6.93
YUCCA FLATS	NV	5.21	5.73	7.11	8.43	9.37	9.97	9.84	9.32	8.92	7.76	6.09	5.31	2834.1	7.76
ALBANY	NY	2.06	2.48	3.08	3.82	4.24	4.77	4.91	4.59	4.05	3.37	2.08	1.68	1253.1	3.43
BINGHAMTON	NY	2.01	1.68	2.35	3.35	3.90	4.54	4.60	4.19	3.79	3.06	1.64	1.62	1119.6	3.07
BUFFALO	NY	1.75	2.24	2.56	3.75	4.37	5.10	5.15	4.66	3.97	3.17	1.64	1.56	1216.2	3.33
MASSENA	NY	1.79	2.26	3.23	3.99	4.55	5.06	5.13	4.66	4.01	3.10	1.78	1.38	1247.0	3.42
CENTRAL PARK	NY	2.15	2.50	3.20	3.86	4.48	4.62	4.67	4.40	4.10	3.64	2.43	1.85	1276.0	3.50
LA GUARDIA	NY	2.53	2.97	3.62	4.29	4.71	5.02	5.09	4.86	4.46	3.99	2.92	2.34	1425.2	3.90
ROCHESTER	NY	1.92	1.65	2.65	3.87	4.43	5.16	5.18	4.71	4.03	3.18	1.67	1.56	1220.0	3.34
SYRACUSE	NY	1.49	1.73	2.57	3.79	4.30	4.99	5.08	4.63	4.07	3.16	1.63	1.60	1190.5	3.26
AKRON-CANTON	OH	1.57	2.04	2.81	3.83	4.62	5.18	5.11	4.95	4.42	3.73	2.22	1.40	1277.0	3.50
CINCINNATI	OH	1.92	2.44	3.01	3.93	4.59	5.11	4.99	5.03	4.46	4.03	2.62	1.87	1340.3	3.67
CLEVELAND	OH	1.93	1.77	2.61	3.82	4.70	5.22	5.35	4.90	4.30	3.54	1.97	1.72	1276.3	3.50
COLUMBUS	OH	1.71	2.13	2.82	3.76	4.49	5.04	4.95	5.13	4.38	3.87	2.36	1.60	1287.8	3.53
DAYTON	OH	1.94	2.44	3.06	4.00	4.73	5.30	5.20	5.14	4.59	4.00	2.55	1.76	1362.3	3.73
TOLEDO	OH	1.72	2.31	3.04	3.99	4.86	5.39	5.47	5.10	4.52	3.84	2.27	1.52	1341.5	3.68
YOUNGSTOWN	OH	1.89	1.66	2.43	3.47	4.27	4.84	4.90	4.52	4.04	3.42	1.88	1.68	1190.4	3.26
OKLAHOMA CITY	OK	3.60	3.99	4.66	5.31	5.66	6.57	6.72	6.51	5.54	5.23	4.43	3.68	1884.7	5.16
TULSA	OK	3.23	3.62	4.22	4.73	5.20	5.96	6.23	6.10	5.13	4.85	3.97	3.30	1722.2	4.72
ASTORIA	OR	1.82	1.85	2.69	3.63	4.57	4.42	5.19	4.81	4.50	3.11	1.96	1.21	1212.2	3.32
BURNS	OR	2.48	3.29	4.27	5.47	6.69	7.61	8.98	8.07	7.14	5.22	3.42	2.54	1987.0	5.44
MEDFORD	OR	1.58	2.78	3.85	5.32	6.50	7.52	8.97	8.16	6.70	4.50	2.43	1.45	1822.8	4.99
NORTH BEND	OR	2.01	2.67	3.53	4.70	5.63	6.07	6.93	6.23	5.41	3.98	2.79	2.02	1584.3	4.34
PENDLETON	OR	1.50	2.29	3.67	4.82	6.13	6.99	8.79	7.76	6.67	4.53	2.37	1.49	1739.9	4.77

PFTEA PROJECT--AVERAGE DAILY AND ANNUAL DIRECT NORMAL INSOLATION ESTIMATES (KWH/SQ. M)

SITE		AVERAGE DAILY AMOUNTS BY MONTH												ANNUAL AMOUNT	AVERAGE DAY
		J	F	M	A	M	J	J	A	S	O	N	D		
PORTLAND	OR	1.71	1.86	2.81	3.86	4.79	5.07	6.70	5.77	4.65	3.10	1.87	1.65	1338.1	3.67
REDMOND	OR	2.61	3.26	4.36	5.73	6.87	7.70	8.98	8.06	7.01	5.01	3.35	2.61	1998.6	5.48
SALEM	OR	1.84	2.03	3.05	4.13	5.11	5.38	7.23	6.29	5.31	3.32	1.99	1.75	1447.2	3.96
ALLENTOWN	PA	2.36	2.76	3.40	4.07	4.48	4.90	5.01	4.68	4.22	3.82	2.70	2.08	1354.6	3.71
ERIE	PA	1.63	1.68	2.65	3.90	4.56	5.25	5.41	4.34	4.15	3.36	1.64	1.41	1219.1	3.34
HARRISBURG	PA	2.35	2.76	3.39	4.05	4.53	5.01	4.99	4.67	4.33	3.82	2.72	2.17	1364.2	3.74
PHILADELPHIA	PA	2.46	2.88	3.50	4.13	4.55	5.02	4.96	4.77	4.37	3.93	2.99	2.32	1397.4	3.83
PITTSBURGH	PA	1.49	1.85	2.67	3.62	4.32	4.83	4.68	4.50	4.05	3.61	2.16	1.89	1209.3	3.31
WILKES-BARRE-SCRANPA		1.86	2.34	2.99	3.76	4.29	4.85	4.95	4.57	4.07	3.72	2.16	1.60	1253.8	3.43
KOROR ISLAND	PN	4.14	4.40	4.39	4.59	4.18	3.80	3.68	3.73	3.97	4.20	4.39	4.10	1507.0	4.13
KWAJALEIN ISLAND	PN	5.20	5.48	5.23	4.80	4.40	4.40	4.32	4.55	4.35	4.34	4.54	4.81	1714.2	4.70
WAKE ISLAND	PN	5.05	5.34	5.70	5.86	6.26	6.22	5.61	5.43	5.31	5.35	5.62	5.27	2038.9	5.59
SAN JUAN	PR	4.79	5.05	5.53	5.52	5.08	5.11	5.37	5.27	4.94	4.96	5.07	4.66	1866.3	5.11
PROVIDENCE	RI	2.34	2.70	3.25	3.96	4.60	4.93	4.74	4.51	4.16	3.83	2.62	2.13	1333.0	3.65
CHARLESTON	SC	2.85	3.39	4.13	5.22	5.32	5.05	5.00	4.47	4.38	4.58	4.18	3.23	1576.6	4.32
COLUMBIA	SC	3.11	3.64	4.29	5.34	5.52	5.57	5.23	5.09	4.72	4.86	4.28	3.41	1676.0	4.59
GREENVILLE-SPARTANSC		3.02	3.51	4.24	5.14	5.25	5.42	5.20	5.12	4.60	4.77	4.15	3.17	1632.0	4.47
HURON	SD	2.60	3.06	3.94	4.87	5.76	6.69	7.44	6.95	5.83	4.95	3.42	2.43	1766.0	4.84
PIERRE	SD	2.98	3.41	4.47	5.34	6.26	7.18	7.98	7.60	6.39	5.47	3.91	2.81	1944.6	5.33
RAPID CITY	SD	3.04	3.58	4.57	5.17	5.83	6.83	7.63	7.35	6.48	5.50	4.08	3.08	1923.9	5.27
SIOUX FALLS	SD	2.86	3.35	4.08	4.87	5.83	6.63	7.17	6.57	5.66	4.92	3.54	2.64	1770.8	4.85
CHATTANOOGA	TN	2.36	2.80	3.48	4.43	4.75	5.01	4.76	4.76	4.25	4.30	3.36	2.51	1424.3	3.90
KNOXVILLE	TN	2.39	2.91	3.62	4.69	5.08	5.35	5.07	5.00	4.57	4.49	3.39	2.53	1494.9	4.10
MEMPHIS	TN	2.73	3.30	3.99	4.83	5.49	6.06	5.91	5.80	5.01	4.96	3.67	2.88	1664.3	4.56

PFTEA PROJECT--AVERAGE DAILY AND ANNUAL DIRECT NORMAL INSOLATION ESTIMATES (KWH/SQ. M)

SITE		AVERAGE DAILY AMOUNTS BY MONTH												ANNUAL AMOUNT	AVERAGE DAY
		J	F	M	A	M	J	J	A	S	O	N	D		
NASHVILLE	TN	2.13	2.69	3.33	4.46	5.20	5.66	5.53	5.40	4.68	4.50	3.10	2.19	1488.8	4.08
ABILENE	TX	3.97	4.43	5.39	5.77	6.22	6.88	6.71	6.34	5.48	5.34	4.65	4.26	1993.2	5.46
AMARILLO	TX	4.85	5.25	6.01	6.93	7.19	7.89	7.55	7.38	6.81	6.45	5.51	4.99	2338.4	6.41
AUSTIN	TX	3.30	3.87	4.40	4.48	5.16	6.20	6.51	6.10	5.34	5.17	4.10	3.56	1772.2	4.86
BROWNSVILLE	TX	3.15	3.56	4.27	4.95	5.60	6.45	7.05	6.39	5.48	5.29	3.97	3.20	1808.8	4.96
CORPUS CHRISTI	TX	3.23	3.76	4.24	4.57	5.31	6.32	6.91	6.29	5.58	5.38	4.13	3.31	1797.7	4.93
DALLAS	TX	3.36	3.81	4.53	4.68	5.47	6.50	6.63	6.34	5.47	5.15	4.18	3.65	1820.3	4.99
DEL RIO	TX	3.77	4.23	5.14	4.88	5.12	5.96	6.25	6.08	5.15	5.22	4.48	3.94	1834.0	5.02
EL PASO	TX	5.41	6.37	7.37	8.70	9.37	9.59	8.43	8.17	7.80	7.59	6.44	5.56	2763.4	7.57
FORT WORTH	TX	3.24	3.80	4.48	4.64	5.48	6.60	6.81	6.51	5.66	5.26	4.19	3.55	1834.1	5.03
HOUSTON	TX	2.70	3.35	3.75	4.12	4.88	5.34	5.12	4.82	4.56	4.75	3.64	2.86	1519.1	4.16
KINGSVILLE	TX	3.30	3.82	4.25	4.63	5.30	6.04	6.51	5.93	5.22	5.18	4.04	3.31	1752.2	4.80
LAREDO	TX	3.57	4.00	4.64	4.94	5.73	6.22	6.61	6.37	5.66	5.29	4.08	3.56	1848.5	5.06
LUBBOCK	TX	5.07	5.60	6.65	7.67	8.20	8.71	8.25	7.88	6.99	6.64	5.83	5.16	2516.3	6.89
LUFKIN	TX	2.97	3.66	4.20	4.60	5.34	6.12	6.03	5.79	5.00	5.39	4.09	3.31	1720.4	4.71
MIDLAND-ODESSA	TX	5.09	5.70	6.93	7.69	8.35	8.82	8.08	7.76	6.93	6.74	5.90	5.31	2535.1	6.95
PORT ARTHUR	TX	2.87	3.54	4.01	4.49	5.35	5.90	5.21	5.08	4.87	5.05	3.82	3.03	1620.5	4.44
SAN ANGELO	TX	4.07	4.45	5.46	5.75	6.18	6.76	6.61	6.32	5.44	5.34	4.72	4.29	1991.3	5.46
SAN ANTONIO	TX	3.40	3.96	4.44	4.49	5.47	6.19	6.58	6.13	5.46	5.18	4.14	3.58	1798.0	4.93
SHERMAN	TX	3.30	3.70	4.32	4.65	5.30	6.41	6.43	6.28	5.51	5.22	4.22	3.53	1793.1	4.91
WACO	TX	3.26	3.83	4.48	4.56	4.89	6.40	6.65	6.31	5.44	5.13	4.11	3.61	1787.2	4.90
WICHITA FALLS	TX	3.78	4.23	4.94	5.43	6.15	6.94	6.88	6.50	5.66	5.41	4.57	4.03	1964.9	5.38
BRYCE CANYON	UT	5.04	5.58	6.69	7.80	8.64	9.48	8.44	7.91	8.29	7.49	6.07	5.16	2636.1	7.22
CEDAR CITY	UT	4.76	5.17	6.37	7.56	8.72	9.82	8.89	8.41	8.67	7.43	5.85	4.81	2633.0	7.21

PFTEA PROJECT--AVERAGE DAILY AND ANNUAL DIRECT NORMAL INSOLATION ESTIMATES (KWH/SQ. M)

SITE		AVERAGE DAILY AMOUNTS BY MONTH												ANNUAL AMOUNT	AVERAGE DAY
		J	F	M	A	M	J	J	A	S	O	N	D		
SALT LAKE CITY	UT	3.28	4.24	5.61	6.63	8.27	9.05	9.62	8.84	8.29	6.73	4.69	3.35	2395.7	6.56
NORFOLK	VA	2.96	3.41	4.15	5.14	5.54	5.87	5.34	5.14	4.74	4.38	3.98	3.13	1637.3	4.49
RICHMOND	VA	2.70	3.14	3.83	4.63	4.93	5.23	4.96	4.75	4.51	4.11	3.47	2.77	1493.4	4.09
ROANOKE	VA	2.89	3.26	3.96	4.68	4.94	5.28	5.06	4.84	4.56	4.43	3.68	2.94	1538.6	4.22
BURLINGTON	VT	1.68	2.11	2.97	3.73	4.34	4.83	4.98	4.58	3.95	3.08	1.59	1.75	1206.7	3.31
OLYMPIA	WA	1.45	1.63	2.63	3.68	4.73	4.77	6.13	5.16	4.43	2.66	1.61	1.41	1229.4	3.37
SEATTLE-TACOMA	WA	1.43	1.62	2.71	3.90	5.14	5.27	8.07	5.62	4.43	2.87	1.65	1.36	1346.4	3.69
SPOKANE	WA	1.44	2.47	3.87	4.94	6.23	6.77	8.77	7.67	6.53	4.36	2.30	1.40	1731.5	4.74
WHIDBEY ISLAND	WA	1.77	2.01	3.20	4.23	5.40	5.39	6.60	5.56	4.75	2.99	2.00	1.27	1378.1	3.78
YAKIMA	WA	1.79	2.78	4.23	5.44	6.65	7.16	8.66	7.74	6.70	4.57	2.57	1.65	1828.1	5.01
EAU CLAIRE	WI	2.35	3.13	3.85	4.39	4.85	5.48	5.85	5.40	4.41	3.71	2.35	1.85	1450.4	3.97
GREEN BAY	WI	2.28	2.94	3.90	4.43	5.00	5.66	5.83	5.37	4.51	3.62	2.43	1.89	1457.4	3.99
LA CROSSE	WI	2.45	3.13	3.82	4.33	4.94	5.62	5.87	5.58	4.59	3.83	2.59	1.98	1483.9	4.07
MADISON	WI	2.64	3.31	3.94	4.16	5.03	5.82	5.99	5.74	4.87	4.08	2.56	2.06	1528.6	4.19
MILWAUKEE	WI	2.30	2.83	3.67	4.35	5.13	5.95	6.13	5.79	4.92	4.02	2.71	1.93	1515.4	4.15
CHARLESTON	WV	1.82	2.17	2.87	3.70	4.42	4.84	4.59	4.41	4.19	3.84	2.71	1.83	1261.1	3.45
HUNTINGTON	WV	2.02	2.49	3.17	4.13	4.73	5.12	4.96	4.70	4.36	4.03	2.89	2.06	1361.4	3.73
CASPER	WY	4.16	4.82	5.82	6.56	7.47	8.84	9.42	8.95	7.99	6.60	5.06	4.16	2432.1	6.66
CHEYENNE	WY	4.54	4.91	5.53	5.97	6.24	7.35	7.48	7.08	7.06	6.39	5.15	4.55	2199.3	6.03
ROCK SPRINGS	WY	4.34	5.16	6.22	7.01	8.20	9.17	9.40	8.87	8.39	7.04	5.33	4.43	2545.5	6.97
SHERIDAN	WY	2.94	3.41	4.50	4.93	5.84	7.00	8.32	7.72	6.50	5.16	3.66	2.87	1915.8	5.25

SECTION IV

DISCUSSION

The model and estimates provided here have a number of shortcomings as described below.

The estimates are only as accurate as the rehabilitated SOLMET data inputs used to calibrate the model. On an average data basis, the rehabilitated SOLMET data may be sufficient, depending on the application intended. A further improvement could be made by computing the \bar{K}_T fractions on an hourly basis rather than on a daily basis for those SOLMET stations with acceptable data (see Reference 5 for a detailed examination of the SOLMET data). In addition, estimates provided here do not capture hourly transients. Models that require a high degree of hourly accuracy (for example, hourly load matching) should use hourly recorded data if available.

It should also be noted that while the estimates are of the direct normal component it is inevitable that on large collector surface areas there will also be some diffuse radiation. Diffuse radiation is not considered in these estimates.

In order to examine the accuracy of the model, comparisons were made between the rehabilitated SOLMET averages (Reference 6), earlier work by Sandia National Laboratories (Reference 7), and the model estimates. Figures 4-1 through 4-6 graph the average daily amounts throughout a twelve month period. The solid lines represent ± 1 standard deviation about the mean of the SOLMET averages. The standard deviation provides an initial view of the uncertainty in the SOLMET averages (by assuming that the data are derived from a Gaussian distribution and by appealing to the Central Limit Theorem (Reference 8)). (The number of observations ranges from four to eight thousand per month over the period of record.) For the most part, the model estimates fall within one standard deviation and between the Sandia values and the SOLMET values. The high estimates by Sandia were due primarily to use of pre-SOLMET raw insolation data. These data were not adjusted for miscalibration and instrument drift that occurred at a number of locations. These constraints have only recently been acknowledged. Of particular interest is the apparent overestimation of the model values in relation to the SOLMET averages from which the model estimates were computed. This may result from use of an exponential fit of the direct normal pattern in Equation 1. The rise and drop-off of SOLMET direct normal insolation at the beginning and end of the day tend to be more abrupt, and the added area in the "tails" contributes to the higher values. In those cases where the SOLMET values and model values agree exactly, the SOLMET data for those cases may more closely resemble the exponential pattern. Further work needs to be done in this area to resolve this difference.

In addition, it should be stressed that the estimates provided here represent the relative solar resources of these locations and should be used only as a first approximation. In situations where the siting of solar plants is under consideration, instrumentation and

actual data collection should also be done in conjunction with a detailed analysis of the insolation resource at the site. This will provide a better understanding of the random characteristics of insolation at that location, and the corresponding impact on the solar energy system facility size, output, cost, and reliability.

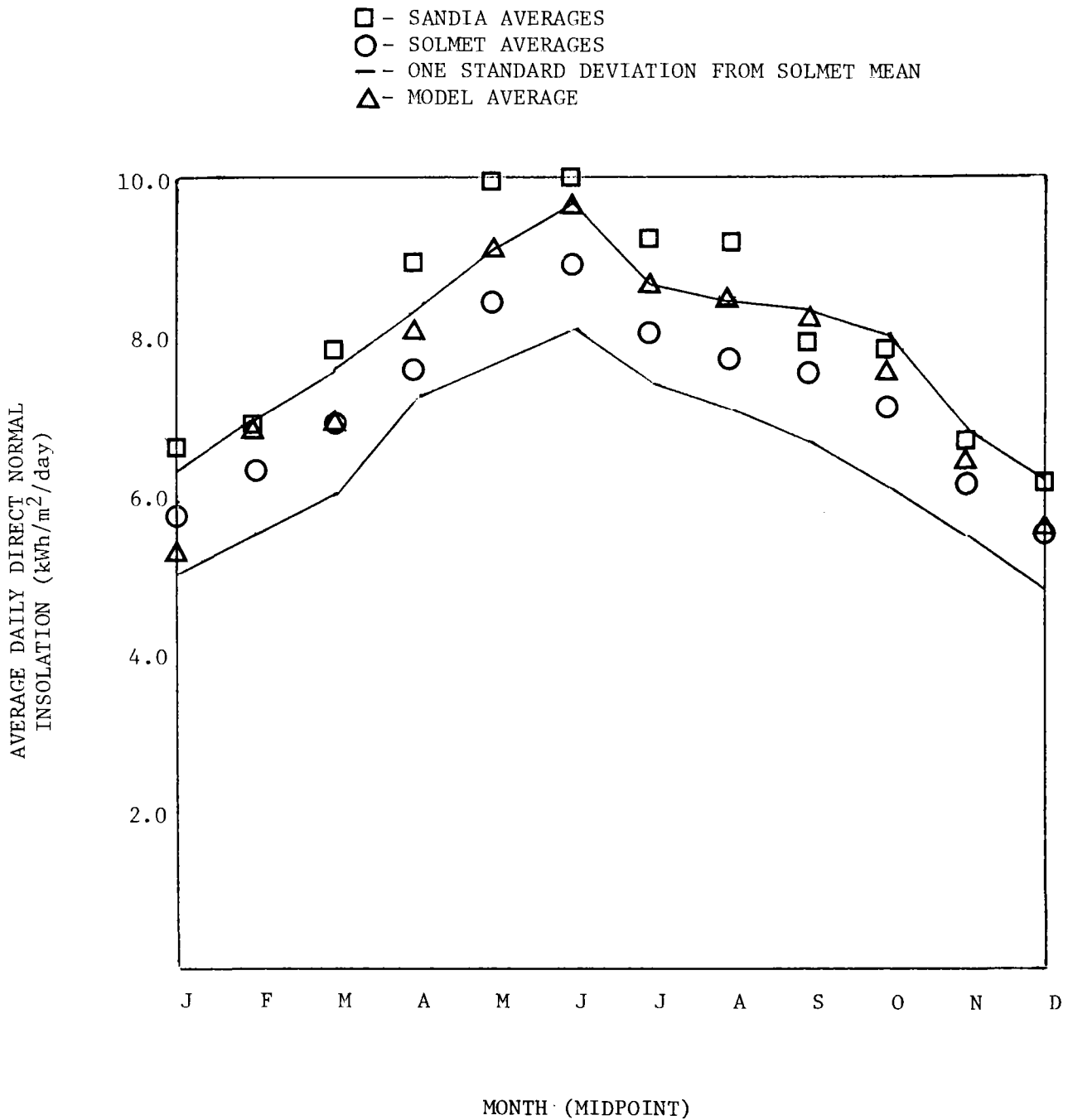


Figure 4-1. Data vs. Model Comparisons: Albuquerque, New Mexico

- - SANDIA AVERAGES
- - SOLMET AVERAGE (AEROSPACE)
- - ONE STANDARD DEVIATION ABOUT SOLMET MEAN
- △ - MODEL AVERAGE

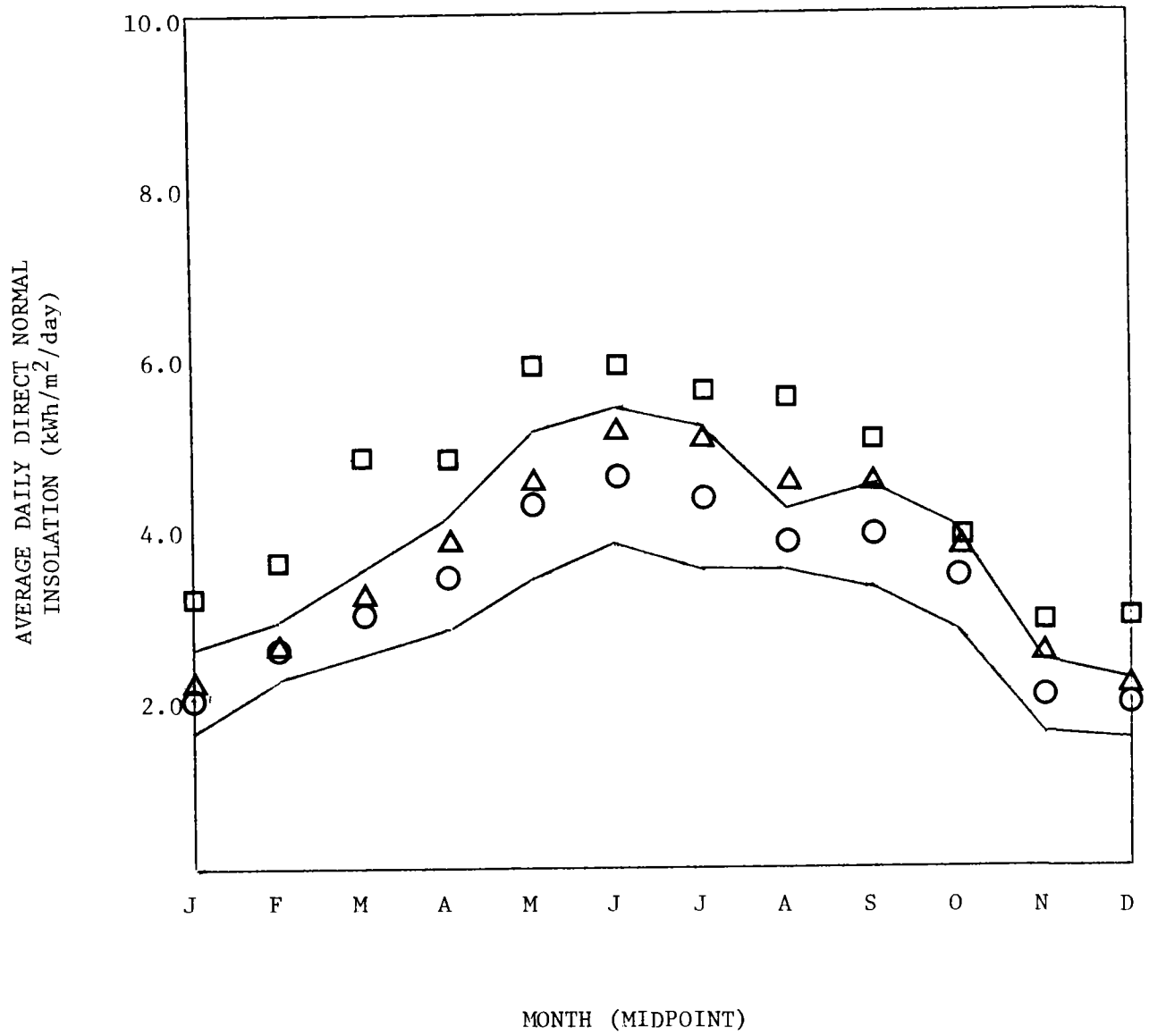


Figure 4-2. Data vs. Model Comparisons: Boston, Massachusetts

- - SANDIA AVERAGES
- - SOLMET AVERAGES
- - ONE STANDARD DEVIATION ABOUT SOLMET MEAN
- △ - MODEL AVERAGE

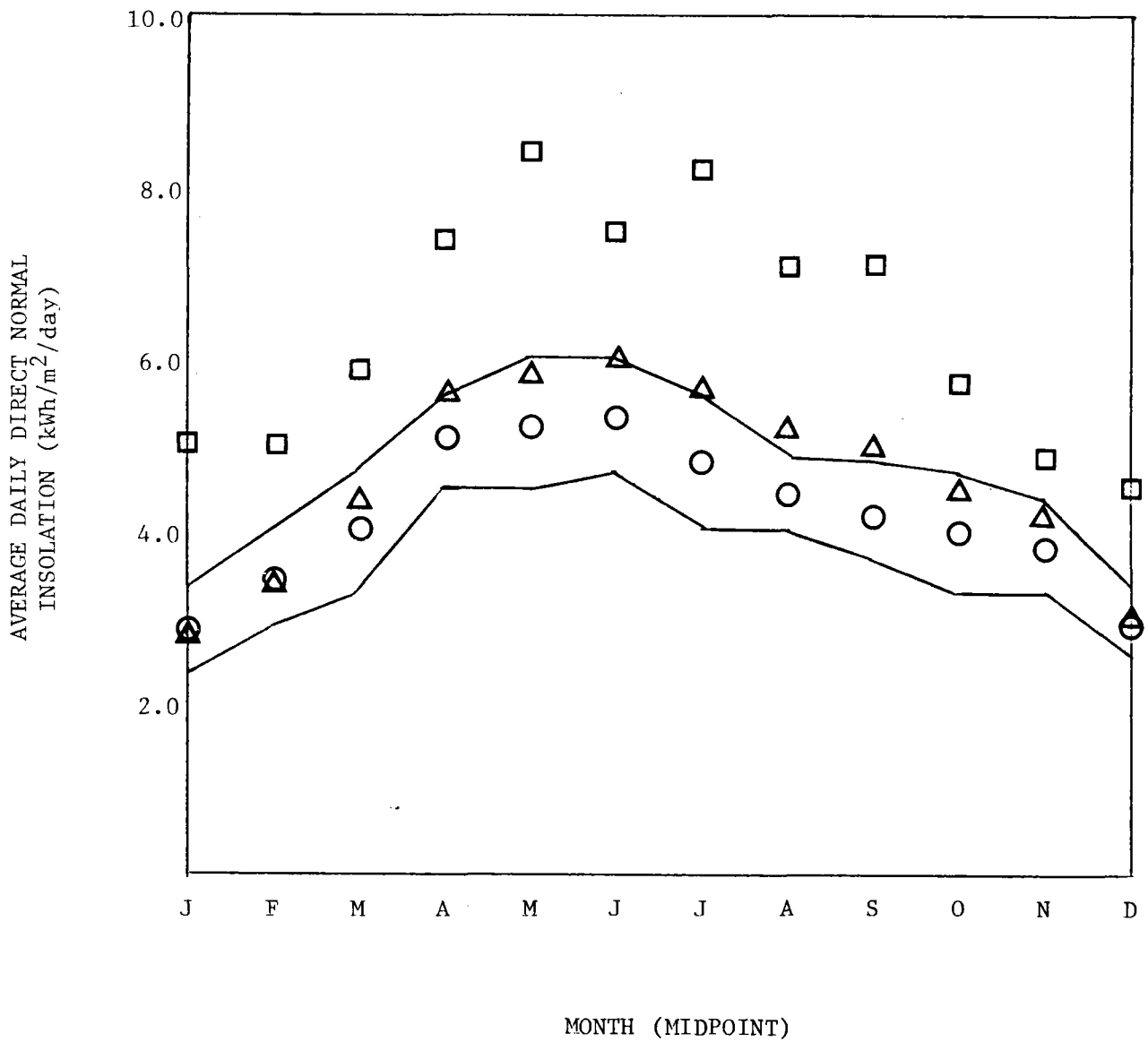


Figure 4-3. Data vs. Model Comparisons: Cape Hatteras, North Carolina

- - SANDIA AVERAGES
- - SOLMET AVERAGE (AEROSPACE)
- - ONE STANDARD DEVIATION ABOUT SOLMET MEAN
- △ - MODEL AVERAGE

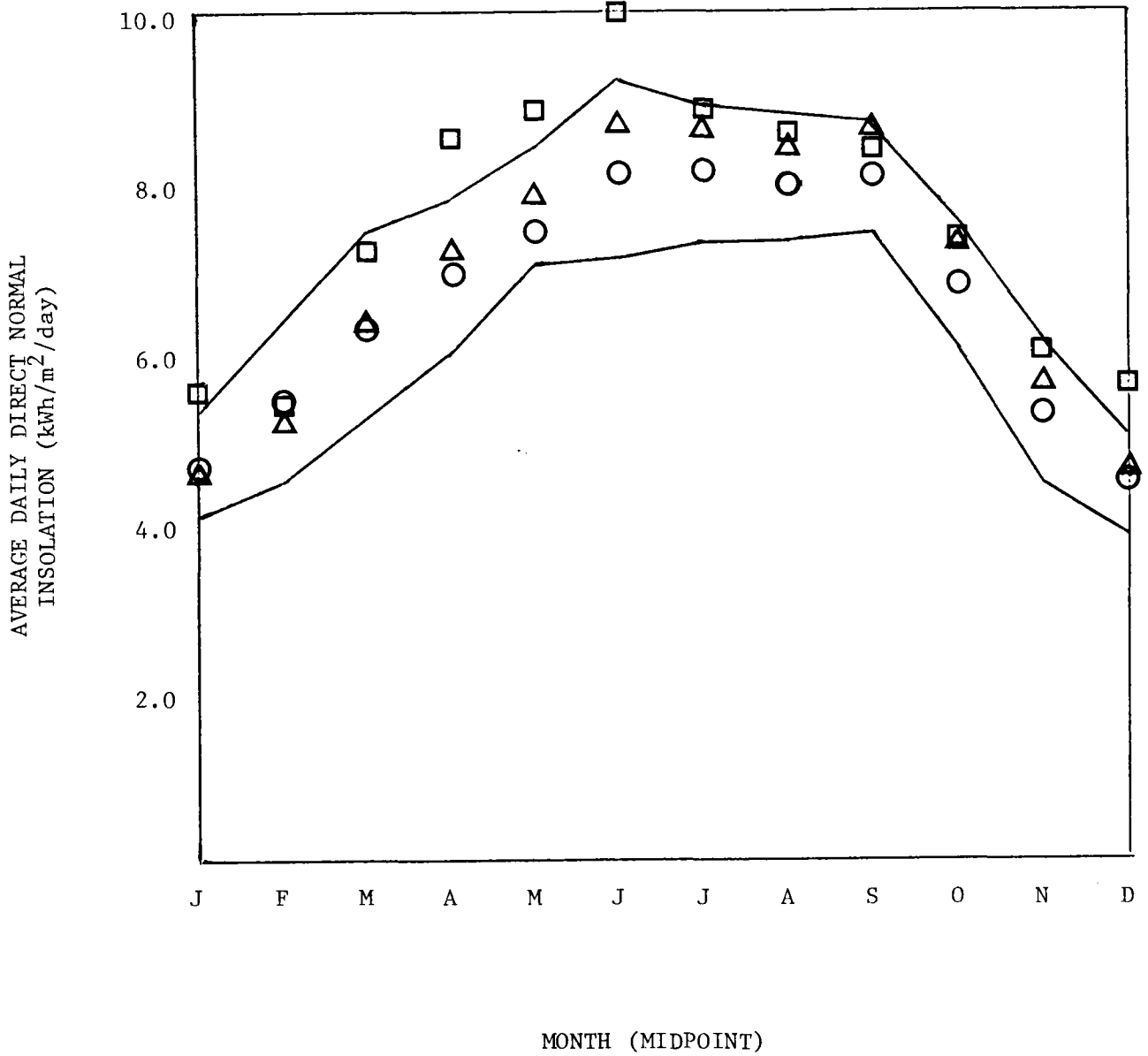


Figure 4-4. Data vs. Model Comparisons: Ely, Nevada

- - SANDIA AVERAGES
- - SOLMET AVERAGE (AEROSPACE)
- - ONE STANDARD DEVIATION ABOUT SOLMET MEAN
- △ - MODEL AVERAGE

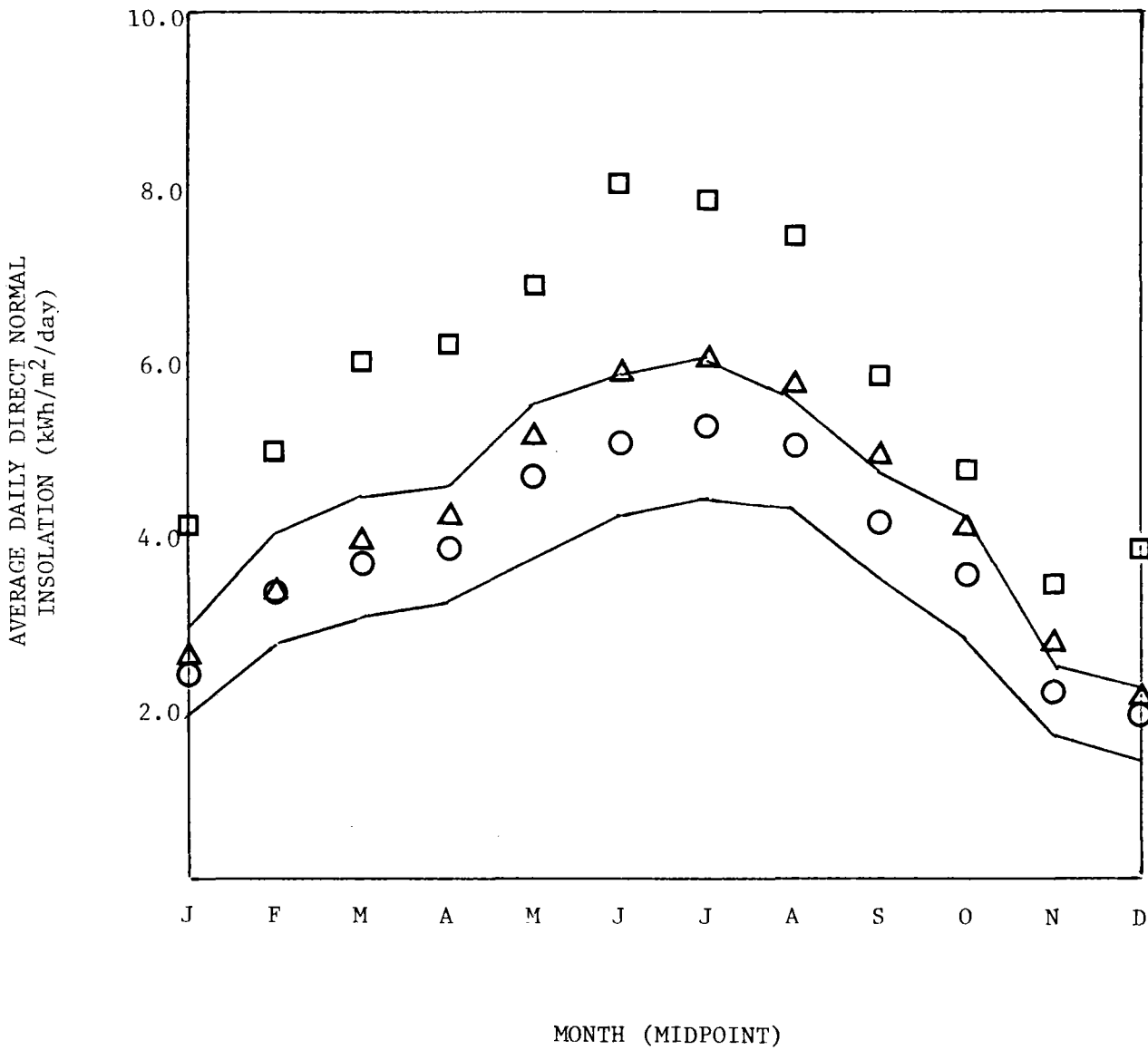


Figure 4-5. Data Vs. Model Comparisons: Madison, Wisconsin

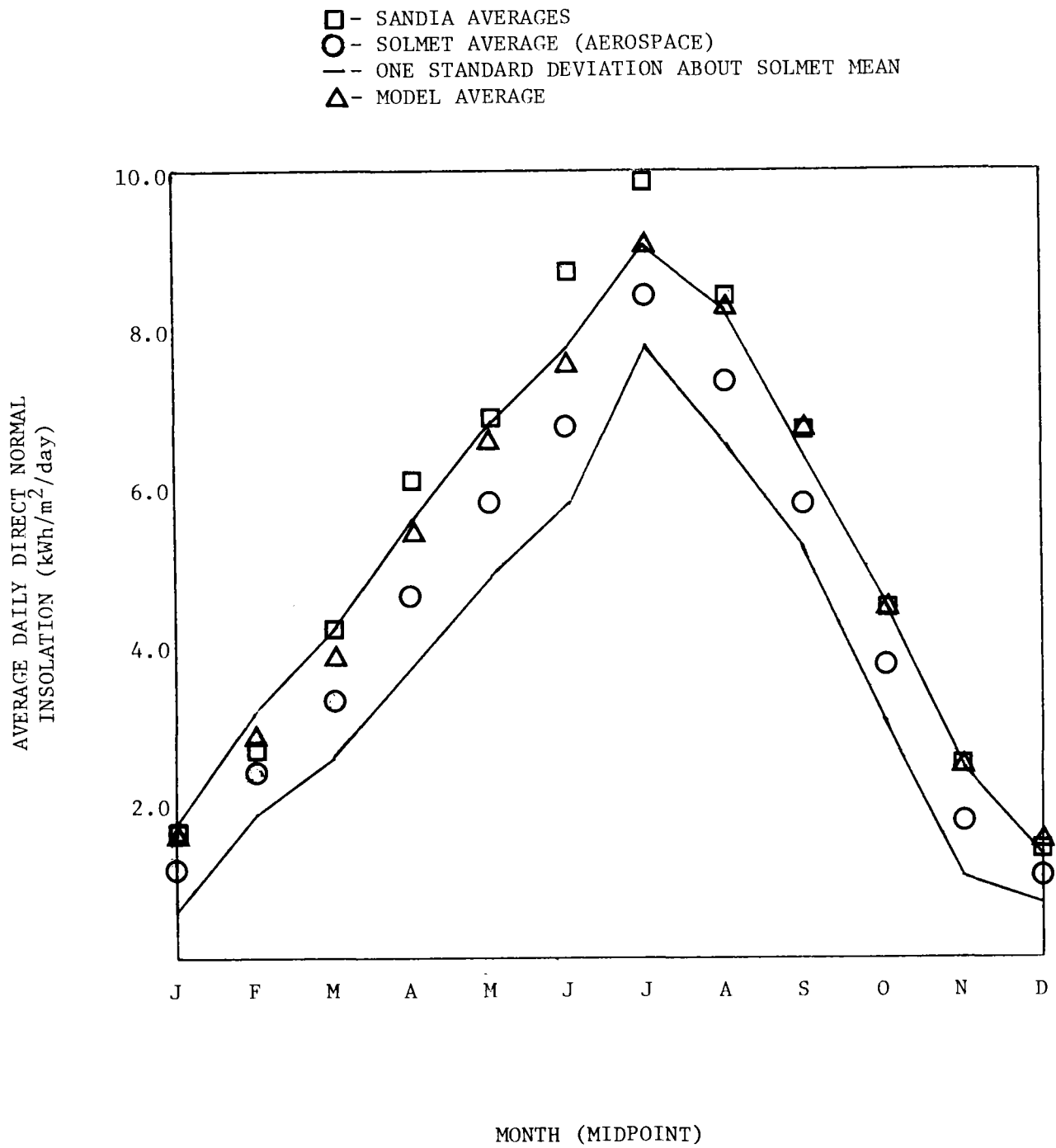


Figure 4-6. Data vs. Model Comparisons: Medford, Oregon

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APPENDIX A

SOLAR CLIMATE PARAMETER DATA FOR 232 LOCALITIES

The following pages provide solar climate parameter data for 232 localities in the United States (see Reference 2). Latitudes are in degree.minute form (e.g. 33.33 is 33 degrees and 33 minutes).

$$\overline{K_T} = \frac{\text{average daily total radiation for month M (Reference 2),}}{\text{average daily total extraterrestrial radiation for month M, } H_0}$$

M = 1,2, . . . ,12

LOCATION	LAT. (DEG.MIN)	LAT.											
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
ADAK	AK 51.53	0.101	0.318	0.347	0.355	0.339	0.319	0.322	0.329	0.363	0.497	0.406	0.322
ANNETTE	AK 55.07	0.295	0.315	0.368	0.439	0.428	0.397	0.418	0.416	0.417	0.364	0.368	0.330
BETHEL	AK 60.47	0.203	0.361	0.444	0.458	0.432	0.414	0.383	0.353	0.420	0.436	0.432	0.311
JUNEAU	AK 58.22	0.267	0.280	0.341	0.387	0.380	0.385	0.376	0.366	0.357	0.327	0.348	0.242
KING SALMON	AK 58.44	0.349	0.381	0.451	0.448	0.437	0.419	0.407	0.390	0.439	0.492	0.494	0.376
KODIAK	AK 57.45	0.321	0.341	0.430	0.444	0.404	0.416	0.413	0.430	0.437	0.483	0.451	0.344
NOME	AK 64.30	0.187	0.332	0.429	0.476	0.474	0.477	0.425	0.400	0.455	0.472	0.421	0.283
SUMMIT	AK 63.29	0.270	0.340	0.455	0.499	0.490	0.445	0.422	0.414	0.457	0.484	0.531	0.243
YAKUTAT	AK 59.31	0.264	0.281	0.361	0.394	0.375	0.366	0.357	0.356	0.366	0.376	0.364	0.247
BIRMINGHAM	AL 33.34	0.402	0.425	0.461	0.506	0.517	0.521	0.505	0.526	0.520	0.540	0.492	0.426
MOBILE	AL 30.41	0.434	0.458	0.485	0.515	0.523	0.511	0.480	0.495	0.503	0.549	0.504	0.444
MONTGOMERY	AL 32.18	0.412	0.435	0.470	0.521	0.529	0.537	0.514	0.530	0.518	0.549	0.505	0.443
FORT SMITH	AR 35.20	0.447	0.455	0.476	0.493	0.533	0.565	0.576	0.577	0.548	0.556	0.515	0.458
LYTLE ROCK	AR 34.44	0.431	0.451	0.473	0.490	0.537	0.570	0.567	0.570	0.550	0.562	0.503	0.452
PHOENIX	AZ 33.26	0.579	0.603	0.644	0.712	0.746	0.744	0.694	0.699	0.720	0.702	0.657	0.547
PRESCOTT	AZ 34.39	0.598	0.600	0.640	0.692	0.732	0.748	0.644	0.641	0.708	0.704	0.675	0.620
TUCSON	AZ 32.07	0.599	0.612	0.652	0.711	0.745	0.743	0.654	0.662	0.697	0.695	0.663	0.610
WINSLOW	AZ 35.31	0.586	0.601	0.644	0.695	0.723	0.734	0.655	0.657	0.701	0.696	0.671	0.607
YUMA	AZ 32.40	0.607	0.623	0.675	0.727	0.761	0.765	0.685	0.708	0.726	0.712	0.678	0.624
ARCATA	CA 40.59	0.389	0.412	0.444	0.499	0.516	0.528	0.506	0.501	0.528	0.495	0.440	0.410
BAKERSFIELD	CA 35.25	0.462	0.503	0.579	0.639	0.699	0.744	0.749	0.744	0.728	0.676	0.572	0.457
CHINA LAKE	CA 35.41	0.553	0.565	0.632	0.682	0.710	0.743	0.729	0.805	0.726	0.687	0.633	0.589
DAWGETT	CA 34.52	0.567	0.578	0.640	0.692	0.722	0.749	0.726	0.731	0.729	0.695	0.647	0.591
EL TORO	CA 33.40	0.540	0.545	0.573	0.584	0.577	0.595	0.660	0.657	0.622	0.607	0.590	0.562
FRESNO	CA 36.46	0.414	0.476	0.578	0.643	0.692	0.738	0.745	0.750	0.737	0.683	0.564	0.417
LONG BEACH	CA 33.49	0.532	0.537	0.574	0.587	0.575	0.580	0.642	0.641	0.610	0.595	0.579	0.550
LOS ANGELES	CA 33.56	0.533	0.538	0.578	0.591	0.574	0.575	0.644	0.635	0.604	0.592	0.582	0.554
MOUNT SHASTA	CA 41.19	0.418	0.450	0.492	0.554	0.612	0.655	0.722	0.703	0.686	0.616	0.496	0.448
NEEDLES	CA 34.46	0.581	0.610	0.658	0.705	0.739	0.756	0.709	0.698	0.730	0.703	0.668	0.614
PAKLAND	CA 37.44	0.461	0.489	0.545	0.593	0.617	0.634	0.648	0.638	0.640	0.592	0.540	0.489
POINT MUGU	CA 34.07	0.536	0.542	0.585	0.592	0.582	0.557	0.591	0.591	0.579	0.585	0.586	0.562
RED BLUFF	CA 40.09	0.406	0.454	0.524	0.598	0.664	0.700	0.747	0.729	0.717	0.636	0.507	0.429
SACRAMENTO	CA 38.31	0.400	0.460	0.551	0.621	0.679	0.723	0.751	0.740	0.725	0.654	0.528	0.420
SAN DIEGO	CA 32.44	0.542	0.548	0.575	0.584	0.558	0.561	0.610	0.625	0.609	0.603	0.594	0.565
SAN FRANCISCO	CA 37.37	0.459	0.484	0.544	0.592	0.621	0.641	0.668	0.658	0.654	0.597	0.537	0.483
SANTA MARIA	CA 34.54	0.506	0.515	0.571	0.585	0.596	0.636	0.653	0.646	0.628	0.621	0.581	0.543
SUNNYVALE	CA 37.25	0.475	0.495	0.553	0.599	0.635	0.662	0.681	0.673	0.659	0.605	0.547	0.492
COLORADO SPRINGS	CO 38.49	0.603	0.581	0.588	0.600	0.594	0.638	0.618	0.634	0.671	0.681	0.645	0.618
DENVER	CO 39.45	0.589	0.568	0.589	0.587	0.596	0.633	0.635	0.643	0.667	0.667	0.625	0.603
EAGLE	CO 39.39	0.527	0.542	0.577	0.613	0.630	0.675	0.667	0.655	0.682	0.669	0.612	0.567
GRAND JUNCTION	CO 39.07	0.542	0.555	0.592	0.618	0.644	0.700	0.689	0.684	0.703	0.679	0.634	0.586
PUEBLO	CO 38.17	0.594	0.570	0.589	0.636	0.603	0.656	0.645	0.656	0.674	0.673	0.639	0.605
HARTFORD	CT 41.56	0.365	0.381	0.389	0.417	0.439	0.453	0.462	0.454	0.461	0.463	0.384	0.352
WASHINGTON-STERLING	DC 38.57	0.389	0.403	0.428	0.454	0.480	0.512	0.508	0.506	0.512	0.505	0.446	0.383
WILMINGTON	DE 39.40	0.399	0.416	0.442	0.462	0.478	0.507	0.510	0.508	0.509	0.503	0.454	0.401
APALACHICOLA	FL 29.44	0.436	0.461	0.503	0.561	0.584	0.547	0.508	0.508	0.528	0.569	0.535	0.464
DAYTONA BEACH	FL 29.11	0.483	0.492	0.526	0.561	0.550	0.501	0.500	0.505	0.505	0.515	0.525	0.486
JACKSONVILLE	FL 30.30	0.469	0.483	0.523	0.555	0.546	0.515	0.504	0.511	0.499	0.515	0.523	0.475
MIAMI	FL 25.48	0.493	0.505	0.528	0.549	0.519	0.474	0.497	0.486	0.483	0.507	0.522	0.517
ORLANDO	FL 28.33	0.495	0.499	0.534	0.565	0.557	0.504	0.505	0.502	0.509	0.531	0.546	0.507
TALLAHASSEE	FL 30.23	0.456	0.471	0.508	0.545	0.541	0.515	0.489	0.505	0.516	0.554	0.528	0.471
TAMPA	FL 27.58	0.493	0.500	0.535	0.567	0.560	0.509	0.492	0.495	0.505	0.542	0.544	0.504
WEST PALM BEACH	FL 26.41	0.473	0.480	0.517	0.537	0.518	0.472	0.501	0.496	0.474	0.483	0.505	0.498
ATLANTA	GA 33.39	0.409	0.427	0.464	0.510	0.517	0.519	0.506	0.521	0.509	0.536	0.507	0.435
AUGUSTA	GA 33.22	0.425	0.445	0.475	0.523	0.520	0.517	0.503	0.508	0.503	0.542	0.522	0.461
MADISON	GA 32.42	0.426	0.441	0.480	0.524	0.525	0.522	0.498	0.522	0.510	0.547	0.525	0.455
SAVANNAH	GA 32.08	0.434	0.446	0.489	0.530	0.517	0.502	0.498	0.492	0.480	0.528	0.517	0.462
BARNES POINT	HI 21.10	0.508	0.519	0.524	0.539	0.562	0.573	0.577	0.584	0.583	0.567	0.550	0.529
HILU	HI 19.43	0.457	0.440	0.425	0.421	0.445	0.474	0.467	0.472	0.492	0.490	0.453	0.446
HONOLULU	HI 21.20	0.497	0.503	0.517	0.528	0.556	0.568	0.572	0.583	0.582	0.562	0.536	0.514
LIHOE	HI 21.59	0.471	0.473	0.472	0.482	0.519	0.527	0.531	0.539	0.562	0.533	0.495	0.485

LOCATION	LAT. (DEG.MIN)	LAT.												
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	
BURLINGTON	IA	42.47	0.423	0.444	0.455	0.483	0.525	0.570	0.584	0.579	0.556	0.558	0.489	0.410
DES MOINES	IA	41.32	0.437	0.454	0.466	0.492	0.523	0.571	0.587	0.582	0.569	0.573	0.500	0.437
MASON CITY	IA	43.09	0.446	0.461	0.473	0.485	0.532	0.568	0.585	0.590	0.571	0.567	0.488	0.432
SIoux CITY	IA	42.24	0.444	0.454	0.468	0.501	0.533	0.571	0.595	0.590	0.571	0.570	0.506	0.440
BOISE	ID	43.34	0.399	0.468	0.532	0.585	0.640	0.662	0.734	0.709	0.711	0.646	0.520	0.435
LEWISTON	ID	46.23	0.319	0.369	0.436	0.470	0.521	0.542	0.660	0.637	0.616	0.531	0.392	0.330
POCATELLO	ID	42.55	0.430	0.483	0.553	0.591	0.640	0.667	0.730	0.719	0.717	0.671	0.554	0.459
CHICAGO	IL	41.47	0.385	0.403	0.439	0.462	0.501	0.540	0.545	0.548	0.539	0.524	0.434	0.305
MOLINE	IL	41.27	0.401	0.427	0.441	0.461	0.491	0.530	0.543	0.545	0.538	0.533	0.450	0.387
SPRINGFIELD	IL	39.50	0.411	0.435	0.440	0.473	0.521	0.564	0.575	0.568	0.563	0.549	0.480	0.410
EVANSVILLE	IN	38.03	0.378	0.398	0.432	0.464	0.497	0.534	0.536	0.541	0.530	0.535	0.433	0.382
FORT WAYNE	IN	41.00	0.335	0.363	0.385	0.428	0.468	0.495	0.500	0.505	0.501	0.489	0.383	0.323
INDIANAPOLIS	IN	39.44	0.347	0.376	0.399	0.437	0.472	0.503	0.505	0.517	0.512	0.501	0.409	0.343
SOUTH BEND	IN	41.42	0.315	0.349	0.393	0.439	0.482	0.517	0.519	0.531	0.513	0.490	0.380	0.308
DODGE CITY	KS	37.46	0.539	0.540	0.553	0.582	0.583	0.636	0.641	0.639	0.635	0.636	0.587	0.553
GOODLAND	KS	39.22	0.546	0.527	0.545	0.570	0.576	0.634	0.648	0.642	0.631	0.644	0.597	0.563
TOPEKA	KS	39.04	0.465	0.466	0.479	0.511	0.535	0.573	0.595	0.598	0.581	0.578	0.532	0.467
WICHITA	KS	37.39	0.509	0.508	0.525	0.550	0.568	0.611	0.625	0.632	0.607	0.609	0.570	0.519
LEXINGTON	KY	38.02	0.359	0.377	0.413	0.457	0.487	0.511	0.517	0.525	0.514	0.514	0.436	0.371
LOUISVILLE	KY	38.11	0.361	0.383	0.415	0.454	0.480	0.513	0.513	0.524	0.515	0.514	0.435	0.375
BATON ROUGE	LA	30.32	0.410	0.438	0.475	0.503	0.522	0.527	0.488	0.506	0.507	0.548	0.483	0.429
LAKE CHARLES	LA	30.07	0.376	0.415	0.450	0.469	0.517	0.539	0.500	0.499	0.512	0.577	0.476	0.405
NEW ORLEANS	LA	29.59	0.429	0.457	0.484	0.532	0.550	0.549	0.508	0.517	0.522	0.557	0.503	0.440
SHREVEPORT	LA	32.28	0.420	0.447	0.471	0.486	0.526	0.562	0.562	0.570	0.549	0.569	0.515	0.453
BOSTON	MA	42.22	0.370	0.383	0.407	0.421	0.454	0.488	0.491	0.476	0.506	0.488	0.395	0.377
BALTIMORE	MD	39.11	0.403	0.418	0.443	0.463	0.478	0.506	0.509	0.502	0.510	0.504	0.457	0.401
PATUXENT RIVER	MD	38.17	0.404	0.420	0.445	0.476	0.492	0.510	0.507	0.508	0.514	0.505	0.473	0.410
BANJUR	ME	46.48	0.395	0.419	0.455	0.466	0.487	0.499	0.524	0.525	0.524	0.494	0.413	0.400
CARIBOU	ME	46.52	0.404	0.445	0.489	0.465	0.447	0.473	0.499	0.497	0.477	0.432	0.356	0.370
PORTLAND	ME	43.39	0.371	0.381	0.396	0.418	0.440	0.460	0.466	0.472	0.475	0.488	0.382	0.363
ALFORD	ME	45.04	0.319	0.359	0.430	0.456	0.485	0.505	0.531	0.517	0.485	0.441	0.359	0.293
DETROIT	MI	42.25	0.326	0.367	0.400	0.445	0.481	0.502	0.515	0.504	0.504	0.482	0.376	0.322
FLINT	MI	42.58	0.306	0.349	0.386	0.427	0.465	0.487	0.505	0.500	0.485	0.463	0.346	0.298
GRAND RAPIDS	MI	42.53	0.294	0.354	0.409	0.450	0.493	0.526	0.537	0.538	0.511	0.478	0.358	0.298
HOOVER	MI	47.10	0.239	0.301	0.405	0.450	0.470	0.494	0.521	0.505	0.440	0.425	0.288	0.237
SAULT STE. MARIE	MI	46.28	0.306	0.367	0.441	0.453	0.477	0.487	0.519	0.502	0.451	0.417	0.316	0.299
TRAVELER CITY	MJ	46.44	0.269	0.327	0.416	0.454	0.487	0.514	0.538	0.524	0.486	0.443	0.329	0.273
DULUTH	MN	46.50	0.373	0.414	0.446	0.451	0.465	0.475	0.525	0.512	0.474	0.455	0.373	0.353
INTERNATIONAL FALLS	MN	48.34	0.376	0.431	0.466	0.482	0.488	0.499	0.546	0.543	0.501	0.468	0.369	0.370
MINNEAPOLIS-ST. PAUL	MN	44.53	0.405	0.442	0.460	0.467	0.489	0.518	0.555	0.550	0.525	0.507	0.423	0.379
ROCHESTER	MN	43.55	0.399	0.424	0.444	0.453	0.477	0.511	0.537	0.538	0.515	0.499	0.416	0.370
COLUMBIA	MO	38.49	0.414	0.431	0.448	0.474	0.525	0.563	0.591	0.588	0.553	0.552	0.480	0.413
KANSAS CITY	MO	39.18	0.447	0.445	0.460	0.491	0.523	0.560	0.587	0.584	0.558	0.554	0.512	0.454
SPRINGFIELD	MO	37.14	0.438	0.440	0.459	0.494	0.525	0.560	0.576	0.581	0.553	0.552	0.500	0.440
ST. LOUIS	MO	38.45	0.424	0.436	0.457	0.486	0.522	0.564	0.572	0.568	0.550	0.550	0.489	0.418
JACKSON	MS	32.19	0.413	0.440	0.480	0.514	0.541	0.551	0.533	0.540	0.532	0.554	0.498	0.437
MERIDIAN	MS	32.20	0.408	0.435	0.466	0.530	0.518	0.534	0.509	0.528	0.513	0.548	0.495	0.432
BILLINGS	MT	45.48	0.443	0.454	0.504	0.497	0.540	0.585	0.673	0.664	0.625	0.599	0.517	0.477
CUT BANK	MT	48.36	0.426	0.448	0.503	0.496	0.536	0.591	0.650	0.637	0.604	0.580	0.514	0.450
DILLON	MT	45.15	0.467	0.495	0.537	0.532	0.561	0.576	0.675	0.681	0.640	0.611	0.539	0.493
GLASGOW	MT	48.13	0.402	0.432	0.489	0.495	0.519	0.551	0.623	0.624	0.595	0.576	0.501	0.444
GREAT FALLS	MT	47.29	0.418	0.452	0.511	0.492	0.524	0.566	0.660	0.643	0.604	0.592	0.500	0.424
HELENA	MT	46.36	0.399	0.432	0.492	0.488	0.526	0.549	0.660	0.637	0.604	0.577	0.503	0.434
LEWISTOWN	MT	47.03	0.408	0.428	0.489	0.476	0.512	0.554	0.648	0.630	0.596	0.572	0.493	0.443
MILES CITY	MT	46.26	0.430	0.452	0.507	0.505	0.536	0.577	0.648	0.652	0.620	0.595	0.524	0.470
MISSOULA	MT	46.55	0.301	0.354	0.424	0.455	0.505	0.520	0.659	0.623	0.588	0.511	0.400	0.325
ASHEVILLE	NC	35.26	0.435	0.444	0.475	0.509	0.503	0.502	0.495	0.500	0.497	0.532	0.516	0.453
CARRE MATTERAS	NC	35.16	0.411	0.433	0.481	0.541	0.547	0.551	0.536	0.524	0.536	0.526	0.527	0.451
CHARLOTTE	NC	35.13	0.430	0.442	0.477	0.517	0.517	0.520	0.511	0.521	0.516	0.542	0.522	0.460
CHEERY POINT	NC	34.54	0.449	0.463	0.501	0.546	0.536	0.525	0.510	0.501	0.518	0.537	0.541	0.485
GREENSBORO	NC	36.05	0.442	0.449	0.481	0.515	0.520	0.528	0.520	0.523	0.522	0.537	0.521	0.455
RALIGH-DURHAM	NC	35.52	0.424	0.435	0.466	0.503	0.504	0.504	0.495	0.496	0.506	0.518	0.500	0.445
BISMARCK	ND	46.46	0.447	0.476	0.503	0.479	0.523	0.554	0.618	0.621	0.585	0.568	0.491	0.449
FARGO	ND	46.54	0.400	0.435	0.474	0.485	0.519	0.536	0.600	0.604	0.565	0.549	0.446	0.409
MINOT	ND	48.16	0.399	0.423	0.463	0.486	0.525	0.532	0.596	0.603	0.567	0.559	0.460	0.413
GRAND ISLAND	NE	40.58	0.486	0.477	0.495	0.533	0.552	0.603	0.620	0.615	0.594	0.602	0.548	0.497
NORTH PLATTE	NE	41.22	0.474	0.468	0.482	0.492	0.524	0.571	0.590	0.591	0.543	0.561	0.485	0.455
NORTH PLATTE	NE	41.08	0.512	0.500	0.523	0.543	0.556	0.610	0.638	0.631	0.617	0.625	0.567	0.532
SCOTT'S BLUFF	NE	41.52	0.515	0.506	0.519	0.528	0.542	0.601	0.640	0.638	0.637	0.620	0.556	0.524
COUNCIL BLUFFS	NE	41.12	0.371	0.378	0.395	0.421	0.444	0.458	0.470	0.468	0.464	0.459	0.377	0.354
LAKEHURST	NJ	40.02	0.397	0.404	0.428	0.456	0.467	0.478	0.476	0.483	0.489	0.493	0.444	0.397
NEWARK	NJ	40.42	0.401	0.409	0.432	0.455	0.472	0.483	0.493	0.495	0.499	0.499	0.437	0.391
ALBUQUERQUE	NM	35.03	0.605	0.608	0.639	0.679	0.707	0.725	0.694	0.703	0.717	0.712	0.680	0.630
CLAYTON	NM	36.27	0.599	0.579	0.608	0.625	0.619	0.653	0.637	0.648	0.667	0.680	0.646	0.617
FARMINGTON	NM	36.45	0.595	0.602	0.625	0.655	0.683	0.720	0.691	0.697	0.718	0.706	0.664	0.607
ROSWELL	NM	33.24	0.592	0.602	0.641	0.671	0.685	0.709	0.681	0.683	0.683	0.679	0.645	0.609
TRUTH OR CONSEQUENCE	NM	33.14	0.630	0.634	0.668	0.706	0.713	0.720	0.660	0.675	0.691	0.700	0.690	0.638
TUCUMCARI	NM	35.11	0.601	0.589	0.620	0.640	0.645	0.672	0.655	0.665	0.667	0.666	0.646	0.621
ZUNI	NM	35.06	0.588	0.588	0.611	0.660	0.689	0.706	0.632	0.638	0.690	0.689	0.654	0.608
ELKO	NV	40.50	0.504	0.536	0.572	0.597	0.644	0.681	0.734	0.733	0.743	0.647	0.599	0.550
ELY	NV	39.17	0.565	0.569	0.614	0.626	0.645	0.677	0.684	0.700	0.743	0.713	0.643	0.583
LAS VEGAS	NV	36.05	0.602	0.620	0.668	0.710	0.737	0.751	0.722	0.726	0.			

LOCATION	LAT. (DEG.MIN)	LAT.												
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	
YUCCA FLATS	NY	31 57	0.604	0.601	0.653	0.691	0.718	0.738	0.740	0.738	0.753	0.727	0.665	0.628
ALBANY	NY	42 45	0.361	0.375	0.397	0.425	0.440	0.465	0.484	0.481	0.473	0.453	0.365	0.339
BINGHAMTON	NY	42 19	0.299	0.309	0.344	0.394	0.419	0.452	0.465	0.455	0.453	0.426	0.323	0.270
BUFFALO	NY	42 58	0.278	0.299	0.359	0.419	0.448	0.485	0.499	0.486	0.467	0.437	0.325	0.271
MASSENA	NY	44 56	0.342	0.360	0.408	0.435	0.455	0.478	0.493	0.484	0.470	0.435	0.342	0.310
CENTRAL PARK	NY	40 47	0.365	0.373	0.405	0.429	0.458	0.460	0.472	0.470	0.476	0.471	0.392	0.349
LA GUARDIA	NY	40 46	0.399	0.411	0.436	0.458	0.473	0.485	0.499	0.501	0.502	0.500	0.436	0.395
ROCHESTER	NY	43 07	0.293	0.308	0.366	0.428	0.451	0.488	0.500	0.489	0.471	0.438	0.328	0.273
SYRACUSE	NY	43 07	0.310	0.314	0.360	0.423	0.443	0.478	0.494	0.484	0.474	0.436	0.324	0.277
AKRON-CANTON	OH	40 55	0.314	0.337	0.377	0.427	0.467	0.495	0.500	0.506	0.500	0.479	0.373	0.327
CINCINNATI	OH	39 04	0.342	0.366	0.391	0.435	0.467	0.495	0.495	0.512	0.502	0.499	0.405	0.350
CLEVELAND	OH	41 24	0.291	0.316	0.363	0.426	0.471	0.496	0.512	0.503	0.491	0.464	0.352	0.283
COLUMBUS	OH	40 00	0.325	0.343	0.378	0.423	0.460	0.488	0.491	0.517	0.497	0.488	0.386	0.323
DAYTON	OH	39 54	0.345	0.367	0.395	0.439	0.475	0.504	0.506	0.518	0.510	0.499	0.401	0.338
TOLEDO	OH	41 36	0.328	0.359	0.394	0.437	0.481	0.505	0.518	0.514	0.506	0.490	0.410	0.320
YOUNGSTOWN	OH	41 16	0.287	0.307	0.350	0.403	0.444	0.473	0.486	0.478	0.472	0.454	0.343	0.279
OKLAHOMA CITY	OK	35 24	0.482	0.482	0.509	0.526	0.534	0.580	0.594	0.600	0.568	0.572	0.547	0.499
TULSA	OK	36 12	0.452	0.454	0.475	0.491	0.508	0.546	0.566	0.576	0.543	0.549	0.515	0.468
ASTORIA	OR	46 29	0.292	0.328	0.369	0.410	0.454	0.437	0.494	0.493	0.506	0.436	0.363	0.302
BURNS	OR	43 35	0.402	0.442	0.484	0.528	0.577	0.613	0.691	0.672	0.663	0.592	0.492	0.429
MEDFORD	OR	42 22	0.317	0.398	0.453	0.521	0.570	0.612	0.694	0.678	0.638	0.539	0.396	0.315
NORTH BEND	OR	43 25	0.358	0.391	0.433	0.483	0.522	0.536	0.592	0.576	0.562	0.505	0.432	0.370
PENDLETON	OR	45 41	0.316	0.364	0.414	0.489	0.543	0.577	0.676	0.654	0.637	0.549	0.401	0.330
PORTLAND	OR	45 36	0.280	0.329	0.378	0.426	0.469	0.477	0.575	0.548	0.515	0.436	0.353	0.291
REDMOND	OR	44 16	0.410	0.441	0.491	0.542	0.585	0.615	0.689	0.671	0.656	0.575	0.489	0.410
SALISBURY	OR	44 59	0.293	0.341	0.395	0.444	0.490	0.497	0.604	0.578	0.556	0.454	0.362	0.298
ALLEN TOWN	PA	40 39	0.383	0.394	0.420	0.443	0.458	0.478	0.494	0.489	0.485	0.486	0.416	0.370
ERIE	PA	42 05	0.260	0.309	0.366	0.431	0.461	0.496	0.514	0.465	0.480	0.451	0.323	0.250
HARRISBURG	PA	40 13	0.382	0.393	0.419	0.442	0.462	0.486	0.493	0.489	0.493	0.485	0.417	0.377
PHILADELPHIA	PA	39 53	0.391	0.402	0.427	0.448	0.464	0.487	0.492	0.496	0.496	0.493	0.440	0.390
PITTSBURGH	PA	40 30	0.300	0.321	0.367	0.413	0.448	0.474	0.473	0.477	0.472	0.468	0.367	0.290
WILKES-BARRRE-SCRANPA	PA	41 20	0.340	0.361	0.390	0.422	0.445	0.473	0.489	0.481	0.474	0.479	0.369	0.327
PROVIDENCE	RI	41 44	0.384	0.391	0.409	0.435	0.464	0.477	0.475	0.477	0.481	0.489	0.411	0.379
CHARLESTON	SC	32 54	0.415	0.432	0.472	0.523	0.518	0.501	0.502	0.482	0.455	0.525	0.525	0.453
COLUMBIA	SC	33 57	0.438	0.452	0.484	0.526	0.528	0.528	0.514	0.520	0.517	0.545	0.534	0.471
GREENVILLE-SPARTANSC	SC	34 54	0.432	0.444	0.480	0.517	0.512	0.519	0.511	0.521	0.510	0.541	0.526	0.453
MURKIN	SD	44 23	0.416	0.425	0.460	0.493	0.527	0.565	0.615	0.614	0.588	0.575	0.496	0.422
PIERRE	SD	44 23	0.451	0.454	0.499	0.520	0.553	0.590	0.641	0.647	0.621	0.611	0.535	0.451
RAPID CITY	SD	44 03	0.455	0.467	0.505	0.511	0.531	0.573	0.625	0.635	0.626	0.612	0.547	0.487
SIOUX FALLS	SD	43 34	0.437	0.447	0.470	0.494	0.532	0.564	0.604	0.595	0.577	0.571	0.503	0.439
RATTAN	TN	35 02	0.379	0.398	0.435	0.499	0.502	0.514	0.503	0.513	0.508	0.524	0.467	0.428
KNOXVILLE	TN	35 49	0.407	0.428	0.462	0.499	0.525	0.553	0.550	0.560	0.535	0.554	0.499	0.497
MEMPHIS	TN	35 03	0.407	0.428	0.462	0.499	0.525	0.553	0.550	0.560	0.535	0.554	0.499	0.497
NASHVILLE	TN	36 07	0.357	0.382	0.414	0.473	0.508	0.530	0.528	0.536	0.515	0.525	0.452	0.368
ABILENE	TX	32 26	0.508	0.509	0.553	0.555	0.568	0.601	0.597	0.594	0.564	0.574	0.588	0.535
AMARILLO	TX	35 14	0.575	0.566	0.591	0.616	0.616	0.647	0.636	0.646	0.642	0.648	0.623	0.590
AUSTIN	TX	30 18	0.448	0.465	0.491	0.480	0.512	0.567	0.589	0.582	0.555	0.559	0.515	0.477
BROWNSVILLE	TX	25 54	0.424	0.437	0.481	0.514	0.542	0.587	0.624	0.604	0.563	0.561	0.493	0.439
CORPUS CHRISTI	TX	27 46	0.436	0.454	0.479	0.488	0.523	0.577	0.614	0.596	0.569	0.569	0.510	0.452
DALLAS	TX	32 51	0.458	0.464	0.501	0.491	0.526	0.580	0.592	0.593	0.563	0.562	0.525	0.470
DEL RIO	TX	29 22	0.485	0.491	0.537	0.537	0.511	0.555	0.576	0.582	0.543	0.561	0.539	0.503
EL PASO	TX	31 48	0.608	0.629	0.666	0.710	0.725	0.731	0.685	0.692	0.697	0.707	0.677	0.625
FORT WORTH	TX	32 50	0.448	0.463	0.499	0.498	0.527	0.585	0.602	0.603	0.575	0.569	0.526	0.481
HUSTON	TX	29 59	0.397	0.425	0.444	0.455	0.496	0.520	0.512	0.508	0.507	0.532	0.478	0.417
KINGSVILLE	TX	27 31	0.441	0.458	0.480	0.493	0.523	0.562	0.593	0.575	0.547	0.556	0.503	0.452
LAREDO	TX	27 32	0.463	0.472	0.507	0.512	0.547	0.572	0.599	0.601	0.574	0.563	0.506	0.473
LUBBOCK	TX	33 39	0.588	0.586	0.627	0.656	0.668	0.690	0.673	0.674	0.652	0.656	0.641	0.603
LUFKIN	TX	31 14	0.422	0.450	0.477	0.487	0.521	0.561	0.561	0.563	0.534	0.575	0.516	0.457
MIDLAND-ODessa	TX	31 56	0.586	0.589	0.642	0.659	0.678	0.699	0.667	0.670	0.648	0.658	0.642	0.639
PORT ARTHUR	TX	29 57	0.411	0.440	0.463	0.481	0.523	0.551	0.517	0.523	0.526	0.551	0.493	0.441
SAN ANGELO	TX	31 22	0.513	0.509	0.557	0.555	0.567	0.596	0.593	0.594	0.561	0.572	0.561	0.535
SAN ANTONIO	TX	29 32	0.455	0.471	0.494	0.481	0.530	0.567	0.594	0.585	0.562	0.559	0.518	0.478
SHERMAN	TX	33 43	0.454	0.457	0.486	0.488	0.516	0.574	0.580	0.589	0.566	0.568	0.529	0.481
WACO	TX	31 37	0.448	0.464	0.497	0.534	0.495	0.576	0.595	0.593	0.561	0.559	0.518	0.484
WICHITA FALLS	TX	33 58	0.496	0.498	0.526	0.534	0.562	0.602	0.604	0.601	0.575	0.581	0.555	0.522
BYRDE CANYON	UT	37 42	0.594	0.593	0.630	0.658	0.684	0.716	0.677	0.671	0.722	0.715	0.666	0.617
Cedar City	UT	37 42	0.574	0.566	0.612	0.646	0.688	0.730	0.699	0.697	0.740	0.712	0.651	0.592
SALT LAKE CITY	UT	40 46	0.466	0.511	0.568	0.595	0.661	0.689	0.725	0.713	0.723	0.680	0.583	0.492
MORFOLK	VA	36 54	0.429	0.439	0.474	0.515	0.526	0.540	0.517	0.520	0.519	0.519	0.517	0.455
RICHMOND	VA	37 30	0.408	0.419	0.451	0.483	0.491	0.505	0.495	0.497	0.505	0.502	0.477	0.424
ROANOKE	VA	37 19	0.424	0.428	0.460	0.487	0.492	0.508	0.501	0.503	0.508	0.523	0.495	0.439
BURLINGTON	VT	44 28	0.330	0.347	0.389	0.418	0.443	0.465	0.485	0.479	0.466	0.432	0.323	0.297
OLYMPIA	WA	46 58	0.263	0.310	0.365	0.413	0.462	0.456	0.542	0.513	0.502	0.401	0.332	0.270
SEATTLE-TACOMA	WA	47 27	0.267	0.310	0.371	0.427	0.486	0.485	0.637	0.538	0.502	0.420	0.338	0.256
SPokane	WA	47 38	0.316	0.382	0.456	0.495	0.544	0.561	0.669	0.647	0.630	0.602	0.403	0.325
Whidbey Island	WA	48 21	0.295	0.344	0.407	0.448	0.500	0.490	0.563	0.534	0.522	0.432	0.376	0.312
YAKIMA	WA	46 34	0.346	0.366	0.406	0.482	0.524	0.568	0.583	0.667	0.652	0.639	0.554	0.450
EAU CLAIRE	WI	44 52	0.394	0.432	0.454	0.461	0.474	0.503	0.532	0.528	0.500	0.487	0.396	0.365
GREEN BAY	WI	44 29	0.386	0.415	0.457	0.464	0.484	0.513	0.532	0.527	0.506	0.478	0.402	0.357
LA CROSSE	WI	43 52	0.400	0.430	0.451	0.458	0.482	0.512	0.535	0.539	0.511	0.494	0.415	0.374
MADISON	WI	43 08	0.415	0.443	0.460	0.447	0.489	0.524	0.543	0.549	0.528	0.511	0.410	0.378
MILWAUKEE	WI	42 57	0.383	0.403	0.440	0.460	0.496	0.531	0.551	0.5				