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Thomas L. Stoffel

Air Resources Laboratories
Silver Spring, Maryland
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ABSTRACT

The results of an analysis of simultaneous measurements of incident solar radiation from six locations in metropolitan St. Louis, Mo. are described. The measurements, part of the EPA-sponsored Regional Air Pollution Study, were taken continuously from September 1975 through March 1977 with pyranometers with all-wave and 395-nm and 695-nm cutoff filters. The objective of the report is to document typical urban-rural variations of incident solar radiation.

Atmospheric pollutants over the center of metropolitan St. Louis reduced incident all-wave solar irradiation by about 3%. Differences between urban and rural irradiation were about 1% greater than average during winter and 1% less than average in summer. At two suburban sites, the irradiation depletion averaged 1% and 2% for summer and winter seasons, respectively. Also, the ratios between stations for the complete experiment, under all conditions, were similar to those for cloudfree conditions. Thus, any variations in cloudiness over the network evidently were not of sufficient magnitude to affect the grand average irradiation distribution over the network.

The comparisons were stratified according to wind direction and speed, visibility, time of day, and day of the week; only wind direction had a clear and significant effect on the interstation ratios. For cloudless days during the complete experiment two suburban sites and a rural site north of the city received about 3.5% more relative irradiation with north than south winds. The explanation for this wind direction effect is that pollutants were advected from major sources near the city center. The two urban sites exhibited only about 1% change due to north-south wind differences. The interstation comparisons for all days during the complete experiment were also partitioned by wind direction. With north winds, the suburban and northern rural sites showed about 2% to 3% more relative irradiation on all days than on cloudless days for both the summer period and the complete experiment. Finally, a climatology is presented of hourly measured irradiation averaged over all network sites during the experiment.

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URBAN-RURAL SOLAR RADIATION MEASUREMENTS IN ST. LOUIS, MISSOURI

1. INTRODUCTION

The difference between solar radiation measured at an urban site and that at a nearby rural site depends on such factors as atmospheric pollutants, cloudiness, and moisture content. Variations in cloudiness are perhaps the most influential, even over relatively short distances. Of pollutants, particulates have the greatest impact, although gaseous pollutants also contribute. Nitrogen dioxide and ozone, in particular, have absorption bands within the solar spectrum. Water vapor concentrations are determined primarily by larger-scale natural processes but potentially can have a small effect. Variations in surface features that affect albedo, and thus the diffuse solar component, also play a minor role, except for their potential effect on snow cover.

Simultaneous measurements of incident solar radiation at six locations in metropolitan St. Louis, Mo. were made as part of the Regional Air Pollution Study (RAPS) sponsored by the U.S. Environmental Protection Agency (EPA) (Myers and Reagan, 1976; Schiermeier, 1978). The data presented herein were collected continuously from September 1975 through March 1977 with pyranometers with all-wave and 395-nanometer (nm) and 695-nm cutoff filters. The objective of this report is to document typical variations between urban and rural incident solar radiation derived from the RAPS measurements. The variations, which represent one aspect of urban climatology, have such applications as identification and quantification of urban pollution effects, input to urban-scale diffusion models that rely on local energy budget formulations, design of solar energy systems, and design of space heating and cooling requirements for buildings.

Many articles have described urban-rural solar radiation differences, but most measurements have been made outside of the United States. The subject has been reviewed by Landsberg (1956), Peterson (1969), Oke (1974), and Chandler (1976). Some of the older literature, going back at least 40 years, indicates that typical differences between urban and rural global irradiance[1] are 15% to 20%. The greatest differences have generally been measured at high latitude cities during early morning or late evening in winter (when solar elevation angles are small). However, particulate pollution levels over many U.S. cities have decreased recently as a result of pollution emission controls. Such improvements also have been noted over

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[1] In this report we use the nomenclature recommended by Beckman et al. (1978). Radiant flux per unit area (e.g., instantaneous measurement by a pyranometer) is termed <u>irradiance</u> and has units in Watts area^{-2}. The time integral of irradiance (radiant energy per unit area or quantity of radiation per unit area) is termed <u>irradiation</u> and has units in Joules area^{-2}.

England along with measurements of the subsequent increase in solar flux (Monteith, 1966; Wood, 1973). Recent measurements in Los Angeles during its late-summer autumn smog season show an average urban depletion of global irradiance of only 6% to 8% (Peterson et al., 1978). During these months the average aerosol optical depth over Los Angeles is probably as great as that of any major U.S. city, except during infrequent air stagnation episodes. Previous measurements on 11 summer days at St. Louis, part of an experiment preliminary to this one, showed only a 2% urban irradiation decrease (Peterson and Flowers, 1977).

Radiation measurements from the six locations across metropolitan St. Louis are analyzed for interstation differences during cloudless periods and during all periods. The former analysis primarily yields information on differences between pollutant concentrations. Results from the latter also depend on differences in cloudiness. We compare our results with the extensive results of the METROMEX program (Changnon et al., 1971), which provided information on inadvertent weather modification and the local distribution of precipitation, cloudiness, severe storms, etc., throughout metropolitan St. Louis. The interstation differences are then stratified by wind speed and direction, visibility, time of day, and day of the week. Finally, the network irradiation climatology during the experiment is discussed.

2. DESCRIPTION OF EXPERIMENT

One component of RAPS was a 25-station, monitoring network covering metropolitan St. Louis, Mo. Four rings of six, six, eight, and four stations were established with radii of about 5, 11, 20, and 44 km around a core site in downtown St. Louis (Fig. 1). A basic objective of the RAPS network was to obtain air quality and meteorological information for developing and validating mathematical diffusion models. Rockwell International Corporation was selected as the prime contractor to install and operate the network.

Radiometers were installed at six of the 25 sites during autumn 1974 and remained in operation until March 31, 1977, when network operation ceased. After an extensive formal acceptance test, the network was accepted by EPA in March 1975. A preliminary experiment in 1972 (Peterson and Flowers, 1977) had indicated that large urban-rural differences of incident irradiation should not be expected in the St. Louis area. The six sites chosen were approximately north-south in orientation, so that cross-sections over the metropolitan area could be obtained (Fig. 1). Wind rose climatology of the area indicated that southerly wind flow occurred most frequently and that flow within sectors SE-SW and WNW-NNW predominated. Wind from the sector NNE-ESE occurred most infrequently. A criterion of the sites selected for radiation measurements was that they have an unobstructed horizon; this was not possible within the city center because of many tall buildings.

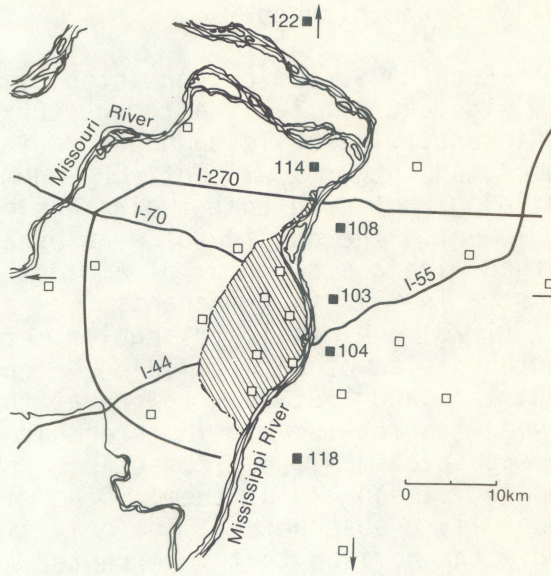

Figure 1. Map of the St. Louis area. St. Louis city limits are hashed. Squares denote RAPS stations. Solid squares indicate stations with radiation measurements.

Site 104, directly east of downtown St. Louis in E. St. Louis, Ill., was the most urban setting. It also had more nearby significant pollution sources than any other site. Site 103 was only a few kilometers northeast of downtown St. Louis and south of the heavy industry of Granite City, Ill. Site 118 was located at the southern edge of the metropolitan area with rural farmland to the south and east. Site 122 was in the most rural location, some 15 km north of Alton, Ill., in the midst of agricultural land. Sites 103 and 114 were classed as (low density) suburban. Some nearby land was cultivated and some was developed.

At each of four of the sites, 103, 114, 118, and 122, five radiometers were installed. These included three Eppley Precision Spectral Pyranometers, an Eppley normal incidence pyrheliometer, and an Eppley pyrgeometer. Pyranometers measured incident global (direct plus diffuse) irradiance on a horizontal surface. They had outer filter hemispheres with different spectral characteristics to give the all-wave, greater than 395-nanometer (nm), and greater than 695-nm irradiance. Pyrheliometers with an aperture of about 5.7° were attached to equatorial mounts; they tracked the sun and measured the direct solar beam. A nine-position filter wheel automatically advanced one position a minute to insert selected filters into the instrument's field of view. The nine positions included blank (zero) and quartz (all-wave) filters, followed by filters with 395, 475, 530, 570, 630, 695, and 780-nm cutoff wavelengths. Pyrgeometers measured incident longwave (3.0- to 50.0-μm wavelength) irradiance. At the other two sites only pyranometers with clear and 395-nm cutoff wavelength filters were installed.

Only data from the pyranometers are analyzed here; measurements from the pyrgeometers were not generally reliable. Available resources were not sufficient to include analysis of pyrheliometer measurements. Pyrheliometer analyses are planned.

Each RAPS station consisted of a small steel building approximately 5 by 3 m wide and 3 m tall, a tower, surrounding fence, sensors, and support equipment. The building housed data acquisition equipment, gas analyzers, pumps, and other equipment. Pyranometers were located on a 2-m stand on the building roof such that their sensing surfaces were above all other rooftop equipment. The outside of each pyranometer outer dome was continuously bathed with a small flow of ambient air to reduce the occurrence of dew and frost. The air flow mechanism was similar to that described by Peterson et al. (1973). A metal, triangular meteorological tower was located on the northern side of each building. Ten-meter towers were installed at sites 108, 114, and 118; 30-m towers at the others. The tower at site 122 was guyed with metal cable in three directions (N, SE, and SW). The two southern guys cast a small, but detectable, shadow on the sensors for 2 to 3 min when the sun passed behind them. Otherwise, the horizons at the sites were generally unobstructed. The only significant obstructions more than 10° above the horizon that intercepted the direct solar beam were three utility poles at station 108. During the winter, these poles cast a shadow over the sensors for 10 to 15 min each day. Data from these periods were corrected with the use of a scheme discussed in Section 3. Station elevations above sea level were: 103-127 m; 104-124 m; 108-130 m; 114-162 m; 118-155 m; 122-180 m. No corrections were made for elevation differences in the results presented herein.

Output voltages from each sensor were increased by about 200:1 with operational amplifiers. On-site data acquisition systems sampled the amplified signals twice per second, from which 1-min average values were obtained. A central processor, linked to each site by telephone lines, interrogated all 25 stations each minute and compiled a comprehensive data set. Sensor and amplifier calibrations were than applied to yield irradiance values. This set of basic, 1-min values was supplied by EPA from the RAPS archive.[1] Also included were hourly average windspeed and direction and ambient surface temperature and dew point at the six radiation sites.

Routine maintenance of the sensors was provided by the contractor. Personnel usually visited each site about twice a week to clean outer instrument domes, check dessicant color, adjust the tracking mechanism of equatorial mounts, check instrument levels, and check air flow over the domes. Maintenance was performed more frequently during summer 1976, when sites were visited approximately every other day.

[1]Requests for RAPS data should be addressed to Director, Meteorology and Assessment Division, ESRL, Environmental Protection Agency, Research Triangle Park, NC, 27711.

The EPA data are based on the original, factory-supplied instrument calibration factors on the International Pyrheliometric Scale (IPS). Immediately after the experiment, the pyranometers and pyrheliometers were recalibrated at the NOAA Solar Radiation Calibration Facility in Boulder, Colo. Instruments were exposed to sunlight out-of-doors and calibrated by intercomparison with NOAA standards. Boulder calibrations were used for all data presented here. In addition, EPA irradiance values were converted to the Absolute Scale by multiplying the IPS data by 1.0256.

Results of the Boulder calibrations are presented in Table 1. Original (C_o) and Boulder (C_B) calibrations, their ratio (R), number of days (N) each sensor was exposed at Boulder, and the standard deviation (σ) of the daily derived calibrations about the overall mean (C_o) are listed. These values were obtained with quartz (clear) filter domes on all instruments. Sensors used in the field with colored domes also were intercompared on a relative basis with their respective cutoff filters in place. Ratios of these derived calibrations to C_B are given in the latter two columns. All but three of the original and Boulder quartz calibrations were within 1.3% of each other, showing good instrument stability with time. Calibrations with the 395-nm cutoff filters in place indicated small, but consistent, differences in the transmission characteristics of these filters. Transmission characteristics of the 695-nm cutoff filters were not so satisfactory, as indicated by the last column of Table 1. Moreover, with the 695-nm filters in place, the Boulder calibration values showed significant within-day variability of more than 10% in some cases. An example is shown in Fig. 2. The three curves represent calibration factors derived from comparison with a Boulder standard instrument as a function of time of day for days 120, 122, and 124 of 1977. Apparently, this non-uniformity of glass opacity over a filter hemisphere progressively worsened while filters were exposed to the St. Louis environment. This added variability of the 695-nm cutoff data reduced the accuracy of the measurements and thus the interstation comparisons. Consequently, analysis of these data is de-emphasized.

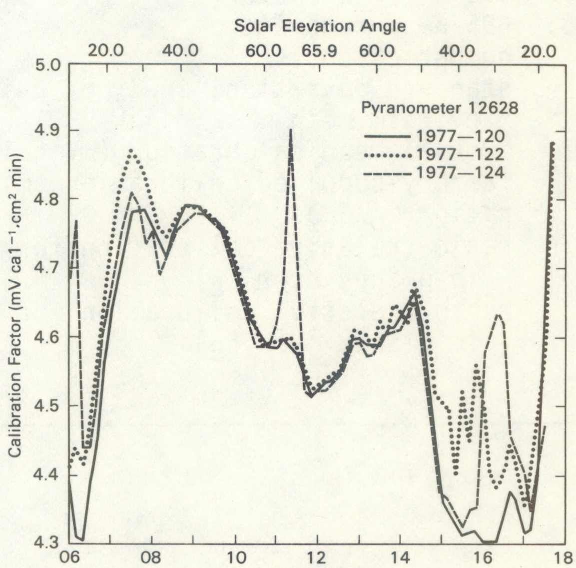

Figure 2. Calibration factor of pyranometer 12628 (with 695-nm cutoff filter) versus time of day derived from outdoor comparison to standard instrument. Three days data are presented.

Table 1. Summary of Instrument Calibrations determined at Boulder.

Site-Instrument	N	σ	C_o	C_B	R	R_3	R_6
103-Q	14	0.31	6.69	6.70	0.999		
103-395	8	0.54	6.93	6.81	1.018	0.985	
103-695	8	0.10	5.07	5.03	1.008		0.996
104-Q	14	0.31	6.83	6.83	1.000		
104-395	8	0.17	7.35	7.32	1.004	1.000	
108-Q	14	0.25	6.13	6.21	.987		
108-395	7	0.17	7.20	7.17	1.004	1.005	
114-Q	13	0.26	5.76	5.70	1.011		
114-395	8	0.50	6.72	6.64	1.012	0.995	
114-695	8	0.26	4.62	4.57	1.011		0.957
118-Q	14	0.25	7.04	7.03	1.001		
118-395	8	0.25	7.12	7.15	.996	0.995	
118-695	8	0.24	4.76	4.68	1.017		0.971
122-Q	14	0.26	5.67	5.61	1.011		
122-395	6	0.16	7.06	7.06	1.000	0.986	
122-695	8	0.38	6.00	5.87	1.022		0.960

KEY:

Q: quartz pyranometer
395: 395-nm pyranometer
695: 695-nm pyranometer
N: number of days
σ: standard deviation, in %, of daily derived calibrations about the overall mean
C_B: overall mean calibration (mV cal^{-1} cm^2 min)
C_o: factory-supplied calibration (mV cal^{-1} cm^2 min)
R: ratio (C_o/C_B)
R_3: ratio (relative calibration for 395-nm pyranometer, with colored dome in place, over C_B)
R_6: ratio (relative calibration for 695-nm pyranometer, with colored dome in place, over C_B)

After the calibrations at Boulder, the instruments were further intercompared at the EPA laboratories at Research Triangle Park, N.C. Quartz-dome pyranometers were exposed side-by-side from late June through October 1977. The extensive intercomparisons were stratified by amount of cloudiness and time of day. Detailed results are given in Appendix 1. In general, the North Carolina measurements, like those from Boulder, confirmed overall differences of 1% or less. For a few specific values, however, especially during early morning or late afternoon (low sun), the North Carolina-derived ratios differed by several percent.

Independent amplifiers were used to increase the output voltage from each sensor to the several-volt range. The first amplifiers used had excessive zero drift and were replaced by more stable units in August 1975. Thus, data subsequent to that time have significantly better quality than those obtained previously. Each amplifier was calibrated several times during the experiment. Input voltages from zero to 20 mV were compared to measured output values. Slope and intercept values were computed from a linear-regression, least-squares best fit of the data. The derived slopes (cal cm^{-2} min^{-1} V^{-1}), which include instrument factory calibration factors, are given in Table 2. These values were used by the contractor for data reduction from the time of one calibration until the time of the next. Values in parentheses in Table 2 are the percentage change of slopes from their previous values. Amplifiers at sites 108, 114, 118, and 122 showed little change during the experiment. At site 103, and to a lesser extent at 104, some large changes occurred, which probably added to the variability of those data.

3. DATA REDUCTION AND PROCESSING

The 1-min average irradiances supplied by EPA were processed in five steps. First, they were adjusted for instrument calibrations according to the Boulder intercomparisons, as described above. Second, a measure of amplifier zero drift was obtained from the nighttime (offset) irradiances. For each instrument, each day, the average signal was calculated from 1-min values for the two hours before morning daylight and after evening darkness. These morning and evening offsets were averaged and their difference from zero subtracted from all irradiances for that instrument-day. However, if the morning and evening offsets differed by more than 0.015 cal cm^{-2} min^{-1}, if the standard deviation of either offset exceeded 0.01 cal cm^{-2} min^{-1}, or if neither offset could be calculated because of missing data, all data for that instrument-day were deleted.

The third adjustment to the EPA data was the deletion of obviously erroneous data. Plots of the 1-min values for each day were scanned to identify bad data caused by amplifier malfunction, dew or frost on domes, or other problems. Fourth, the plots were also used to determine when the instruments were shaded from direct sun at site 108 by nearby telephone poles. When clouds did not obscure the sun and the time of shadow could be identified, the data were reconstructed by linear interpolation between unaffected points. During cloudy periods, influence of the poles could not be detected

Table 2. Summary of Amplifier Calibrations. Entries are slopes (cal cm^{-2} $min^{-1}V^{-1}$) of the linear transfer equations used to convert amplified voltages to irradiance. Values were determined from amplifier calibrations on the specified dates and factory-supplied instrument calibrations. The percentage change from the previous calibration is listed (in parentheses) below the slope value.

Date	Station 103	Station 104	Station 108	Station 114	Station 118	Station 122
	Quartz Pyranometer					
7/75	.3695	.3567	.3929	.4338	.3481	.4343
6/76	.3731	.3549	.3910	.4286	.3469	.4321
	(1.0)	(-0.1)	(-0.5)	(-1.2)	(-0.3)	(-0.5)
11/76	.3501					
	(-6.2)					
12/76	.3619	.3600				
	(3.4)	(1.4)				
3/77	.3659	.3572	.3902	.4291	.3460	.4317
	(1.1)	(-0.8)	(-0.2)	(0.1)	(0.3)	(-0.1)
	395-nm Pyranometer					
7/75	.3575	.3354	.3414	.3696	.3443	.3468
6/76	.3524	.3318	.3413	.3655	.3411	.3454
	(-1.4)	(-1.1)	(0.0)	(-1.1)	(-0.9)	(-0.4)
11/76	.3561					
	(1.0)					
12/76	.3444	.3299				
	(-3.4)	(-0.6)				
3/77	.3569	.3365	.3408	.3649	.3411	.3455
	(3.6)	(2.0)	(-0.1)	(-0.2)	(0.0)	(0.0)
	695-nm Pyranometer					
7/75	.4867			.5376	.5261	.4146
5/76	.4970			.5357	.5223	.4132
	(0.5)			(-0.4)	(-0.7)	(-0.3)
11/76	.4838					
	(-2.7)					
3/77	.4873			.5346	.5210	.4131
	(0.7)			(-0.2)	(-0.2)	(0.0)

on the plots. Finally, the 1-min data were combined to form hourly averages when no more than five values were missing. This strict criterion was necessary since a research objective was to compare measurements taken simultaneously at different sites.

The derived hourly average irradiances derived from these five steps served as the basic set of data for the analyses in this report.[1] Data begin at day of the year (DOY) 244 (September 1), 1975 (after installation of improved amplifiers) and continue through DOY 90 (March 31), 1977, when the RAPS network operation ended. Data are lacking for the last 22 days of 1975; otherwise they are continuous. The data were processed and analyzed in blocks: DOY 244-343, 1975; DOY 1-100, 1976; DOY 101-200, 1976; DOY 201-300, 1976; DOY 301-366, 1976; DOY 1-90, 1977.

A summary of missing hourly values for each instrument is given in Table 3. Nine of the instruments had valid hourly data more than 80% of the time. There were several periods of extended instrument outages. All instruments at site 114 had many missing data from DOY 256-297, 1975, because a data acquisition malfunction led to reporting of less than 55 min per hour. The quartz-dome pyranometer at site 114 also was frequently inoperative from DOY 329, 1976, to DOY 65, 1977, because of an amplifier problem. The 395-nm instrument at site 104 had an unstable amplifier offset from DOY 301-348, 1976.

This analysis emphasizes site-to-site differences during all periods and during those times when all six sites had cloudless skies. The 1-min daily plots, along with hourly meteorological observations at St. Louis Lambert Field (22 km northwest of site 103), Civic Memorial Airport near Alton, Ill. (17 km northeast of site 114), and Bi-State Parks Airport near E. St. Louis, Ill. (4 km south of site 104) were used to determine cloudless periods. For the 556 total days of data, 162 days had at least one hour between sunrise and sunset with clear skies at all sites; 1339 cloudless hours occurred on those days, an average of 8.3 hours per day. The distribution of clear days and the average number of clear hours per day were consistent during the two years, but slightly more clear hours occurred per day during autumn. During winter the distribution of clear hours through the day was uniform. During summer two to three times more clear hours occurred before noon than after, because of frequent convective cumulus clouds during early afternoon.

Intersite irradiation comparisons are treated here in two basic ways. First, the quantity of radiation per unit area (irradiation) at pairs of sites is calculated day-by-day for all hours when both sites have valid data. Since only two sites are compared at a time, the effects of missing data are minimized. By summing the incident irradiance over a day, or over a group of days, those hours with greatest radiation have most influence on the site-to-site comparisons. Ratios of such irradiation at one site to another will be

[1]These hourly data are available from National Climate Center, NOAA, Asheville, N.C.

Table 3. Percentage of hourly irradiation values missing from data set used for this analysis. Data are given for each pyranometer (Quartz, 395-nm, and 695-nm filters) at each site for six periods during the experiment.

Day of Year	Station	103			104		108	
	Instrument	Q	395	695	Q	395	Q	395
244-343 (1975)		15.8	17.3	15.4	13.0	12.6	23.3	23.7
1-100 (1976)		17.5	21.0	16.3	11.9	10.5	18.2	18.0
101-200 (1976)		11.9	13.4	10.3	12.2	12.5	12.5	13.5
201-300 (1976)		11.4	12.1	10.5	7.3	9.2	19.7	18.3
301-366 (1976)		10.7	18.2	14.7	11.3	54.9	14.0	13.8
1-100 (1977)		16.8	20.7	16.1	11.3	19.2	14.6	15.3
Complete Experiment		14.2	17.0	13.8	11.2	17.3	17.3	17.4

Day of Year	Station	114			118			122		
	Instrument	Q	395	695	Q	395	695	Q	395	695
244-343 (1975)		52.0	51.9	51.3	19.6	19.4	19.0	16.5	16.6	15.1
1-100 (1976)		16.6	14.2	15.2	19.3	20.1	22.8	28.3	24.7	25.3
101-200 (1976)		24.1	20.4	22.4	27.5	27.7	29.3	11.9	11.8	11.5
201-300 (1976)		18.8	19.2	20.7	12.3	12.1	13.3	11.6	11.6	11.7
301-366 (1976)		57.1	10.7	10.6	25.6	26.5	24.6	9.2	8.2	7.9
1-100 (1977)		42.6	3.5	3.1	7.6	7.8	8.0	16.3	15.6	15.1
Complete Experiment		33.5	21.0	21.6	18.3	18.6	19.3	16.1	15.2	14.9

referred to as "ratios of irradiation sums." Second, the intersite differences are determined on an hourly basis. For each hour when at least five of the six locations had valid data, the ratio of average irradiance at each site to that at site 118 is calculated. If 118 was missing, site 122 is used as reference. Site 118 was chosen as the primary reference location site because its data quality was judged best of the two most rural sites. Data from the one-hour periods after sunrise and before sunset were not analyzed since the small values at those times could potentially give unrepresentative ratios. This technique of computing hourly, site-to-site ratios gave equal emphasis to each hour of the day. Ratios computed by this second method will be referred to as "ratios of hourly irradiance."

4. INTERSTATION DIFFERENCES -- CLOUDLESS PERIODS

A summary of the interstation ratios is presented in Table 4 for all cloudless periods. The average ratio to the reference site (118) is given for each station and instrument and for each block of data. Results from the two methods of analysis (irradiation sums and hourly irradiance) are presented separately (upper and lower sections). The upper half of the table gives ratios of irradiation sums for each data block when each site together with 118 had valid data. The number in parentheses under each ratio is the number of hours of measured irradiance that comprise the ratio. For the quartz pyranometers, the grand average ratios are based on about 140 kJ cm^{-2} of irradiation measured during the total experiment. The lower half of Table 4 was compiled from ratios of hourly irradiance at each site to that at site 118. For each data block and the complete experiment, the average ratio is given for the number of hours (in parentheses) of comparable measurements, regardless of the time of day or number of hours per day of data.

Transmission characteristics of the 695-nm cutoff filters were discussed in Section 3. From the instrument intercomparisons at Boulder, transmission was shown to vary over the filter hemispheres. Therefore, data from the pyranometers with 695-nm filters are presented for information and will be discussed only briefly. Although the "695" site-to-site ratios for the complete experiment for sites 122/118 agree well with similar ratios for the other instruments, at site 114 the "695" ratios are higher than those from the other instruments. The large, within-day variations of the 695 calibration factors were smoothed for these many-hour averages, but became increasingly important for analyses over shorter time scales.

The 395-nm cutoff filter pyranometers measured much the same energy as did the quartz filter pyranometers. Typically, their signals differed by about 5% to 7%, depending primarily on cloudiness and solar zenith angle. Throughout the experiment, the quartz and 395 ratios agreed well at some sites (114, 122) but differed significantly at others (103, 108). The causes of these discrepancies are not clear: they could have resulted from instrumental and/or amplifier errors as well as from actual atmospheric phenomena.

Table 4. For cloudless periods only, summary of ratios of A. Irradiation Sums (upper) and ratios of B. Hourly Irradiance (lower), both referenced to site 118. Numbers in parentheses give the hours of comparable measurements used to compute the ratios in each category. Interstation differences are summarized by station, instrument type, and data blocks.

Day of Year	Quartz Pyranometers					395-nm Pyranometers					695-nm Pyranometers		
	103	104	108	114	122	103	104	108	114	122	103	114	122
A. IRRADIATION SUMS													
244-343 (1975)	0.974	0.965	0.976	0.979	0.984	0.953	0.967	0.945	0.984	0.980	0.905	0.966	0.975
	(125)	(140)	(126)	(69)	(136)	(121)	(136)	(128)	(68)	(133)	(143)	(76)	(156)
1-100 (1976)	0.980	0.970	0.989	0.987	0.987	0.959	0.974	0.959	0.987	0.983	0.962	1.018	0.989
	(123)	(123)	(124)	(127)	(115)	(127)	(130)	(129)	(130)	(117)	(136)	(136)	(121)
101-200 (1976)	0.991	0.969	0.990	0.996	1.007	0.973	0.958	0.975	1.000	1.009	0.963	1.019	0.998
	(157)	(154)	(155)	(144)	(153)	(153)	(152)	(154)	(145)	(151)	(164)	(153)	(161)
201-300 (1976)	0.995	0.955	0.985	0.987	0.999	0.948	0.953	0.972	0.991	1.002	0.966	1.021	0.997
	(181)	(186)	(176)	(168)	(176)	(182)	(186)	(175)	(168)	(177)	(185)	(171)	(182)
301-366 (1976)	0.975	0.914	0.982	0.984	0.975	0.926	0.882	0.957	0.986	0.973	0.962	1.004	0.982
	(81)	(83)	(79)	(47)	(84)	(78)	(48)	(77)	(73)	(78)	(109)	(103)	(109)
1-90 (1977)	0.965	0.945	0.984	0.994	0.994	0.926	0.900	0.972	0.993	0.995	0.960	1.018	0.998
	(101)	(93)	(103)	(65)	(96)	(128)	(108)	(117)	(117)	(99)	(115)	(131)	(119)
Complete Experiment	0.982	0.956	0.985	0.989	0.993	0.950	0.948	0.965	0.991	0.993	0.953	1.012	0.990
	(768)	(779)	(763)	(620)	(760)	(769)	(760)	(780)	(701)	(755)	(852)	(770)	(842)
B. HOURLY IRRADIANCE													
244-343 (1975)	0.970	0.968	0.971	0.977	0.988	0.950	0.966	0.942	0.974	0.979	0.915	0.973	0.986
	(145)	(169)	(156)	(71)	(160)	(143)	(163)	(153)	(72)	(157)	(158)	(78)	(176)
1-100 (1976)	0.978	0.971	0.989	0.988	0.986	0.959	0.974	0.959	0.985	0.979	0.968	1.018	0.990
	(138)	(146)	(140)	(145)	(128)	(135)	(147)	(137)	(143)	(127)	(130)	(133)	(114)
101-200 (1976)	0.991	0.975	0.993	0.997	1.002	0.977	0.972	0.974	0.996	0.998	0.976	1.014	0.994
	(148)	(145)	(147)	(128)	(141)	(144)	(141)	(146)	(131)	(138)	(143)	(127)	(138)
201-300 (1976)	0.992	0.955	0.988	0.985	0.997	0.947	0.956	0.973	0.989	0.997	0.976	1.020	0.995
	(200)	(212)	(190)	(181)	(196)	(203)	(213)	(190)	(182)	(198)	(201)	(182)	(197)
301-366 (1976)	0.959	0.915	0.976	0.975	0.965	0.922	0.875	0.944	0.973	0.966	0.966	0.999	0.976
	(98)	(97)	(89)	(46)	(98)	(98)	(45)	(90)	(92)	(98)	(100)	(92)	(100)
1-90 (1977)	0.962	0.953	0.979	0.990	0.991	0.928	0.925	0.968	0.990	0.989	0.971	1.016	0.993
	(142)	(152)	(154)	(102)	(140)	(132)	(149)	(153)	(162)	(140)	(144)	(162)	(147)
Complete Experiment	0.979	0.960	0.984	0.988	0.991	0.950	0.956	0.963	0.987	0.988	0.963	1.012	0.990
	(871)	(921)	(876)	(673)	(863)	(855)	(858)	(869)	(782)	(858)	(876)	(744)	(872)

The Table 4 results are similar regardless of which analysis method was used. The grand average ratios for the complete experiment for quartz pyranometers differ by no more than 0.004 between the two methods for any site. For individual data blocks, like ratios between methods are somewhat greater but still small. This agreement is surprising since the hourly irradiance analyses give equal weight to each hour of comparison data regardless of time of day, whereas the irradiation sums are weighted toward those (midday) hours with greatest energy.

To estimate the average irradiation at each site relative to that at 118 for the complete experiment, the ratios for quartz and 395 instruments were combined for each analysis method. Results are given in Table 5. Corresponding values of the two analysis methods are again very close to one another; maximum difference is only 0.006. There is an increasing progression of grand average ratios from the most urban to most rural locations, which are also the most southern to the most northern non-reference sites. Combining all values for sites 103 and 104, the two truly urban locations, an average urban-rural irradiation depletion of 4% is obtained relative to reference site 118. Combining the two suburban sites yields a depletion of about 2%. The rural location to the north (122) had less than 1% less incident irradiation than 118. Much of the 122-118 difference can be explained by the natural winter north-south gradient of mid-latitudes.

The distributions of interstation ratios of daily irradiation at sites 104 and 122 to that at site 118 are shown in Fig. 3. The histograms give the number of days of occurrence of interstation ratios in intervals of 0.025 on cloudless days during the complete experiment. These two sites, the most

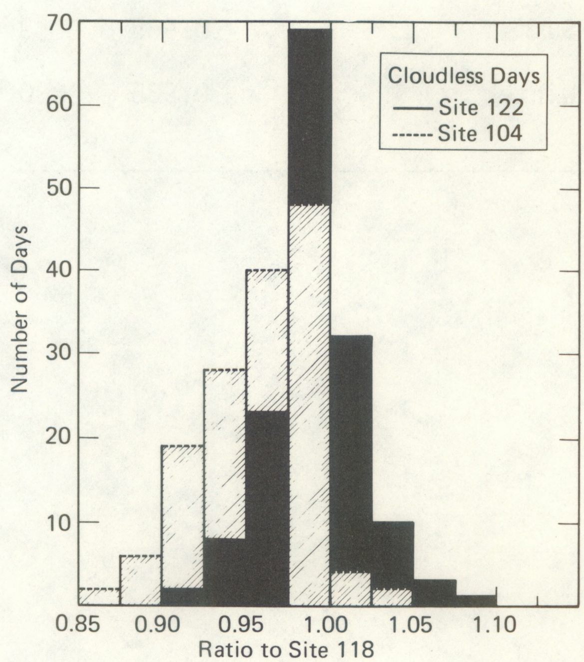

Figure 3. Histograms showing distribution of ratios of daily irradiation at sites 104 and 122 to that at site 118 for cloudless days during the complete experiment.

Table 5. For cloudless periods only, average ratios of irradiation at each site to irradiation at site 118, as obtained by two analysis methods separately for the complete experiment, summer, and winter for quartz and 395 pyranometers combined. Station order is from most urban (104) to most rural (122).

Analysis Method Period	Station 104	Station 103	Station 108	Station 114	Station 122
IRRADIATION SUMS					
Complete Experiment	0.952	0.966	0.975	0.990	0.993
Summer	0.959	0.977	0.981	0.994	1.004
Winter	0.931	0.955	0.974	0.989	0.985
HOURLY IRRADIANCE					
Complete Experiment	0.958	0.965	0.974	0.988	0.990
Summer	0.965	0.977	0.982	0.992	0.999
Winter	0.936	0.951	0.969	0.984	0.979

urban and most rural of the five, were selected for this presentation to highlight the urban-rural variability of incident irradiation. On only six days did the irradiation at site 104 exceed that at 118. The 104-118 daily ratios show a steady decrease of values less than 1.0. In contrast, the 122-118 ratios have a sharp maximum in the 0.975 to 1.0 interval with similar distributions above and below that interval. Another indicator of the day-to-day variation of the interstation ratios is the standard deviation about the mean of the complete experiment mean. At site 104 this standard deviation was about 0.03, at site 103 about 0.02, and at the other three sites about 0.025.

A seasonal urban-rural effect is also evident from the Table 5 information. The summer data are from DOY 101-300, 1976; the winter statistics were computed from DOY 1-100 and 301-366, 1976, and DOY 1-90, 1977. The 1975 measurements were not used. All sites had more radiative depletion, relative to 118, during winter than summer. This can be ascribed to the greater solar path length through the atmosphere during winter, which increases the effective optical density of air pollutants at those times. Averaging the two urban locations yields an overall urban-rural, cloudless-sky difference of 3% during summer and 5% during winter. The two rural sites had practically identical incident summer irradiation.

A natural north-south gradient of daily solar irradiation across the midwestern United States is evident in both winter and annual climatological statistics (Baldwin, 1973). During summer this gradient is practically nil in the vicinity of St. Louis. Based on simple radiative calculations and interpolations from Baldwin's maps, the winter gradient is about 1% across the RAPS network from sites 118 to 122 (0.6° latitude). Thus, somewhat more than one-half of the measured 118-122 wintertime radiative difference resulted from the natural latitudinal decrease.

5. INTERSTATION DIFFERENCES -- ALL PERIODS

A summary of the interstation irradiation ratios for all time periods is presented in Table 6. It is a companion to Table 4 in that the values were computed identically, except for the different time periods used. The entries are average ratios of incident radiation for a respective site and instrument to the corresponding measurement at site 118 for the six blocks of data. The 695-nm cutoff filter pyranometer data are again presented primarily for completeness; these measurements are less reliable because of the filter transmission characteristics previously discussed.

The lower half of Table 6 (ratios of hourly irradiance) must be interpreted cautiously. These results cannot be directly compared with the irradiation sums in the upper half of the Table. For cloudy periods (especially partly cloudy periods) average hourly irradiance often differed widely between sites with a resulting site-to-site ratio far different from 1.0. A few hourly values higher than 8 were measured. Moreover, the site-to-site irradiation differences increased as the distance between the stations increased. This feature has been studied by Atwater and Ball (1978) for the eastern United States and by Suckling and Hay (1976) for western Canada.

Table 6. For all time periods, summary of ratios of A. Irradiation Sums (upper) and ratios of B. Hourly Irradiance (lower), both referenced to site 118. Numbers in parentheses give the hours of comparable measurements used to compute the ratios in each category. Interstation differences are summarized by station, instrument type, and data blocks.

Day of Year	Quartz Pyranometers					395-nm Pyranometers					695-nm Pyranometers		
	103	104	108	114	122	103	104	108	114	122	103	114	122
A. IRRADIATION SUMS													
244-343 (1975)	0.968 (706)	0.969 (738)	0.972 (658)	0.952 (394)	0.975 (711)	0.945 (704)	0.966 (742)	0.940 (658)	0.948 (394)	0.969 (710)	0.923 (726)	0.953 (405)	0.981 (726)
1-100 (1976)	0.982 (729)	0.967 (766)	0.987 (728)	0.991 (731)	0.994 (623)	0.965 (684)	0.971 (769)	0.959 (722)	0.988 (740)	0.986 (655)	0.963 (703)	1.012 (708)	0.996 (632)
101-200 (1976)	0.971 (876)	0.964 (886)	0.996 (893)	0.996 (754)	1.025 (873)	0.954 (857)	0.964 (882)	0.977 (881)	0.993 (794)	1.025 (873)	0.968 (874)	1.014 (759)	1.026 (859)
201-300 (1976)	0.977 (945)	0.951 (976)	0.980 (844)	0.982 (853)	0.995 (936)	0.937 (943)	0.950 (956)	0.961 (864)	0.985 (848)	0.996 (939)	0.949 (956)	1.015 (820)	0.998 (927)
301-366 (1976)	0.956 (395)	0.920 (381)	0.965 (382)	0.968 (118)	0.965 (400)	0.920 (365)	0.885 (206)	0.936 (375)	0.977 (386)	0.965 (397)	0.956 (386)	1.000 (399)	0.973 (412)
1-90 (1977)	0.949 (694)	0.936 (744)	0.987 (714)	0.976 (483)	0.983 (700)	0.921 (657)	0.911 (672)	0.973 (705)	0.985 (802)	0.981 (704)	0.966 (698)	1.014 (807)	0.989 (709)
Complete Experiment	0.970 (4345)	0.955 (4491)	0.984 (4219)	0.983 (3403)	0.995 (4243)	0.943 (4210)	0.951 (4227)	0.962 (4205)	0.984 (3964)	0.993 (4278)	0.954 (4343)	1.008 (3898)	0.998 (4265)
B. HOURLY IRRADIANCE													
244-343 (1975)	0.964 (636)	0.959 (661)	0.988 (597)	0.955 (387)	1.012 (644)	0.942 (641)	0.961 (667)	0.953 (605)	0.955 (392)	1.008 (647)	0.911 (698)	0.952 (415)	1.024 (694)
1-100 (1976)	1.033 (650)	1.009 (670)	1.053 (664)	1.070 (657)	1.128 (586)	1.033 (635)	1.023 (691)	1.030 (675)	1.076 (679)	1.135 (628)	1.092 (704)	1.193 (712)	1.290 (657)
101-200 (1976)	1.017 (911)	0.989 (905)	1.067 (934)	1.070 (833)	1.133 (920)	1.007 (901)	0.989 (904)	1.051 (920)	1.076 (863)	1.148 (926)	1.017 (1002)	1.098 (917)	1.155 (1002)
201-300 (1976)	1.017 (852)	0.988 (871)	1.033 (784)	1.039 (810)	1.070 (855)	0.991 (837)	0.988 (839)	1.011 (780)	1.045 (793)	1.084 (841)	1.010 (816)	1.094 (801)	1.134 (889)
301-366 (1976)	0.968 (326)	0.938 (325)	0.986 (322)	0.985 (188)	1.019 (333)	0.927 (317)	0.906 (218)	0.958 (314)	1.003 (314)	1.033 (327)	0.970 (421)	1.036 (432)	1.044 (447)
1-90 (1977)	0.961 (538)	0.952 (542)	1.010 (558)	0.983 (391)	1.015 (541)	0.941 (567)	0.912 (552)	1.009 (604)	1.020 (631)	1.048 (574)	0.996 (661)	1.049 (747)	1.065 (674)
Complete Experiment	0.999 (3913)	0.978 (3974)	1.030 (3859)	1.033 (3266)	1.072 (3879)	0.981 (3898)	0.974 (3871)	1.010 (3898)	1.040 (3672)	1.085 (3943)	1.003 (4302)	1.083 (4024)	1.125 (4363)

The ratio of irradiance at one site to that at another is a statistic bounded on one side, i.e., it cannot be less than zero, but can be much greater than one. Consequently, even though irradiation sums at two sites may be nearly equal, as the distance between the sites increases with an increase in the variability of the hourly ratios, the average ratio of hourly irradiance increases above 1.0. This arithmetical phenomenon is evident in Table 6. For each instrument throughout the complete experiment the difference between hourly irradiance and irradiation sum increases as the distance between site 118 and the other sites increases. Consequently, we do not believe that the hourly irradiance statistics in Table 6 indicate more radiation (less cloudiness) at the northern sites relative to site 118. The lower half of Table 6 is presented for completeness and to show variations at individual stations; it is not intended to indicate real interstation variations.

The similarity between the values in Table 6 and the corresponding ones in Table 4 is striking. For specific time blocks, more than half of the corresponding entries in the two tables are within 1% of each other; for the complete experiment all but one pair have less than 1% separation. The Table 6 irradiation sums for quartz and 395 pyranometers are combined in Table 7 and stratified for summer and winter periods. The irradiation sums for the three groupings are quite similar to the corresponding Table 5 (cloudless) results. Except for the site 103 summer value, all corresponding ratios differ by no more than 0.01.

The distribution of interstation ratios of daily irradiation at sites 104 and 122 are shown in Fig. 4 for all days during the complete experiment. These histograms are a companion to the cloudless-days results shown in Fig. 3. In contrast to those Fig. 3 distributions, the all-days ratios cover a much wider range. Extreme daily irradiation ratios, reflecting short-term interstation cloudiness differences, exceeded 2.0 and were less than 0.5. Site 104 is much closer to the reference site than is 122 and consequently has a more peaked distribution.

Figure 4. As in Fig. 3, except for all days.

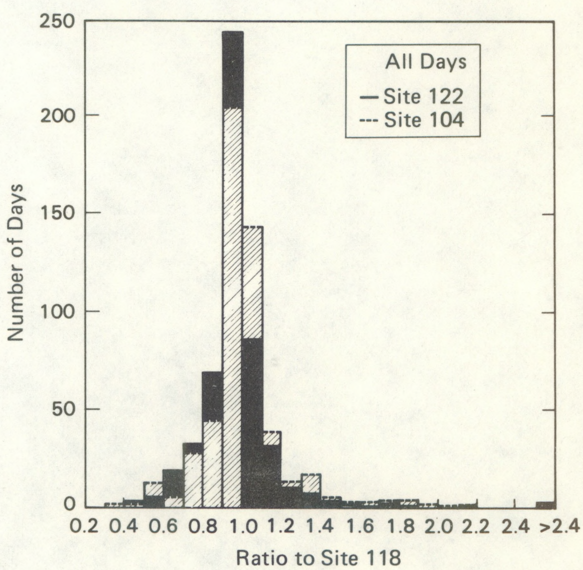

Table 7. For all time periods, average ratios of irradiation sums for the complete experiment, summer, and winter at each site to those at site 118 for quartz and 395-nm pyranometers combined. Station order is from most urban (104) to most rural (122).

Analysis Method Period	Station 104	Station 103	Station 108	Station 114	Station 122
IRRADIATION SUMS					
Complete Experiment	0.953	0.957	0.973	0.984	0.994
Summer	0.957	0.960	0.979	0.989	1.010
Winter	0.941	0.951	0.971	0.985	0.981

The Table 4-Table 6 and Table 5-Table 7 intercomparisons show very good agreement. Analyses of sums of irradiance over approximate 100-day periods, seasons, or the complete experiment show little difference between cloudless and all periods results. Any variation of cloudiness over the network was not sufficiently large to alter the cloudless period results. In addition, the overall urban-rural difference of some 4% was still evident in the all periods results, with slightly more urban attenuation during winter than summer.

These St. Louis solar radiation measurements indicate that metropolitan-scale variations of cloudiness were not sufficiently large to alter the spatial distribution of irradiation averaged over the complete experiment. During the METROMEX program, many measurements were made of cloud-related parameters, including rainfall amount, frequency, and intensity; occurrence of hail and severe local storms; radar first-echoes; and convective cloud heights (Huff and Vogel, 1978; Changnon, 1978; Braham and Wilson, 1978; Braham and Dungey, 1978). All these studies identified urban-oriented anomalies. However, for several reasons these anomalies did not translate into long-term radiative anomalies at our network. First, the METROMEX anomalies (e.g., point hailfall frequencies) were usually centered east (prevailing downwind) of the urban center and radiation monitoring sites. In other words, the radiation sites were not strategically located in terms of the major urban-induced precipitation anomalies. Second, some anomalies (e.g., summer rainfall amount) had a diurnal maximum after 1800 hours, when radiation is small. Third, some precipitation-related parameters, such as number of days per year with thunder, may simply not be indicators of variable areal coverage or vertical density of cloudiness. Fourth, the cloud and radiation measurement periods did not overlap much. METROMEX operated from 1971 to 1975, whereas most of our measurements followed that period. Finally, the METROMEX anomalies may not occur with sufficient frequency to affect irradiation sums over 100 days.

To amplify this last point, recall that the ratios of irradiance sums were computed by summing over each complete data block the irradiances at site 118 separately with each of the other five sites for hours when both reported valid data. Consequently, those periods with high irradiance, i.e., times with no clouds or only thin, scattered clouds, are given the most weight in this analysis. In contrast, for a day with thick, overcast clouds and low radiation, a large difference in irradiation percentage between sites would have a small impact on 100-day irradiation. Thus, the important climatological effect of a well-developed raincell, giving 1.0 cm of rain in the city but only 0.8 cm out of the city during late afternoon, may not significantly affect irradiation.

6. WIND DIRECTION EFFECTS

If pollutants emitted from the metropolitan area have an impact on incident irradiance, the location of that impact ought to depend on wind direction since highest pollutant concentrations occur downwind of sources. To study the effect of wind direction, the station-to-station comparisons were stratified according to wind direction for both the cloudless-days and all-days analyses. The irradiation sums approach was used exclusively. The specific hours used for the cloudless-periods intercomparisons were identified. The prevailing wind direction over the network for each day during these hours was determined from hourly National Weather Service surface observations at Lambert Field and EPA hourly average values at the six sites. Of approximately 150 useable cloudless days during the experiment only 6 had excessively varying wind direction. Six direction classifications of 60° each (330° to 029°, etc.) were originally calculated, but because of relatively few occurrences of northeast and southeast winds, the sectors from 30° to 89° and 90° to 149° and the sectors from 210° to 269° and 270° to 329° were combined. Thus, the cloudless-days analysis used four sectors centered on north, east, south, and west. For the all-days analysis, the Lambert surface observations from 0600 to 1800 were used to classify each day. Wind directions during this period were required to be within a 60° sector centered on each of the four cardinal points for a valid typing. Otherwise, that day was excluded for these directional studies. About one-half of all days during the experiment were used. Since the radiation sites were laid out in a north-south line (see Fig. 1), those directions will be emphasized herein.

Results of the wind direction stratification for cloudless days during the complete experiment are shown in Fig. 5. For each station pair (103-118, 104-118, etc.), irradiation was summed over the cloudless hours of each day when both stations reported valid data. Daily site-to-site ratios of irradiation were computed and then averaged for all similar wind types. An average of 136 days were used for these comparisons, 70 of the days had west winds, 13 north, 24 east, and 29 south.

A distinct difference between the effects of north and south winds is evident for sites 108, 114, and 122. These sites received about 3.5% more irradiation, relative to site 118, with north than with south winds. The suggested reason for this interesting finding is the advection of pollutants from urban sources. With north winds, irradiance at these three sites would

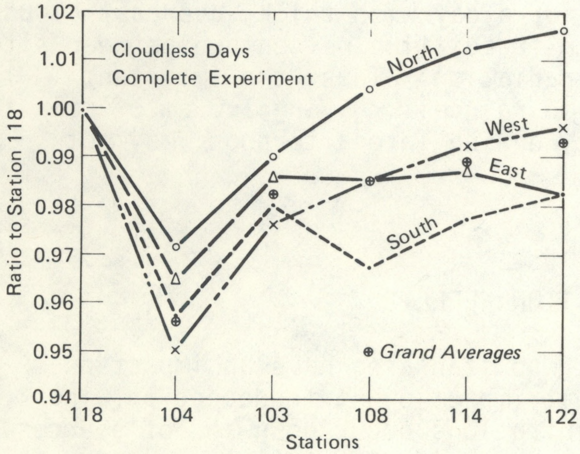

Figure 5. Average of ratios of daily irradiation at five stations to that at station 118 for cloudless days during the complete experiment. For each station results are stratified by wind direction (curves are so labeled).

have had only a small impact from St. Louis pollutants, whereas site 118 would be downwind of the city. The quartz-pyranometer, irradiation sums, complete-experiment results (labeled as Grand Averages) are also shown in Fig. 5. Irradiation variability across the metropolitan area is greater when the data are stratified by wind direction. The Fig. 5 data also show, for north winds, that the three northern sites had more average irradiation than site 118. In contrast, when south winds carry pollutants over these sites they average 2% to 3% less irradiation than 118. The north wind maximum urban-rural difference (122-104) averages about 4.5%, which is similar to that for southerly flow (118-104). Sites 103 and 104, near the city center, show the same relative effect, but have an absolute north-south change of only about 1%. At these sites, the greatest average departure from 118 irradiation occurs with west winds, a windflow associated with a long suburban-urban fetch. The south wind minimum at 108 relative to 103 could be a local urban feature stemming from pollutant emissions from steel manufacturing at Granite City, Ill., within 4 km south of 108.

The cloudless-days wind direction stratification was extended by examining the summer and winter data separately (summer and winter periods were defined in Section 4). An average of 51 days with cloudless periods were used for the summer analyses; 17 days had west winds, 9 north, 12 east, and 13 south. The summer results are shown in Fig. 6. The north-south effect at sites 108, 114, and 122 is again evident but reduced in magnitude (an average difference of about 2%). At 104 and 103 the wind direction effect is small. The maximum urban-rural difference is about 6% for north winds, but only 3% for south winds. Results for the winter periods (Fig. 7) are more difficult to interpret because of the wind direction frequency of occurrence.

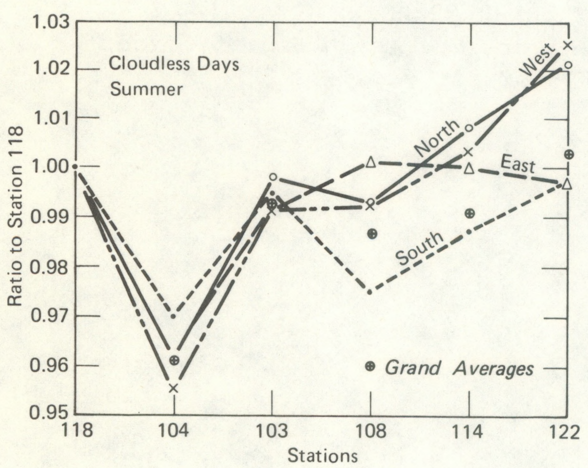

Figure 6. As in Fig. 5, except for summer periods only.

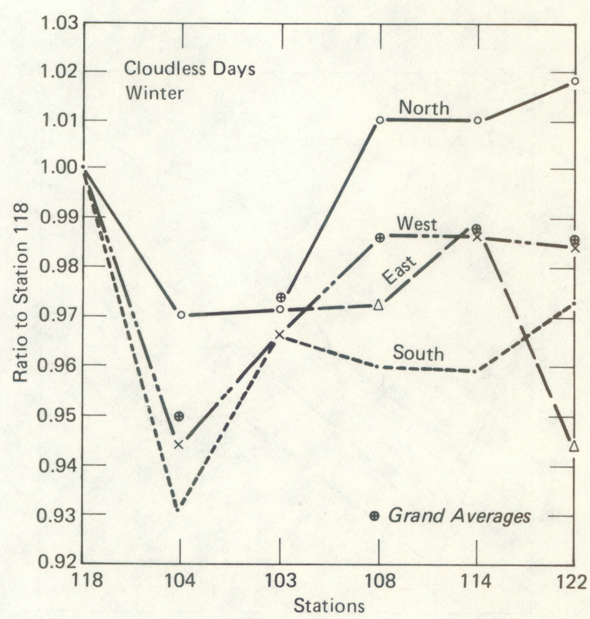

Figure 7. As in Fig. 5, except for winter periods only.

Of an average 61 cloudless days used for the site-to-site comparisons, 42 had west winds, 3 had north, 6 east, and 10 south. Thus, little confidence can be attached to the north and east statistics, and the data are presented primarily for completeness.

Results of the wind direction stratification for all days during the complete experiment are shown in Fig. 8. For each pair of stations, irradiation was summed over all hours when both quartz pyranometers yielded valid data. Daily irradiation for most pairs averaged about 800 to 1000 J cm^{-2}, with higher values, obviously, during summer. For the station pairs, an average of 5% of all days had no available data. Of the remaining days, about 40% could not be typed by wind direction, 20% had west winds, 18% south, 10% east, and 12% north.

At sites 103 and 104 the ratios for all four components for all days are within 1% of those for cloudless days, except for the west component at 103. Thus, addition of days with clouds to the data set had little impact on the overall statistics. The greatest change between the cloudless and all-days analyses occurred at sites 108, 114, and 122 for north winds. Here the all-days analysis showed about 2% to 3% more irradiation relative to site 118. The suggestion of this result is that these three sites had less cloudiness than did 118, in amount and/or thickness. As discussed above, the METROMEX findings did show various cloud and precipitation anomalies downwind (usually to the east) of the city. The suggestion of more cloudiness at 118 than at the northern sites with north winds agrees with those conclusions. Results for east and west wind groups are similar for the two analyses, except at site 122. There, irradiation ratios for all days are 4% higher with east winds, but 4% lower with west winds. The results for north wind days were

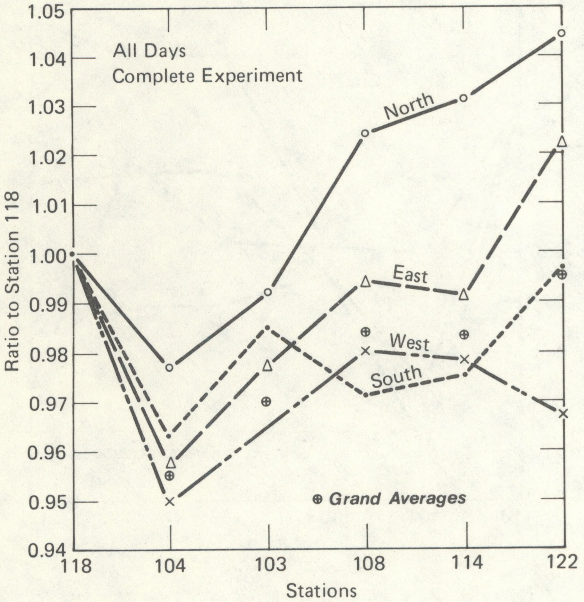

Figure 8. As in Fig. 5, except for all days.

similar to those for cloudless days: sites 108, 114, and 122 all received more irradiation than 118. Moreover, their northwind-southwind difference averaged about 5% relative to 118, which is about 1.5% more than that for cloudless conditions. The Fig. 8 data also show a large urban-rural difference of nearly 7% for north winds with a consistent irradiation decrease from site 122 toward the city center.

The all-days wind direction stratification also included a breakdown by summer and winter periods. The results are shown in Fig. 9 (summer) and Fig. 10 (winter). These seasonal patterns show small departure from the complete experiment results and have some similarity to those for cloudless days. At 103 and 104 little north-south wind dependence of irradiation relative to 118 is observed. Significant north-south wind differences do occur at the other three sites; they are smaller in summer than winter, but are larger than the corresponding results for cloudless days. For summer, the south wind cases have similar absolute values for cloudless days and all days. The north wind all-days data at 108, 114, and 122, however, average about 2% more irradiance than those for cloudless days, again suggesting relatively more clouds at 118. Such conclusions are not possible for winter since the cloudless results are unreliable because of few days with north, east, or south winds.

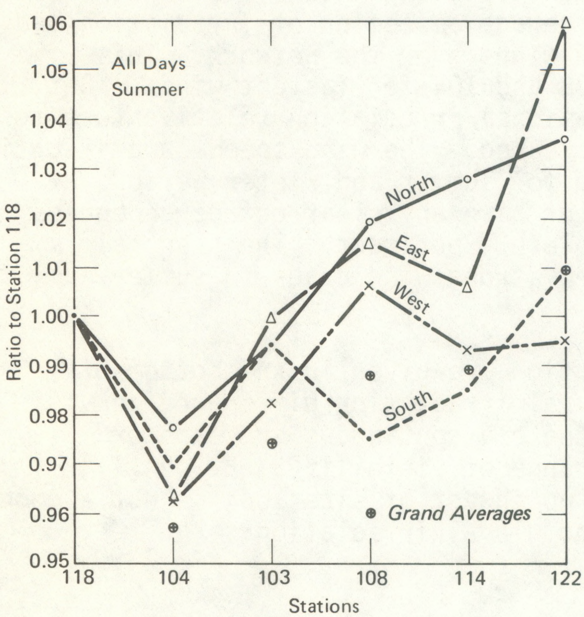

Figure 9. As in Fig. 5, except for all days, summer periods only.

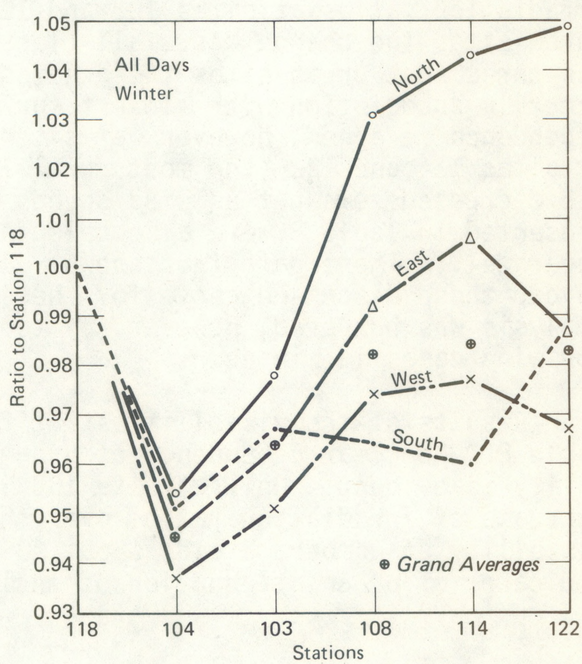

Figure 10. As in Fig. 5, except for all days, winter periods only.

7. WIND SPEED AND VISIBILITY EFFECTS

Most mathematical diffusion models show an inverse dependence between pollutant concentrations and wind speed. Thus, as wind speeds increase, urban pollutants would be expected to decrease, along with urban-rural differences of incident irradiation. Prevailing visibility has been used as an indicator of pollutant concentrations. Consequently, urban-rural visibility differences should translate into irradiation differences. To test these concepts, the station-to-station irradiation intercomparisons were stratified by wind speed and visibility classes. The cloudless-days interstation ratios of daily sums of irradiation were used. In a manner identical to that described above for wind direction (Section 6), average wind speed over the network was estimated during the cloudless hours of each day from the Lambert Field measurements and EPA six-station hourly measurements. Wind speed was classed in three groups: 0 to 2.5 m s^{-1}, 2.6 to 5.0 m s^{-1}, and greater than 5.0 m s^{-1}. Since visibility was not measured by EPA, only the Lambert Field observations were used to specify visibility in three groups: 0 to 9.6 km (6 miles), 9.7 to 16 km (10 miles), and greater than 16 km.

Results of the wind speed and visibility partitioning are shown in Table 8. As the wind increased from low to moderate speeds, irradiation at the two most urban sites (104 and 103) increased relative to that at site 118 by about 2%. A small increase was registered at site 108. This change is in agreement with the concepts discussed in the preceding paragraph. However, for a wind speed increase from moderate to the highest values, average irradiation ratios at sites 103 and 104 decreased slightly. At the other three sites the change was small (less than 0.5%) and inconsistent. Thus, at the three most urban sites the greatest average depletion of irradiation did occur in association with slowest surface winds over the network. This dependence reversed, however, at sites 103 and 104 for fastest winds. But, at sites 114 and 122 (the most rural locations) irradiation relative to site 118 decreased somewhat as wind speeds increased. The wind speed stratifications presented in Table 8 were also calculated for summer and winter periods separately. These data (not shown) did not have any clear-cut dependencies beyond those discussed above for the complete experiment. The seasonal analysis was hampered, however, by too few strong wind cases in summer and low wind cases in winter.

Results of the visibility stratification are given in the bottom of Table 8. No clear dependence of urban-rural irradiation difference on visibility is evident. Only at site 108 is there a continuous increase or decrease of irradiation ratios over the range of visibility. Evidently, visibility at Lambert Field, about 20 km northwest of site 104, is not a good indicator of urban attenuation of incident global irradiation.

Table 8. Average of daily ratios of irradiation sums at five stations to those at station 118 for cloudless periods during the complete experiment. The data are stratified by wind speed and visibility. The number of days used for each interstation comparison is given in parentheses.

	Station 104	Station 103	Station 108	Station 114	Station 122
<u>WIND SPEED</u> (m s^{-1})					
0 - 2.5	0.943 (25)	0.965 (27)	0.977 (27)	0.994 (19)	1.008 (27)
2.6 - 5.0	0.962 (84)	0.983 (80)	0.982 (82)	0.989 (67)	0.990 (75)
> 5.0	0.956 (40)	0.976 (36)	0.985 (42)	0.987 (33)	0.986 (39)
<u>VISIBILITY</u> (km)					
0 - 9.6	0.959 (17)	0.987 (17)	0.971 (17)	0.991 (13)	0.992 (17)
9.7 - 16.0	0.951 (74)	0.976 (68)	0.980 (72)	0.984 (51)	0.995 (72)
> 16.0	0.957 (60)	0.978 (58)	0.987 (60)	0.989 (55)	0.990 (60)

8. TIME OF DAY EFFECTS

When the sun is low in the sky its radiation passes through a relatively long atmospheric path. A given concentration of atmospheric pollutants will cause greater attenuation of incident solar radiation when the path length is longer than when the sun has a higher elevation. By such reasoning, the urban-rural irradiation difference ought to be greater during early morning and/or late afternoon than during midday. A basic assumption for this statement is that the vertically integrated amount of pollutants in the urban-influenced atmosphere does not change significantly during the day. Although this assumption is not generally true, the station-to-station irradiation ratios were stratified by time-of-day to investigate the variability of urban-induced irradiation depletion on a within-day time scale.

The ratios of hourly irradiance were used for this analysis since it was necessary to process the measurements on an hourly basis. The ratio of hourly average irradiance at each site to that at site 118 was calculated for each hour when at least five of the sites reported valid data. In this section, only the cloudless-periods data were analyzed because of the computational problems (discussed above) involved when these ratios are calculated from measurements of all periods; i.e., they are bounded by zero on one side. For those time periods with no clouds over the network, the hourly irradiance ratios were stratified into five time classes: before 0900, 0900 to 1100, 1100 to 1300, 1300 to 1500, and after 1500 local time.

The results of the time-of-day stratification are presented in Table 9. The average of the hourly ratios of irradiance and the number of hours of data comprising those averages are given for each station for the five time classes. The standard deviation about the mean and the 95% confidence interval about the mean were computed by standard statistical procedures (assuming normally distributed values) for each entry in Table 9. The standard deviations ranged from about 0.02 to 0.05. The smallest values tended to occur during midday; four stations had their lowest values during 1100 to 1300. The smaller internal variability of the station-to-station ratios during midday largely stems from the larger irradiance, with smaller relative instrumental errors, at these times. The 95% confidence intervals ranged from about 0.002 to 0.01. Thus, from a statistical viewpoint the differences between many of the values in Table 9 are significant.

In spite of this statistical significance, the patterns of within-day variation are ambiguous. According to the concepts discussed above, the smallest pollutant optical thicknesses would occur during midday. However, not one of the stations had its greatest relative irradiance during 1100 to 1300. At four stations, the highest average ratios occurred with the lowest sun elevations. In contrast, an encouraging aspect of this analysis is that the pair of urban sites (103 and 104) both had greater solar attenuation after 1100 than before that time. These inconclusive results exhibited by the Table 9 data suggest that the effect of variation of pollutant optical path length due to changing solar elevation was outweighed by the within-day variations of pollutant concentrations resulting from variable emission and

Table 9. Average of ratios of hourly irradiance, stratified by time of day, at each station to that at station 118 during cloudless periods of the complete experiment. Numbers in parentheses give the number of hours of comparative measurements for that station and time period.

Station	Time of Day				
	Before 0900	0900-1100	1100-1300	1300-1500	After 1500
104	0.966 (205)	0.968 (174)	0.961 (149)	0.951 (142)	0.945 (115)
103	1.002 (205)	0.981 (167)	0.973 (149)	0.974 (134)	0.978 (109)
108	0.980 (202)	0.982 (170)	0.979 (149)	0.993 (136)	0.999 (111)
114	1.000 (177)	0.993 (140)	0.985 (108)	0.982 (108)	0.984 (97)
122	1.020 (195)	0.999 (169)	0.985 (149)	0.976 (135)	0.974 (113)

meteorological patterns. Alternately, various errors associated with the measurements and data reduction and/or the influence of such other factors as wind direction may have obscured the time-of-day signature in the results.

9. WEEKDAY-WEEKEND EFFECTS

The site-to-site ratios of daily irradiation sums were further stratified by day of the week for measurements during cloudless periods. Two classes were used: Monday to Friday (weekdays) and Saturday and Sunday (weekends). The same irradiation sums from the cloudless hours of each day that were used for the analyses in Sections 6 and 7 were used again here. Previous researchers (Mateer, 1961) have found weekday-weekend differences of urban attenuation of incident irradiance, resulting from the weekly cycle of human activity, wherein pollutant emissions are reduced on weekends.

Results of the day-of-the-week stratification are presented in Table 10. The two urban sites did receive less daily irradiation (relative to site 118) on weekdays than on weekends, but the difference is small (less than 0.5%). At the other three suburban and rural measurement locations the weekday and weekend averages are also close together. However, these sites received slightly more irradiation on weekdays than on Saturday and Sunday. In summary, although a weekday-weekend effect in the center of the city is suggested, the measured effect is too small to be of significance. Futher stratification of these data according to summer and winter seasons did not yield results with any more significance.

Table 10. Average of daily ratios of irradiation sums at five stations to that at station 118 for cloudless periods during the complete experiment. The data are stratified by weekends and weekdays. The number of days used for each interstation comparison is given in parentheses.

Time of Week	Station				
	104	103	108	114	122
Weekends	0.959 (45)	0.981 (41)	0.981 (44)	0.987 (37)	0.987 (44)
Weekdays	0.955 (105)	0.979 (101)	0.983 (105)	0.989 (81)	0.993 (103)

10. NETWORK IRRADIATION CLIMATOLOGY

To summarize the irradiation measured across the network during the experiment, the results are presented in two ways. First, for each hour, observed irradiation was averaged from all stations that reported valid data to give a network average. Hourly values at a site were originally obtained from the basic 1-min measurements whenever at least 55 min of valid data were available. Thus, the network hourly average irradiation was computed with from one to six available values. These hourly averages (J cm^{-2}) for the complete experiment are tabulated in Appendix 2. An entry of 0.0 indicates that none of the six sites reported valid data for that hour. The hourly values are summed to give daily total irradiation (J cm^{-2}) in the most right-hand column of the Appendix 2 tables. The daily totals are starred when one or more hourly values were missing. This summary of hourly measurements is presented here primarily for the use of future researchers.

The second network summary is a graphical presentation of the daily irradiation sums (Figs. 11 and 12). The Appendix 2 values were used directly when all hourly values for the day were valid. If only one hourly value was missing, it was replaced by an average of the preceding and succeeding entries to compute a daily sum. If more than one hourly value was missing, a void was left in Fig. 11 or 12. These figures clearly show an annual cycle

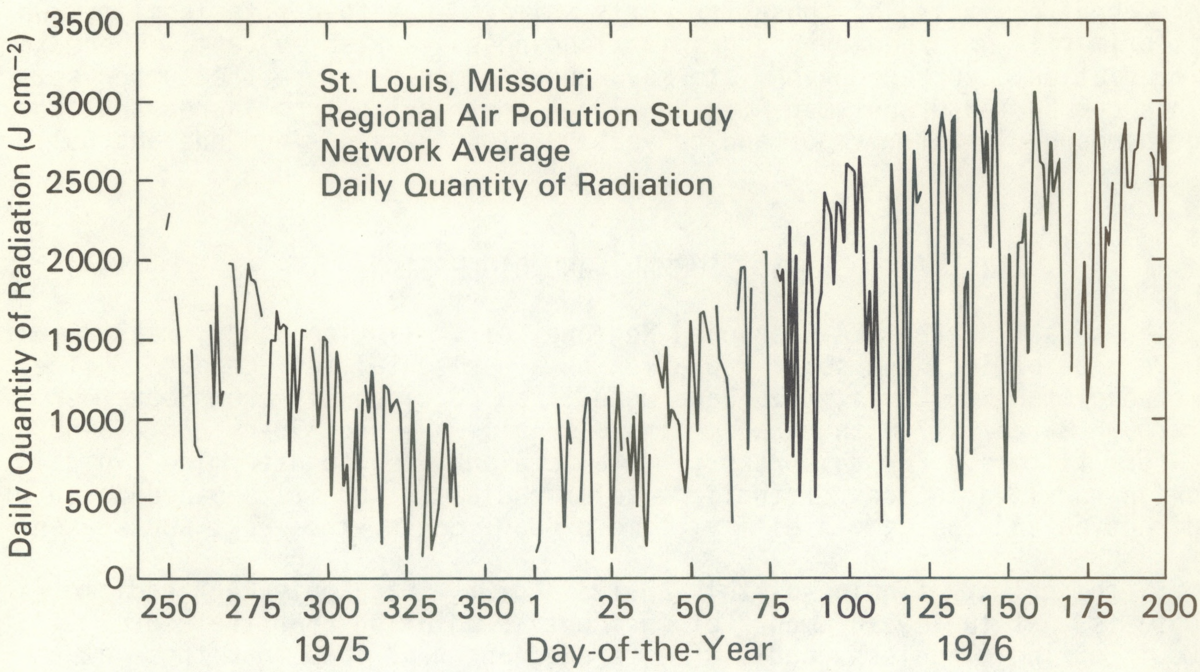

Figure 11. Daily irradiation (J cm^{-2}) averaged over all network sites from DOY 244, 1975, through DOY 200, 1976.

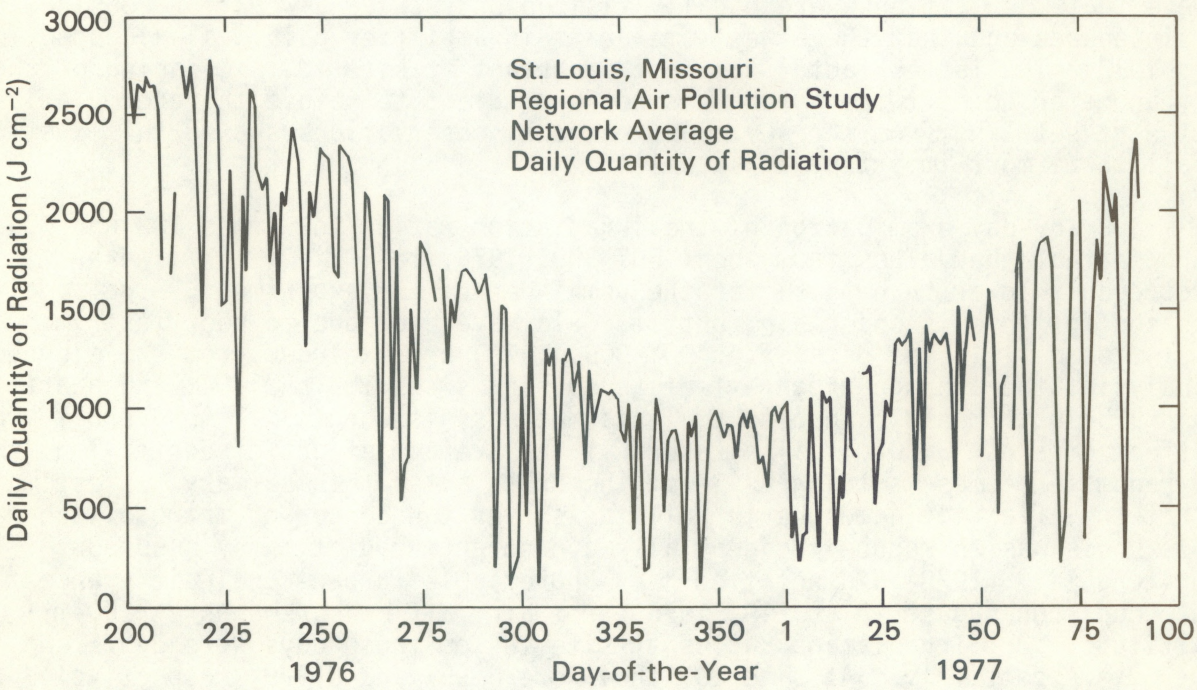

Figure 12. As in Fig. 11, except for DOY 200, 1976, through DOY 90, 1977.

resulting from changing solar declination. Values for cloudless winter days are about one-third of those for early summer. Day-to-day variability, which is primarily governed by changes in cloudiness, is also evident. The maximum irradiation occurred during late May, about a month before the summer solstice. This common feature of mid-American locations results from increasing amounts of atmospheric water vapor and convective cloudiness during June and July.

11. SUMMARY AND DISCUSSION

As part of the EPA-sponsored Regional Air Pollution Study, measurements were made of incident solar radiation on a horizontal surface at six sites in metropolitan St. Louis, Mo. Data were taken continuously from September 1975 through March 1977 with pyranometers with all-wave and 395-nm and 695-nm cutoff filters. For this report, data were analyzed to determine typical urban-rural variations of incident solar radiation and its dependence on wind direction and speed, visibility, time-of-day, day-of-the-week, and season.

The primary finding of this analysis of the St. Louis RAPS radiometric data is that the measurements of incident irradiation near the center of St. Louis during cloudless conditions averaged about 4% less than those at a nearby non-urban location. However, this 4% figure is probably an upper limit to the true average effect of the St. Louis urban atmosphere. In Sections 2 and 3, on network operation and data reduction, we discussed several factors that caused uncertainty about accuracy of the measurements. We believe that the two most important sources of error in this experiment were that the stations were usually visited only twice a week for routine maintenance and that there was some drift in amplifier gain, as evidenced in Table 2. The latter factor was most important at site 103. Cleaning of the pyranometer domes twice a week was not sufficient to remove the accumulation of dirt settling from the sky. Our personal observations showed this dustfall to be most important at site 104.

Day-by-day examination of the irradiation ratios for sites 103 and 104 showed that the values from about DOY 300, 1976, to DOY 50, 1977, were noticeably lower than those for the remainder of the experiment. The specific reason for this is uncertain, but it could have been due to poor instrument maintenance. If the data after DOY 300, 1976, are excluded from the cloudless analysis, the average urban effect (combining sites 103 and 104, the quartz and 395 instruments, and both analysis methods) is about 3%. An overall urban effect of about 3% would also result if the average effect of dustfall on the pyranometer domes is taken as 1% at the urban sites. In summary, we estimate that the effect of atmospheric pollutants over the center of metropolitan St. Louis was to reduce incident all-wave solar irradiation by about 3%. White et al. (1978) did not find "any appreciable" urban-rural differences at St. Louis on August 18 and 19, 1976, from aircraft measurements at 150-m altitude. Our irradiation ratios at site 104 on those days were 0.972 and 0.969, respectively. At site 103 they were 0.997 and 0.999, respectively. Although White et al. did not quantify their results, findings of the two studies are in fair agreement on these days.

In addition to the overall urban irradiation depletion of about 3%, a seasonal effect was also found. The urban-rural differences were about 1% greater than average in winter and 1% less than average in summer. At two suburban sites, the irradiation depletion averaged 1% and 2% for summer and winter seasons, respectively. During all conditions, cloudy as well as cloudless, the interstation ratios for the complete experiment were similar to those for cloudfree conditions. Thus, any variations in cloudiness over the network evidently were not of sufficient magnitude to affect the grand average irradiation distribution over the network.

The urban-rural interstation irradiation comparisons were stratified according to wind direction and speed, visibility, time of day, and day of the week to study the influence of these factors. Only wind direction had a clear and significant impact on the interstation ratios. For cloudless days during the complete experiment the two suburban sites and the northern rural site received about 3.5% more relative irradiation with north than south winds. The obvious explanation for this wind direction effect is that pollutants were advected from major sources near the city center. The two urban sites exhibited only about 1% north-south change. This north-south effect of wind direction was not as pronounced when the data were stratified for the summer season only. The winter results were difficult to interpret because of very few instances of north winds. The interstation comparisons for all days during the complete experiment were also partitioned by wind direction. With north winds, the suburban and northern rural sites showed about 2% to 3% more relative irradiation in the all-days average than in the cloudless-days average for both the summer period and the complete experiment. These results imply that more cloudiness occurred downwind of the city at the non-urban reference station. METROMEX researchers also found various cloud and precipitation anomalies downwind of the city. Most of these anomalies were to the east of the city, however, because of the prevailing westerly winds.

The major findings of this project can be generalized and summarized as follows:

Average Annual Cloudless-Sky Urban Irradiation Depletion	3%
Summer Period	2%
Winter Period	4%
Range of Irradiation Depletion for North vs. South Winds	1%
Average Annual Cloudless-Sky Suburban Irradiation Depletion	1½%
Summer Period	1%
Winter Period	2%
Range of Irradiation Depletion for North vs. South Winds	3½%

The results discussed herein refer to global irradiance measurements. Many theoretical and empirical studies have shown that atmospheric aerosols have a greater effect on the direct solar beam than on global irradiance. Much of the radiation scattered from the direct beam is scattered foreward and reaches the earth as diffuse radiation. Thus, the urban-rural changes in global irradiance presented here, underestimate the corresponding changes of direct beam irradiance. Certain solar energy collectors are designed to concentrate the direct beam and for such applications information on the effects of the urban atmosphere on direct irradiance is needed. The ratio of direct to global irradiance depends on solar elevation, turbidity, water vapor amount, spectral response of the instrument, etc. Thus, it is not possible to make definitive statements about urban-rural direct beam values based on our global irradiance analyses. However, according to the experimental data of Wesely and Lipschutz (1976), direct beam irradiance decreases by roughly 2.5 to 3 times more than global irradiance for a given atmospheric aerosol increase.

12. ACKNOWLEDGEMENTS

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Appendix 1

EPA CALIBRATIONS OF RAPS PYRANOMETERS

Memo from J.H. Rudisill to J.T. Peterson describing calibrations of RAPS pyranometers at the Environmental Protection Agency laboratories at Research Triangle Park, N.C. Tables of relative instrument response as a function of time-of-day and sky condition are also included.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
ENVIRONMENTAL RESEARCH LABORATORIES
Meteorology Laboratory (EPA)-ARL
Research Triangle Park, NC 27711

DATE: April 26, 1978

TO: J. T. Peterson
Chief, A&I Group, GMCC

FROM: J. H. Rudisill
Met. Tech., GRB-ML JHR

THRU: G. C. Holzworth GCH
Chief, GRB-ML

SUBJECT: Comparison of RAPS Quartz Instruments

I have completed the data reduction for the comparison of the RAPS pyranometers with quartz hemispheres. The data period began on June 28, 1977 and ended on November 1, 1977. The RAPS quartz instruments were operated side by side along with my instrument 8660D1 which has a WG295 hemisphere. The calibration factors used for the RAPS quartz instruments and 8660D1 are from the test made on April 22-28, 1977 at the Solar Radiation Calibration Facility, Boulder, Colorado. The factor used is the IPS (English units) scale and units.

When we discussed how this instrument comparison would be conducted, we agreed we would use 0600 LST through 1800 LST hours as the daily comparison period. Because of the sunrise (0501 EST on June 28 and 0637 EST on November 1) and sunset (1935 EST on June 28 and 1720 EST on November 1) and the early morning and evening exposure conditions for each instrument the final daily comparison period used was from 0700 LST to 1700 LST.

Tables I through V contain the instrument comparisons using 0700 LST to 1700 LST as the daily comparison period. Each daily comparison is broken down by hours into four periods: 0701 LST to 1000 LST, 1001 LST to 1400 LST, 1401 LST to 1700 LST and 0701 LST to 1700 LST. Each hour of the daily comparison was grouped according to the sky condition for that hour. Four types of sky conditions were used for this grouping; Clear, Scattered, Broken and Overcast. Clear sky condition consisted of no clouds, less than 1/10 clouds at the middle and high cloud range and thin scattered high clouds. Scattered sky condition consisted of 1/10 to 5/10 total sky cover of clouds in any of the three cloud height ranges, thin broken high clouds and partial obscuration with or without scattered clouds above. Broken sky condition consisted of 6/10 to 9/10 total sky cover of clouds in any cloud height range. Overcast sky condition consisted of 10/10 total sky cover of clouds at any cloud height, 10/10 total sky cover with breaks and total obscuration.

The effects of rain, frost, dew, etc., on the instruments was felt to be equal on each instrument and therefore the comparisons didn't remove any data collected under these conditions. I felt that this way the comparisons were better with respect as to how they were used in the RAPS study and in making data comparisons between the different RAPS sites.

Instrument 12685F3 from RAPS Site 114 was used as the reference instrument for the other five RAPS sites. Instrument 8660D1 was used as the reference instrument for 12685F3. The ratio of each comparison was derived by dividing the $ly\text{-}min^{-1}$ of the test instrument by the $ly\text{-}min^{-1}$ of the reference instrument. The $ly\text{-}min^{-1}$ output for 8660D1 is also included in each table.

The instruments, calibration factor and site used in the RAPS study follows:

Serial No.	(K(IPS) ($mv/ly\text{-}min^{-1}$)	RAPS Site Location	Original K (IPS-EPLAB)
8660D1	4.63	-	-
12685F3	5.76	114	5.70
12633F3	6.13	108	6.21
12686F3	6.83	104	6.83
12686F3	5.67	122	5.61
12691F3	7.04	118	7.03
12632F3	6.69	103	6.70
12634F3	6.84	Trvling Inst.	6.79

Tables I through V data comparison input breaks down as follows:

Total Input: 1130 day hours or 67,800 comparisons for a 100% total.

Clear Sky Condition: 208 day hours or 12,480 comparisons for 18.4% of the total input.

Scattered Sky Condition: 415 day hours or 24,900 comparisons for 36.7% of the total input.

Broken Sky Condition: 254 day hours or 15,240 comparisons for 22.5% of the total input.

Overcast Sky Condition: 253 day hours or 15,180 comparisons for 22.4% of the total input.

Each ratio in each period in Tables I through V are the sum of all comparisons during that period divided by the number of comparisons.

TABLE I

COMPLETE PERIOD REGUARDLESS OF SKY CONDITION.

TIME LST	DAY HOURS	8660D1 ly-min^{-1}	SITE 114	SITE 108	SITE 104	SITE 122	SITE 118	SITE 103	TRVLNG INST.
0701-1000	340	.4853	.9791	1.0088	1.0147	1.0062	1.0071	1.0034	1.0023
1001-1400	455	.8586	1.0068	1.0088	1.0041	1.0020	1.0085	1.0011	1.0009
1401-1700	335	.5050	.9963	1.0161	1.0048	1.0009	1.0158	1.0014	1.0034
DAILY AVERAGE	1130	.6414	.9953	1.0109	1.0075	1.0029	1.0102	1.0019	1.0020

TABLE II

CLEAR SKY CONDITION.

0701-0800	33	.3274	.9875	.9990	1.0081	1.0395	1.0087	1.0055	1.0337
0801-0900	35	.5973	.9748	1.0107	1.0239	1.0072	1.0015	.9982	1.0003
0901-1000	37	.8603	.9864	1.0051	1.0189	1.0045	1.0087	1.0038	1.0065
1001-1100	27	1.0165	.9984	1.0050	1.0084	1.0052	1.0069	1.0024	1.0024
1101-1200	13	1.0804	1.0025	1.0002	1.0061	1.0035	1.0102	1.0020	1.0035
1201-1300	6	1.0562	1.0024	1.0137	1.0055	1.0013	1.0159	1.0024	1.0053
1301-1400	10	.9498	1.0065	1.0063	1.0027	.9976	1.0162	.9985	1.0034
1401-1500	11	.8136	1.0028	1.0168	1.0028	.9964	1.0206	.9975	1.0033
1501-1600	14	.6051	.9964	1.0183	1.0051	.9956	1.0207	.9958	1.0028
1601-1700	22	.3942	.9843	1.0242	1.0095	.9989	1.0289	.9936	1.0042
DAILY AVERAGE	208	.7066	.9899	1.0086	1.0119	1.0085	1.0115	1.0006	1.0082
0701-1000 AVG.	105	.6052	.9829	1.0050	1.0172	1.0164	1.0063	1.0025	1.0130
1001-1400 AVG.	56	1.0237	1.0012	1.0051	1.0065	1.0030	1.0103	1.0016	1.0031
1401-1700 AVG.	47	.5552	.9922	1.0207	1.0066	.9973	1.0245	.9952	1.0036

TABLE III

SCATTERED SKY CONDITION.

0701-0800	33	.3414	.9662	1.0134	1.0236	1.0070	1.0050	1.0076	.9976
0801-0900	32	.6412	.9841	.9971	1.0156	1.0064	1.0019	.9971	.9960
0901-1000	33	.8139	.9894	1.0074	1.0123	1.0081	1.0081	1.0068	1.0035
1001-1100	40	.9993	1.0025	1.0049	1.0067	1.0038	1.0058	1.0019	1.0014
1101-1200	51	1.0929	1.0065	1.0075	1.0048	1.0022	1.0069	1.0013	1.0011
1201-1300	48	1.0656	1.0126	.9990	1.0036	1.0007	1.0084	1.0005	1.0008
1301-1400	45	1.0019	1.0246	1.0110	1.0025	.9997	1.0103	.9889	1.0006
1401-1500	47	.8321	1.0173	1.0124	1.0018	.9979	1.0116	.9993	1.0014
1501-1600	44	.6697	1.0172	1.0126	1.0014	.9944	1.0128	.9955	1.0007
1601-1700	42	.4080	1.0103	1.0203	1.0071	.9988	1.0207	.9995	1.0053
DAILY AVERAGE	415	.6054	1.0052	1.0087	1.0071	1.0014	1.0094	1.0006	1.0010
0701-1000 AVG.	98	.5984	.9799	1.0061	1.0172	1.0072	1.0050	1.0039	.9991
1001-1400 AVG.	184	1.0432	1.0116	1.0056	1.0043	1.0015	1.0079	1.0006	1.0010
1401-1700 AVG.	133	.6444	1.0151	1.0150	1.0033	.9970	1.0149	.9981	1.0024

TABLE IV

BROKEN SKY CONDITION.

TIME LST	DAY HOURS	8660D1 ly-min^{-1}	SITE 114	SITE 108	SITE 104	SITE 122	SITE 118	SITE 103	TRVLNG INST.
0701-0800	16	.2636	.9671	1.0099	1.0155	1.0093	1.0065	1.0039	1.0050
0801-0900	17	.4597	.9818	1.0073	1.0128	1.0094	1.0084	1.0053	1.0042
0901-1000	19	.6969	.9909	1.0074	1.0110	1.0072	1.0077	.9992	1.0017
1001-1100	26	.7821	.9971	1.0087	1.0075	1.0045	1.0067	1.0026	1.0019
1101-1200	32	.8675	1.0121	1.0102	1.0064	1.0039	1.0089	1.0023	1.0020
1201-1300	37	.9041	1.0253	1.0086	1.0021	1.0000	1.0073	.9997	1.0002
1301-1400	32	.7739	1.0047	1.0092	1.0019	.9991	1.0081	1.0002	1.0003
1401-1500	31	.6339	1.0007	1.0115	1.0033	1.0000	1.0123	1.0012	1.0027
1501-1600	26	.5250	.9966	1.0136	1.0045	.9987	1.0132	1.0034	1.0031
1601-1700	18	.2935	.9861	1.0138	1.0026	.9999	1.0119	1.0017	1.0030
DAILY AVERAGE	254	.6700	1.0003	1.0100	1.0058	1.0025	1.0091	1.0017	1.0021
0701-1000 AVG.	52	.4860	.9806	1.0081	1.0130	1.0086	1.0076	1.0026	1.0035
1001-1400 AVG.	127	.8371	1.0110	1.0092	1.0042	1.0017	1.0078	1.0011	1.0010
1401-1700 AVG.	75	.5145	.9958	1.0128	1.0035	.9995	1.0125	1.0021	1.0029

TABLE V

OVERCAST SKY CONDITION.

0701-0800	30	.1205	.9453	1.0254	1.0234	.9977	1.0197	.9900	.9911
0801-0900	30	.2167	.9448	1.0142	1.0045	.9786	1.0061	1.0306	.9919
0901-1000	25	.2965	.9904	1.0097	1.0005	.9975	1.0037	.9909	.9933
1001-1100	22	.3596	.9903	1.0292	1.0031	1.0016	1.0087	.9989	.9979
1101-1200	18	.4111	.9928	1.0098	1.0022	1.0030	1.0087	1.0008	.9985
1201-1300	22	.4201	.9950	1.0181	1.0009	1.0026	1.0078	1.0037	.9989
1301-1400	26	.4047	.9967	1.0113	1.0010	1.0034	1.0089	1.0032	1.0008
1401-1500	23	.3120	.9890	1.0165	1.0056	1.0080	1.0125	1.0075	1.0058
1501-1600	28	.2582	.9731	1.0333	1.0162	1.0200	1.0274	1.0240	1.0090
1601-1700	29	.1509	.9459	1.0059	1.0006	1.0039	1.0059	.9987	1.0014
DAILY AVERAGE	253	.2822	.9785	1.0175	1.0068	1.0013	1.0112	1.0053	.9987
0701-1000 AVG.	85	.2062	.9725	1.0168	1.0100	.9909	1.0102	1.0046	.9920
1001-1400 AVG.	88	.3986	.9939	1.0172	1.0017	1.0027	1.0085	1.0018	.9991
1401-1700 AVG.	80	.2348	.9678	1.0185	1.0075	1.0107	1.0153	1.0101	1.0053

Appendix 2

HOURLY IRRADIATION AVERAGED OVER ALL NETWORK STATIONS

Hourly irradiation (J cm^{-2}) was averaged over all network stations with valid data for each day of the year (DOY) during the experiment. Hourly values were summed to give daily totals (TOTAL). An * indicates that at least one hour of data was missing during daylight period (indicated by a 0.0 entry). Hours listed are beginning times.

HOURLY AVERAGE IRRADIANCE AT ALL RAPS SITES

YR	DOY	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	TOTAL
75	244	0.0	3.7	42.0	109.2	178.8	229.5	275.6	301.5	302.9	279.9	238.5	180.7	111.7	43.4	3.0	0.0	2300.3
75	245	0.0	0.0	43.3	110.1	175.7	234.9	277.8	298.1	0.0	0.0	0.0	0.0	0.0	35.9	2.5	0.0	1178.3*
75	246	0.0	2.6	24.9	75.3	156.3	223.8	274.0	299.9	297.7	261.4	0.0	0.0	99.4	37.5	1.8	0.0	1754.5*
75	247	0.0	1.8	31.1	0.0	0.0	0.0	222.4	0.0	0.0	238.0	179.0	154.5	90.2	28.7	1.2	0.0	946.7*
75	248	0.0	2.5	29.8	87.9	0.0	0.0	229.2	291.7	210.1	178.5	173.4	127.3	75.5	19.3	2.4	0.0	1427.6*
75	249	0.0	2.3	43.2	110.4	178.7	238.5	248.8	272.6	273.6	263.6	242.2	168.8	110.4	39.6	1.6	0.0	2194.4
75	250	0.0	3.2	41.3	109.7	176.9	239.4	285.2	306.5	303.3	279.5	235.7	175.6	106.1	38.4	1.6	0.0	2302.4
75	251	0.0	2.1	38.6	102.2	160.0	0.0	0.0	295.2	285.2	265.9	203.9	137.0	63.8	22.8	.6	0.0	1583.4*
75	252	0.0	2.4	26.8	86.0	148.6	218.4	250.8	276.1	252.0	215.4	117.9	99.8	51.4	31.2	1.7	0.0	1780.5
75	253	0.0	2.5	32.0	68.8	157.2	217.1	253.4	240.3	201.6	144.9	31.6	48.2	57.8	30.0	.5	0.0	1508.0
75	254	0.0	.1	5.4	4.3	14.9	19.8	61.7	131.4	128.0	132.5	86.9	0.0	11.1	2.5	.6	0.0	604.4*
75	255	0.0	1.0	19.2	67.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	87.9*
75	256	0.0	2.5	37.2	115.3	163.6	189.0	209.4	289.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1006.0*
75	257	0.0	2.0	25.9	84.5	155.4	202.5	207.8	214.4	174.9	141.6	97.3	82.5	48.8	13.2	.1	0.0	1450.8
75	258	0.0	1.0	17.2	34.5	84.3	114.6	70.4	91.0	157.5	109.4	96.0	64.1	16.6	3.5	.1	0.0	860.2
75	259	0.0	.3	5.3	9.7	23.7	63.1	102.5	132.2	150.5	115.4	59.2	65.7	33.0	0.0	0.0	0.0	761.3*
75	260	0.0	.5	10.0	36.6	89.2	142.9	99.5	68.6	65.1	135.9	63.4	32.2	16.8	6.2	0.0	0.0	769.1
75	261	0.0	.8	11.5	37.1	66.0	91.2	0.0	0.0	191.8	188.6	133.9	105.4	66.9	15.9	0.0	0.0	909.1*
75	262	0.0	.0	6.2	15.4	18.8	42.0	0.0	0.0	0.0	0.0	44.5	17.5	18.3	9.9	0.0	0.0	174.6*
75	263	0.0	1.4	33.0	100.2	171.0	221.7	248.1	256.3	197.3	144.7	102.9	72.4	36.5	10.7	0.0	0.0	1596.0
75	264	0.0	1.0	0.0	79.8	110.4	88.9	136.9	170.6	127.3	118.7	107.1	99.2	25.9	5.6	0.0	0.0	1073.5*
75	265	0.0	.9	26.5	90.7	157.1	218.0	254.7	242.7	246.7	189.7	177.6	142.3	75.3	22.9	0.0	0.0	1845.1
75	266	0.0	.6	12.7	53.8	96.3	162.6	181.0	148.1	143.4	100.5	74.6	65.7	32.7	6.6	0.0	0.0	1078.6
75	267	0.0	.3	14.7	55.8	108.9	133.1	166.1	138.2	126.9	145.3	117.1	102.7	67.4	8.3	0.0	0.0	1184.8
75	268	0.0	.5	16.2	49.9	135.3	0.0	0.0	130.2	70.3	141.2	127.6	90.0	68.8	16.4	0.0	0.0	846.6*
75	269	0.0	.9	26.0	92.9	159.1	217.6	259.0	274.0	276.4	249.8	205.1	143.5	72.8	12.4	0.0	0.0	1989.5
75	270	0.0	.9	29.7	93.1	158.6	220.5	261.7	279.2	273.0	249.0	205.5	141.0	69.6	11.6	0.0	0.0	1993.4
75	271	0.0	.5	24.7	86.5	152.9	207.6	243.0	265.0	259.3	230.2	178.3	95.0	29.3	5.0	0.0	0.0	1777.1
75	272	0.0	.4	18.1	0.0	64.0	111.4	177.3	192.5	210.0	185.3	149.3	99.9	41.8	7.2	0.0	0.0	1257.1*
75	273	0.0	.4	19.7	73.8	136.4	182.9	219.9	0.0	236.2	205.2	161.4	92.6	32.8	3.0	0.0	0.0	1364.4*
75	274	0.0	0.0	6.0	20.8	114.4	203.2	216.7	246.1	240.2	216.2	192.8	0.0	0.0	10.3	0.0	0.0	1466.6*
75	275	0.0	0.0	24.9	89.1	161.2	221.4	266.7	285.6	278.8	249.8	202.1	137.5	65.3	8.7	0.0	0.0	1991.2
75	276	0.0	0.0	18.5	75.1	143.8	213.3	257.8	275.3	270.4	242.2	195.6	131.3	60.1	7.4	0.0	0.0	1890.9
75	277	0.0	0.0	21.7	83.9	152.0	206.9	249.8	270.4	266.0	239.9	192.9	129.5	58.9	6.8	0.0	0.0	1880.7
75	278	0.0	0.0	15.9	70.2	138.4	195.2	237.0	252.3	250.6	228.3	184.2	123.7	55.6	6.4	0.0	0.0	1757.8
75	279	0.0	0.0	16.6	73.3	138.0	189.3	229.3	245.6	237.0	212.7	0.0	108.1	43.2	3.9	0.0	0.0	1497.1*
75	280	0.0	0.0	15.7	66.9	133.4	0.0	0.0	211.3	158.8	0.0	0.0	40.5	14.7	1.6	0.0	0.0	644.9*
75	281	0.0	0.0	2.7	11.9	26.6	63.8	122.0	187.2	155.5	148.2	132.4	94.3	36.4	0.0	0.0	0.0	982.9*
75	282	0.0	0.0	12.8	60.9	125.0	180.0	219.2	235.4	229.1	202.8	132.5	77.0	26.5	2.1	0.0	0.0	1503.2
75	283	0.0	0.0	8.6	59.8	115.4	154.3	180.8	236.5	232.7	214.4	161.3	95.9	35.0	2.8	0.0	0.0	1497.7
75	284	0.0	0.0	16.0	72.4	137.8	196.2	235.6	253.2	248.4	217.0	166.6	104.6	40.5	2.4	0.0	0.0	1690.7
75	285	0.0	0.0	12.6	63.8	127.7	182.0	220.1	238.0	224.8	207.5	161.0	98.2	36.8	2.3	0.0	0.0	1574.8
75	286	0.0	0.0	12.9	65.4	124.9	184.9	223.5	234.7	231.6	210.3	164.9	104.7	40.2	2.3	0.0	0.0	1600.2
75	287	0.0	0.0	16.9	63.1	131.4	178.1	205.0	244.3	237.7	210.8	163.8	97.3	34.0	1.8	0.0	0.0	1584.5
75	288	0.0	0.0	8.9	34.9	53.6	45.5	83.0	89.6	135.2	131.7	98.6	59.9	27.3	1.8	0.0	0.0	769.9
75	289	0.0	0.0	9.1	47.9	126.5	183.5	231.6	250.8	232.2	187.5	137.0	105.5	40.7	2.2	0.0	0.0	1554.4
75	290	0.0	0.0	8.5	42.7	112.2	144.4	185.4	100.0	125.3	162.4	99.5	49.5	15.2	1.4	0.0	0.0	1046.5
75	291	0.0	0.0	9.4	60.3	102.9	177.8	201.2	214.5	163.0	96.4	83.2	78.0	32.9	1.4	0.0	0.0	1220.9
75	292	0.0	0.0	8.3	64.2	135.5	192.4	231.9	248.8	241.1	213.4	124.6	77.4	31.1	1.7	0.0	0.0	1570.4
75	293	0.0	0.0	11.0	62.9	126.7	180.1	217.0	235.7	230.9	204.0	158.5	99.2	33.9	.9	0.0	0.0	1560.6

HOURLY AVERAGE IRRADIANCE AT ALL MAPS SITES

YR	DOY	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	TOTAL
75	294	0.0	0.0	9.9	61.4	0.0	0.0	217.5	232.8	229.6	195.2	149.1	65.9	24.5	.7	0.0	0.0	1206.7*
75	295	0.0	0.0	9.5	57.5	121.3	175.1	210.1	227.8	209.1	188.7	143.0	92.9	26.4	.7	0.0	0.0	1462.1
75	296	0.0	0.0	10.0	56.6	78.9	159.7	200.9	218.5	214.1	177.4	123.5	49.2	13.6	.5	0.0	0.0	1303.2
75	297	0.0	0.0	6.5	54.6	108.6	164.8	162.2	159.4	107.1	90.6	56.4	24.9	8.8	-.4	0.0	0.0	945.5
75	298	0.0	0.0	5.9	58.8	121.5	183.1	214.7	219.6	142.7	89.6	60.3	38.8	11.4	.5	0.0	0.0	1147.1
75	299	0.0	0.0	7.9	58.4	125.0	182.1	221.6	238.1	230.3	202.0	153.4	86.2	26.1	.0	0.0	0.0	1533.1
75	300	0.0	0.0	8.0	56.7	122.2	177.8	213.3	228.8	223.0	195.5	149.6	88.0	26.3	.3	0.0	0.0	1489.6
75	301	0.0	0.0	2.5	17.4	24.5	41.1	46.6	92.9	104.1	77.1	56.6	50.9	10.6	.1	0.0	0.0	524.5
75	302	0.0	0.0	2.6	12.1	80.6	115.7	148.6	149.9	176.9	173.8	133.9	76.3	19.3	-.1	0.0	0.0	1089.1
75	303	0.0	0.0	6.7	51.9	116.3	172.8	209.9	226.5	219.7	182.5	143.6	80.3	21.1	.2	0.0	0.0	1431.4
75	304	0.0	0.0	4.3	0.0	98.6	155.3	189.2	214.3	204.3	176.1	96.4	45.7	13.1	.3	0.0	0.0	1197.8*
75	305	0.0	0.0	2.4	10.2	0.0	45.5	76.1	117.1	118.0	90.7	69.7	27.4	6.6	0.0	0.0	0.0	563.6*
75	306	0.0	0.0	3.7	27.7	53.5	77.1	91.7	89.3	90.5	104.5	111.7	56.8	11.8	0.0	0.0	0.0	718.3
75	307	0.0	0.0	.5	7.7	14.5	20.0	21.5	0.0	32.7	27.9	15.6	7.1	4.0	0.0	0.0	0.0	151.4*
75	308	0.0	0.0	1.4	9.8	20.5	42.2	70.7	94.2	131.4	101.8	94.0	50.5	14.8	0.0	0.0	0.0	631.2
75	309	0.0	0.0	2.2	16.2	79.8	146.2	180.4	197.4	190.3	156.2	83.2	18.1	2.9	0.0	0.0	0.0	1072.7
75	310	0.0	0.0	.9	7.8	12.3	0.0	60.7	80.4	74.9	80.7	48.7	23.0	10.3	0.0	0.0	0.0	399.6*
75	311	0.0	0.0	2.5	30.3	88.7	134.1	176.2	194.1	183.3	153.1	102.4	48.6	11.5	0.0	0.0	0.0	1124.6
75	312	0.0	0.0	3.0	38.9	96.8	145.9	179.9	197.8	192.7	165.1	120.1	63.2	12.8	0.0	0.0	0.0	1216.0
75	313	0.0	0.0	2.2	27.7	89.3	118.4	106.5	157.1	187.2	167.9	0.0	57.3	11.8	0.0	0.0	0.0	925.4*
75	314	0.0	0.0	2.4	39.9	101.9	159.0	196.1	212.9	0.0	180.4	130.8	68.6	14.0	0.0	0.0	0.0	1106.1*
75	315	0.0	0.0	2.4	37.8	97.6	152.5	187.9	202.3	186.7	89.0	60.1	45.5	12.7	0.0	0.0	0.0	1074.8
75	316	0.0	0.0	2.0	36.5	98.0	142.0	133.3	104.1	82.7	43.1	23.6	8.5	2.0	0.0	0.0	0.0	675.8
75	317	0.0	0.0	.3	2.7	9.7	31.0	36.4	33.0	30.5	30.4	28.8	0.0	3.4	0.0	0.0	0.0	206.1*
75	318	0.0	0.0	2.1	39.3	96.9	145.1	183.2	198.0	194.2	167.3	121.1	57.1	12.4	0.0	0.0	0.0	1216.5
75	319	0.0	0.0	1.7	32.9	92.0	145.9	182.4	198.4	192.6	0.0	116.7	61.6	11.1	0.0	0.0	0.0	1035.4*
75	320	0.0	0.0	1.5	31.6	75.9	106.3	159.8	174.0	177.8	156.8	105.4	52.1	8.2	0.0	0.0	0.0	1049.4
75	321	0.0	0.0	1.5	29.4	81.7	129.1	163.7	181.5	181.7	155.8	109.9	54.2	8.5	0.0	0.0	0.0	1096.9
75	322	0.0	0.0	1.4	28.9	85.2	138.2	173.8	189.2	183.9	159.2	111.9	53.9	8.4	0.0	0.0	0.0	1133.8
75	323	0.0	0.0	1.3	27.8	81.0	130.6	163.1	179.5	175.6	148.7	94.2	47.9	7.2	0.0	0.0	0.0	1056.8
75	324	0.0	0.0	.3	13.6	39.5	135.7	105.7	82.5	56.4	29.3	16.8	8.4	1.1	0.0	0.0	0.0	469.3
75	325	0.0	0.0	.0	1.9	6.0	11.0	19.1	21.2	23.3	15.9	10.6	7.0	1.4	0.0	0.0	0.0	117.5
75	326	0.0	0.0	.4	7.1	22.7	51.3	83.0	123.6	163.7	139.2	89.7	45.8	7.9	0.0	0.0	0.0	734.6
75	327	0.0	0.0	.5	44.6	83.2	140.0	165.2	187.6	182.5	158.7	110.5	43.8	5.2	0.0	0.0	0.0	1121.8
75	328	0.0	0.0	0.0	13.0	41.1	77.6	132.7	135.4	27.0	10.5	10.9	6.2	1.4	0.0	0.0	0.0	455.9*
75	329	0.0	0.0	.2	2.7	12.9	25.2	44.8	52.1	39.7	27.0	16.6	14.6	1.4	0.0	0.0	0.0	237.2
75	330	0.0	0.0	-.1	4.8	8.3	0.0	23.9	22.4	20.4	17.8	13.4	8.2	.8	0.0	0.0	0.0	120.0*
75	331	0.0	0.0	.6	13.5	41.0	79.9	0.0	110.2	103.8	77.8	70.9	37.5	0.0	0.0	0.0	0.0	535.2*
75	332	0.0	0.0	.2	0.0	78.4	129.5	164.4	175.3	179.3	126.0	52.5	18.8	3.8	0.0	0.0	0.0	928.1*
75	333	0.0	0.0	.2	2.6	9.4	23.7	24.1	37.0	34.0	21.6	9.9	10.9	2.2	0.0	0.0	0.0	175.8
75	334	0.0	0.0	.2	6.8	38.3	63.5	41.4	23.6	26.1	32.8	30.9	22.0	4.4	0.0	0.0	0.0	290.1
75	335	0.0	0.0	0.0	13.3	29.6	31.1	32.9	69.0	96.7	67.1	46.9	38.7	8.5	0.0	0.0	0.0	433.8
75	336	0.0	0.0	0.0	6.7	30.2	63.9	67.2	139.9	102.3	126.6	103.4	46.4	4.7	0.0	0.0	0.0	691.2
75	337	0.0	0.0	0.0	0.0	64.5	113.3	152.3	169.0	166.4	146.8	102.2	49.3	5.3	0.0	0.0	0.0	969.1*
75	338	0.0	0.0	0.0	15.7	64.9	114.4	144.9	167.8	167.5	141.4	99.0	49.3	7.7	0.0	0.0	0.0	972.7
75	339	0.0	0.0	0.0	12.5	45.1	63.6	85.4	0.0	67.7	91.5	27.9	6.9	1.3	0.0	0.0	0.0	401.9*
75	340	0.0	0.0	0.0	2.8	19.2	62.6	142.3	173.4	171.2	145.7	94.7	37.6	4.3	0.0	0.0	0.0	853.9
75	341	0.0	0.0	0.0	5.5	18.5	35.6	53.3	74.6	100.5	82.6	50.5	24.8	2.2	0.0	0.0	0.0	448.3
75	342	0.0	0.0	0.0	5.2	17.7	0.0	37.5	36.2	14.6	18.0	0.0	14.8	2.1	0.0	0.0	0.0	146.1*
75	343	0.0	0.0	0.0	1.1	5.7	15.8	31.2	35.6	43.3	43.3	31.3	16.5	2.4	0.0	0.0	0.0	226.3

HOURLY AVERAGE IRRADIANCE AT ALL RAPS SITES

YR	DUY	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	TOTAL
76	1	0.0	0.0	0.0	1.2	8.2	18.2	23.1	23.8	30.5	23.8	21.5	8.8	1.3	0.0	0.0	0.0	160.5
76	2	0.0	0.0	0.0	6.9	45.2	25.6	29.1	30.5	32.5	40.2	7.7	18.9	5.8	0.0	0.0	0.0	242.4
76	3	0.0	0.0	0.0	7.6	0.0	110.0	151.6	161.3	105.1	123.1	107.8	60.2	11.8	0.0	0.0	0.0	838.4*
76	4	0.0	0.0	0.0	8.4	54.3	110.0	155.7	0.0	0.0	162.0	119.3	65.0	0.0	0.0	0.0	0.0	674.7*
76	5	0.0	0.0	0.0	3.6	33.1	98.7	145.7	168.6	0.0	0.0	0.0	64.8	12.8	0.0	0.0	0.0	527.3*
76	6	0.0	0.0	0.0	4.9	36.6	87.4	58.7	116.9	149.6	112.8	59.1	28.0	8.6	0.0	0.0	0.0	662.8
76	7	0.0	0.0	0.0	1.5	9.8	0.0	48.4	67.7	68.5	49.9	40.1	24.7	4.4	0.0	0.0	0.0	315.0*
76	8	0.0	0.0	0.0	7.0	54.4	111.5	158.8	186.3	190.8	172.2	128.9	74.0	16.1	0.0	0.0	0.0	1099.9
76	9	0.0	0.0	0.0	4.5	24.8	60.0	101.2	118.4	155.6	117.6	75.0	68.5	15.7	0.0	0.0	0.0	741.5
76	10	0.0	0.0	0.0	5.1	29.2	75.0	76.7	44.6	18.4	27.6	31.3	14.5	2.7	0.0	0.0	0.0	325.2
76	11	0.0	0.0	0.0	7.2	51.2	105.5	148.5	168.5	175.9	151.4	113.7	67.2	17.0	0.0	0.0	0.0	1006.2
76	12	0.0	0.0	0.0	7.8	43.5	83.3	114.9	107.9	148.3	163.5	107.1	0.0	9.2	0.0	0.0	0.0	785.6*
76	13	0.0	0.0	0.0	1.1	3.5	9.6	34.0	13.4	25.1	0.0	0.0	51.2	0.0	0.0	0.0	0.0	137.9*
76	14	0.0	0.0	0.0	8.5	55.8	112.0	154.5	0.0	0.0	0.0	128.5	73.8	0.0	0.0	0.0	0.0	533.1*
76	15	0.0	0.0	0.0	11.0	54.3	61.7	106.8	123.3	46.3	40.5	26.1	10.1	2.0	0.0	0.0	0.0	482.2
76	16	0.0	0.0	0.0	1.6	14.3	53.5	137.9	176.2	191.6	174.3	134.7	78.2	21.6	.2	0.0	0.0	984.0
76	17	0.0	0.0	0.0	9.4	58.1	117.6	163.3	186.5	193.4	174.2	134.1	78.6	22.3	.3	0.0	0.0	1137.8
76	18	0.0	0.0	0.0	11.5	62.3	118.3	163.4	187.0	192.5	172.5	134.0	77.7	21.9	.3	0.0	0.0	1141.5
76	19	0.0	0.0	0.0	1.5	7.2	19.6	30.9	26.8	18.7	15.7	18.5	11.7	3.7	.0	0.0	0.0	154.3
76	20	0.0	0.0	0.0	8.5	55.3	114.9	160.9	0.0	195.6	178.0	138.3	0.0	0.0	.3	0.0	0.0	651.7*
76	21	0.0	0.0	0.0	7.3	50.3	0.0	148.0	0.0	162.0	153.5	98.2	68.2	22.2	.8	0.0	0.0	710.4*
76	22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0*
76	23	0.0	0.0	0.0	10.1	57.9	115.0	157.2	0.0	188.5	170.2	135.6	83.4	0.0	.3	0.0	0.0	918.2*
76	24	0.0	0.0	0.0	10.4	0.0	115.5	163.3	186.6	192.5	172.3	138.9	84.9	27.6	.5	0.0	0.0	1092.4*
76	25	0.0	0.0	0.0	.5	3.3	9.1	18.1	32.1	27.1	29.8	20.7	10.4	3.3	.1	0.0	0.0	154.4
76	26	0.0	0.0	0.0	3.2	15.3	30.5	73.4	184.9	189.4	183.1	146.1	92.4	31.4	1.0	0.0	0.0	950.9
76	27	0.0	0.0	0.0	12.0	64.1	123.7	169.9	199.4	201.0	185.0	145.9	87.4	30.1	.8	0.0	0.0	1219.2
76	28	0.0	0.0	0.0	12.2	44.0	64.4	73.8	103.0	145.2	106.7	137.7	92.6	33.2	1.1	0.0	0.0	813.9
76	29	0.0	0.0	0.0	13.8	68.5	128.8	0.0	206.0	207.9	189.6	0.0	95.6	35.9	1.5	0.0	0.0	947.6*
76	30	0.0	0.0	0.0	6.7	39.0	76.3	137.4	160.0	159.0	0.0	98.7	59.1	19.1	.8	0.0	0.0	756.1*
76	31	0.0	0.0	0.0	5.7	48.1	63.2	47.7	57.0	85.4	108.9	0.0	97.3	36.0	1.3	0.0	0.0	550.6*
76	32	0.0	0.0	.0	10.3	21.4	49.4	125.9	176.4	193.1	176.2	121.6	103.5	37.0	2.0	0.0	0.0	1016.7
76	33	0.0	0.0	.2	5.6	15.7	19.4	40.8	69.9	84.9	74.1	0.0	44.8	21.3	1.8	0.0	0.0	378.5*
76	34	0.0	0.0	.3	13.6	49.7	114.5	150.6	201.8	212.6	169.6	91.5	103.4	46.5	1.8	0.0	0.0	1155.9
76	35	0.0	0.0	.0	11.5	44.2	49.3	51.7	67.0	75.8	53.8	34.1	20.7	7.9	1.0	0.0	0.0	416.8
76	36	0.0	0.0	.3	2.2	4.0	10.7	18.9	19.9	38.8	44.7	36.6	20.4	7.4	.7	0.0	0.0	204.8
76	37	0.0	0.0	.3	5.4	23.6	60.6	126.7	135.2	139.8	102.5	83.2	70.1	34.4	2.5	0.0	0.0	784.4
76	38	0.0	0.0	.4	16.0	0.0	0.0	0.0	226.6	232.3	214.9	174.4	115.8	49.1	3.4	0.0	0.0	1032.8*
76	39	0.0	0.0	.2	20.7	80.5	0.0	191.4	218.0	222.9	206.9	168.9	112.4	49.4	4.1	0.0	0.0	1275.5*
76	40	0.0	0.0	.4	22.4	76.9	132.7	183.1	212.7	220.0	181.5	150.9	87.4	27.1	3.1	0.0	0.0	1298.3
76	41	0.0	0.0	.4	8.8	43.1	100.0	175.4	179.0	210.6	190.5	156.7	102.4	31.7	3.0	0.0	0.0	1201.5
76	42	0.0	0.0	.3	17.4	83.5	146.5	196.9	227.0	232.8	214.6	173.4	116.3	51.4	4.7	0.0	0.0	1464.9
76	43	0.0	0.0	.4	23.5	83.4	132.8	136.8	126.7	94.6	79.3	126.6	98.9	48.0	4.7	0.0	0.0	955.8
76	44	0.0	0.0	.4	12.3	47.8	75.1	110.4	161.2	187.7	167.7	143.4	98.5	46.9	4.6	0.0	0.0	1061.9
76	45	0.0	0.0	.5	25.4	56.5	0.0	101.9	139.0	161.3	176.9	141.5	84.9	37.0	4.2	0.0	0.0	929.0*
76	46	0.0	0.0	.5	17.1	49.1	76.4	127.2	150.3	159.7	155.0	124.8	74.1	38.0	4.7	0.0	0.0	976.9
76	47	0.0	0.0	.7	7.0	26.2	34.9	158.3	123.2	39.3	111.5	117.0	62.2	44.8	6.6	0.0	0.0	731.8
76	48	0.0	0.0	.9	22.2	48.2	68.0	102.5	137.8	76.8	32.8	22.0	21.8	8.5	1.5	0.0	0.0	542.9
76	49	0.0	0.0	.6	3.2	10.4	21.3	23.9	69.1	65.2	151.9	181.2	131.5	60.8	9.3	0.0	0.0	728.4
76	50	0.0	0.0	.9	30.5	97.5	162.4	213.0	244.9	251.0	232.1	192.0	133.4	63.2	0.0	0.0	0.0	1620.8*

HOURLY AVERAGE IRRADIANCE AT ALL RAPS SITES

YR	DOY	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	TOTAL
76	51	0.0	0.0	1.3	30.8	70.1	142.7	191.4	206.8	207.8	0.0	143.5	113.8	53.6	8.8	0.0	0.0	1170.5*
76	52	0.0	0.0	.3	13.3	31.5	77.8	161.5	146.0	155.9	141.4	143.9	47.6	4.7	.7	0.0	0.0	924.4
76	53	0.0	0.0	1.6	30.2	99.6	170.3	220.7	249.1	254.1	235.5	195.3	136.3	66.9	10.5	0.0	0.0	1670.0
76	54	0.0	0.0	1.8	34.8	101.3	167.9	216.9	244.5	254.9	236.8	198.5	140.8	70.6	12.0	0.0	0.0	1680.9
76	55	0.0	0.0	1.4	36.5	108.5	176.7	212.7	234.9	251.6	218.9	190.0	102.1	41.9	0.0	0.0	0.0	1575.4*
76	56	0.0	0.0	1.3	31.1	95.2	152.5	195.9	207.7	221.2	199.5	171.3	131.3	61.0	9.4	0.0	0.0	1477.3
76	57	0.0	0.0	2.1	32.8	99.1	168.2	219.5	209.8	185.4	0.0	0.0	90.4	65.3	9.7	0.0	0.0	1082.0*
76	58	0.0	0.0	3.5	45.5	115.4	176.6	224.6	254.0	257.1	237.0	187.1	137.8	70.6	14.3	0.0	0.0	1723.5
76	59	0.0	0.0	2.0	0.0	61.2	115.6	157.7	192.7	216.9	215.0	186.9	130.4	62.7	11.3	0.0	0.0	1352.5*
76	60	0.0	0.0	3.4	31.5	74.3	156.0	206.9	201.3	177.5	164.4	152.0	100.7	56.9	10.8	0.0	0.0	1335.6
76	61	0.0	0.0	2.7	22.9	63.2	118.1	195.2	227.5	194.9	151.2	144.5	85.5	0.0	5.6	-.3	0.0	1211.1*
76	62	0.0	0.0	1.7	23.7	60.0	86.1	113.3	193.0	175.1	181.3	127.0	68.8	32.1	5.9	-.1	0.0	1067.9
76	63	0.0	0.0	1.4	12.8	19.0	21.2	17.1	55.1	85.7	65.8	33.1	22.1	12.6	3.9	.0	0.0	350.7
76	64	0.0	0.0	1.4	9.1	53.0	75.2	126.0	198.7	182.2	65.3	82.1	0.0	0.0	3.9	-.3	0.0	796.7*
76	65	0.0	0.0	2.7	27.7	73.0	115.2	189.8	262.1	275.7	257.9	218.2	155.4	83.6	18.7	-.0	0.0	1680.6
76	66	0.0	0.0	6.6	55.3	128.1	199.7	250.7	261.0	285.5	265.2	221.4	160.3	85.9	19.7	-.2	0.0	1959.3
76	67	0.0	0.0	7.5	60.2	134.6	199.1	249.3	279.9	284.3	262.9	219.2	159.6	86.4	18.6	-.1	0.0	1961.5
76	68	0.0	0.0	3.3	34.6	84.1	102.9	106.1	97.1	84.1	73.2	83.2	87.7	41.5	9.4	-.0	0.0	807.2
76	69	0.0	0.0	6.0	49.5	117.6	187.7	234.2	260.5	267.8	247.6	205.0	155.7	82.4	19.8	.0	0.0	1833.8
76	70	0.0	0.0	7.5	35.3	53.2	71.8	70.1	97.3	238.5	239.1	0.0	0.0	7.3	6.6	.2	0.0	826.9*
76	71	0.0	0.0	9.7	49.6	66.1	68.6	65.0	102.2	127.4	167.0	180.1	118.1	33.3	5.9	.1	0.0	993.0
76	72	0.0	0.0	8.8	53.4	118.8	0.0	0.0	262.5	269.5	263.6	215.1	0.0	72.1	11.3	.2	0.0	1275.3*
76	73	0.0	0.0	3.1	35.9	127.2	203.6	260.7	297.0	301.5	280.7	235.2	173.3	97.7	26.1	-.1	0.0	2048.0
76	74	0.0	0.0	13.4	73.8	148.9	213.9	0.0	290.1	292.7	272.1	227.7	166.0	87.6	22.3	-.0	0.0	1808.6*
76	75	0.0	0.0	2.9	11.1	25.0	51.3	48.3	97.1	139.7	81.3	50.2	39.3	20.3	5.0	.1	0.0	571.7
76	76	0.0	-.0	0.0	0.0	0.0	238.9	253.7	216.4	281.0	250.3	230.3	166.0	96.2	27.6	0.0	0.0	1762.6*
76	77	0.0	.4	8.7	41.5	105.4	0.0	254.5	293.5	299.3	261.1	219.6	162.0	86.6	23.8	.0	0.0	1756.4*
76	78	0.0	.3	11.3	52.8	125.3	179.9	249.7	245.5	264.9	272.3	221.8	155.7	68.1	22.9	.4	0.0	1870.8
76	79	0.0	.1	15.5	73.4	149.0	212.2	229.1	238.4	258.9	266.9	228.5	161.9	86.8	26.7	.5	0.0	1947.8
76	80	0.0	.4	14.0	57.2	100.4	136.7	108.6	37.1	93.9	37.8	123.3	105.6	78.6	27.3	.6	0.0	921.6
76	81	0.0	.4	19.0	86.8	165.6	227.3	271.2	291.8	305.4	289.7	239.3	184.5	108.1	33.9	.6	0.0	2223.6
76	82	0.0	.3	14.9	38.0	80.5	151.4	66.6	76.2	64.4	82.4	56.8	54.6	46.6	21.9	1.1	0.0	759.7
76	83	0.0	.7	11.2	38.8	77.7	170.0	275.3	302.2	305.9	285.3	242.8	183.0	107.6	34.4	.7	0.0	2035.7
76	84	0.0	.2	16.7	73.1	140.6	115.9	43.0	35.9	26.2	17.6	12.1	11.6	9.8	8.0	1.7	0.0	512.4
76	85	0.0	.1	21.4	81.5	155.9	201.1	183.7	134.1	113.1	0.0	79.4	140.7	42.4	10.2	.8	0.0	1164.4*
76	86	0.0	.3	23.2	90.3	162.7	224.2	273.5	296.7	246.6	236.6	154.7	47.1	26.2	2.6	-.0	0.0	1784.5
76	87	0.0	.4	15.4	66.7	99.3	173.4	278.6	302.2	318.7	298.5	252.2	188.5	113.4	39.3	1.2	0.0	2147.7
76	88	0.0	.5	31.3	95.7	170.9	234.9	278.7	291.6	282.8	239.0	116.0	58.6	29.0	12.0	.4	0.0	1841.2
76	89	0.0	.4	8.5	19.4	39.1	53.8	65.4	40.7	34.9	50.7	79.6	63.1	39.6	12.5	4.7	0.0	512.3
76	90	0.0	.9	32.2	93.3	154.3	205.0	233.2	186.6	160.6	188.5	125.2	166.2	107.0	40.8	2.6	0.0	1696.1
76	91	0.0	.9	23.7	104.5	180.9	245.4	276.9	219.5	169.0	211.1	162.4	132.1	58.3	25.3	1.0	0.0	1811.1
76	92	0.0	1.2	32.6	101.7	178.6	243.6	295.8	321.7	324.9	305.7	260.0	198.8	122.8	47.1	2.9	0.0	2437.5
76	93	0.0	1.5	36.5	106.5	180.6	242.4	290.7	314.5	310.0	0.0	251.3	190.3	117.3	40.0	3.1	0.0	2090.7*
76	94	0.0	1.7	32.5	101.1	175.9	236.2	265.6	305.8	309.9	289.1	245.0	179.6	110.9	35.9	3.2	0.0	2292.4
76	95	0.0	1.0	14.6	64.6	116.7	139.6	178.0	177.9	280.8	248.1	234.5	197.2	123.9	47.1	2.9	0.0	1846.8
76	96	0.0	2.5	39.4	108.3	177.3	247.9	285.2	310.2	314.8	292.3	242.9	184.7	113.9	43.0	2.6	0.0	2365.4
76	97	0.0	2.7	38.3	107.2	180.1	243.5	291.1	313.1	313.7	282.2	235.2	181.2	109.9	39.9	2.4	0.0	2340.5
76	98	0.0	2.7	36.7	103.8	174.0	236.0	279.1	289.2	280.2	255.5	218.0	122.4	71.0	25.6	1.6	0.0	2095.9
76	99	0.0	5.0	53.2	130.2	208.3	271.8	316.9	339.0	337.6	312.5	265.1	200.8	124.2	47.2	2.8	0.0	2614.4
76	100	0.0	4.4	50.8	127.2	203.8	267.5	315.3	339.3	337.2	314.7	257.2	193.8	121.8	47.8	3.2	0.0	2584.1

HOURLY AVERAGE IRRADIANCE AT ALL MAPS SITES

YR	DOY	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	TOTAL
76	101	0.0	3.6	47.6	122.9	199.4	264.7	310.5	334.5	335.2	307.9	262.4	198.3	120.1	47.0	2.6	0.0	2556.7
76	102	0.0	3.0	38.8	99.6	125.0	214.0	210.6	271.9	242.3	221.9	236.7	195.6	125.6	52.3	4.9	0.0	2048.0
76	103	0.0	5.4	54.5	132.1	207.6	272.5	318.4	341.4	341.7	316.8	270.9	207.6	131.5	53.2	4.7	0.0	2658.2
76	104	0.0	5.6	49.0	120.7	193.1	254.8	298.6	312.0	312.8	258.7	236.6	156.7	93.5	0.0	3.5	0.0	2295.8*
76	105	0.0	2.9	29.4	30.4	67.6	114.2	148.8	148.1	189.0	201.1	165.0	144.7	95.2	41.8	4.4	0.0	1433.6
76	106	0.0	4.3	38.6	100.6	160.0	164.8	193.3	193.9	262.5	243.1	190.2	116.6	102.3	33.6	2.9	0.0	1806.9
76	107	0.0	9.5	48.3	77.2	104.3	131.2	105.0	94.4	131.6	168.9	101.1	25.9	41.1	25.5	5.2	0.0	1069.2
76	108	0.0	5.6	47.7	117.0	114.3	162.7	250.0	247.4	322.4	297.6	213.5	136.3	80.3	33.6	5.6	0.0	2086.1
76	109	0.0	10.8	55.0	118.0	87.9	60.7	27.2	42.7	151.0	170.9	151.5	132.2	84.1	35.1	5.4	0.0	1152.7
76	110	0.0	4.9	17.2	38.2	38.7	43.2	36.5	30.5	23.6	34.5	21.4	32.5	22.4	8.8	1.8	0.0	354.0
76	111	0.0	2.4	22.4	52.6	0.0	0.0	0.0	206.0	66.4	49.2	34.0	73.7	0.0	43.5	8.3	0.0	558.5*
76	112	0.0	3.2	23.7	46.8	64.6	69.4	82.9	62.6	66.4	47.4	27.6	76.9	0.0	58.8	7.9	0.0	638.1*
76	113	0.0	9.5	56.0	132.4	206.4	268.0	312.5	334.9	332.5	308.6	263.3	200.4	0.0	51.9	6.4	0.0	2482.8*
76	114	0.0	8.7	58.6	130.9	187.1	257.2	294.9	291.3	191.2	220.3	255.7	174.1	119.2	59.9	8.8	0.0	2257.9
76	115	0.0	8.0	28.0	10.5	25.0	28.4	84.3	102.4	86.2	107.6	138.1	101.1	68.1	30.7	6.4	0.0	824.9
76	116	0.0	3.8	14.7	24.3	22.5	33.8	34.3	52.7	0.0	43.0	24.0	19.8	10.9	4.7	1.0	0.0	269.2*
76	117	0.0	13.9	74.2	152.2	226.7	286.8	328.8	355.3	354.5	328.4	281.5	209.6	131.7	60.6	10.2	0.0	2814.5
76	118	0.0	4.8	26.3	69.6	101.7	150.0	134.4	104.7	55.0	30.9	43.9	68.1	73.4	27.5	4.8	0.0	895.3
76	119	0.0	3.4	14.7	26.4	34.7	77.3	95.1	117.9	138.7	166.3	190.7	180.3	118.3	56.9	10.2	0.0	1230.9
76	120	0.0	16.9	68.5	142.9	219.4	285.5	326.0	343.3	335.7	295.3	268.3	203.9	133.6	53.1	9.9	0.0	2702.4
76	121	0.0	15.3	72.1	135.8	198.7	252.1	295.9	317.4	297.8	279.9	223.0	144.8	79.8	38.2	7.5	0.0	2358.4
76	122	.0	7.3	39.8	70.2	148.3	221.9	272.3	330.9	314.7	316.0	278.5	219.7	133.1	63.6	11.1	0.0	2427.5
76	123	.5	14.0	0.0	127.5	188.5	160.8	218.8	176.3	147.7	221.5	248.0	192.5	121.7	0.0	11.7	0.0	1830.7*
76	124	.5	13.8	82.8	158.4	230.0	290.2	316.5	334.6	330.9	313.5	267.8	212.2	151.1	73.9	14.0	0.0	2790.2
76	125	.3	20.0	83.1	159.9	231.8	290.4	330.6	336.8	351.1	326.5	277.9	218.6	145.4	69.8	12.8	0.0	2855.1
76	126	.1	20.7	48.9	80.5	151.6	191.2	251.6	261.2	260.2	191.8	150.9	137.0	80.7	40.1	2.2	0.0	1874.9
76	127	-.6	4.2	17.0	51.5	47.9	102.6	197.5	136.4	102.5	77.8	39.1	32.4	28.0	12.5	1.9	0.0	850.8
76	128	.6	21.4	85.2	159.1	232.4	204.4	334.0	348.0	349.6	312.8	255.3	183.1	121.1	55.7	14.7	0.0	2767.3
76	129	.7	23.3	87.0	164.8	237.9	298.2	341.5	361.6	357.6	331.6	282.2	220.4	147.2	70.9	14.1	0.0	2939.1
76	130	.5	22.7	86.3	101.2	233.9	290.4	337.2	356.6	354.9	331.9	236.9	154.4	116.8	64.6	12.0	0.0	2766.2
76	131	.6	18.2	60.0	124.6	169.7	177.5	169.3	248.8	247.1	257.5	199.5	161.7	78.2	41.3	14.6	0.0	1968.5
76	132	.8	19.7	76.3	151.8	223.8	284.3	328.5	351.4	350.7	326.1	282.8	222.9	152.8	70.8	17.9	0.0	2806.7
76	133	.7	24.7	88.7	164.8	236.4	294.9	336.1	357.6	355.9	332.0	286.9	208.8	142.1	0.0	11.1	0.0	2841.0*
76	134	.0	2.1	12.9	22.9	78.0	22.4	31.2	63.4	121.6	107.7	0.0	82.8	85.2	42.0	7.7	0.0	679.8*
76	135	.1	9.1	25.6	51.8	45.6	30.4	74.6	91.2	51.6	67.6	49.1	29.5	16.3	7.2	2.3	0.0	552.2
76	136	.4	6.2	25.4	51.7	47.0	169.3	267.4	291.0	290.7	228.3	183.2	115.4	117.3	40.0	7.9	0.0	1841.0
76	137	.8	25.7	94.0	161.4	226.6	283.0	280.4	295.7	93.8	141.8	209.2	54.7	37.8	28.4	9.9	.7	1943.8
76	138	.5	4.4	8.3	13.8	25.5	28.9	20.9	22.7	71.6	141.9	113.3	159.2	0.0	42.1	16.7	-.1	609.7*
76	139	1.0	27.5	94.2	171.9	240.7	301.4	347.3	370.9	367.1	341.3	296.7	233.9	163.4	85.3	21.0	.1	3063.8
76	140	1.1	26.3	94.8	173.0	238.9	293.6	328.8	359.0	332.9	329.1	289.1	227.7	157.6	85.6	22.3	.3	2960.1
76	141	.9	27.0	91.3	164.8	237.2	296.5	333.2	345.4	339.6	300.1	284.4	227.6	157.3	83.4	22.7	.2	2911.5
76	142	1.4	27.8	86.2	157.6	220.3	278.5	311.0	299.5	290.2	245.2	216.0	179.8	138.7	67.2	16.3	.2	2537.7
76	143	1.4	27.1	85.4	150.1	225.9	281.9	322.3	341.9	339.8	315.1	265.7	212.8	146.1	76.8	20.8	.3	2813.4
76	144	.9	15.0	64.2	130.2	196.3	228.4	251.8	246.0	293.3	233.0	171.5	141.5	73.9	36.4	7.0	.5	2090.0
76	145	1.3	30.6	94.2	163.2	234.4	290.6	326.2	348.7	328.7	323.0	280.7	224.6	156.0	81.3	25.4	.5	2911.4
76	146	1.8	33.1	101.2	177.1	247.7	308.7	348.9	367.9	364.8	340.7	293.9	232.3	164.9	78.3	28.7	.5	3090.6
76	147	1.6	25.3	82.3	150.5	237.9	289.7	329.9	330.3	322.5	288.6	228.7	161.3	88.9	53.4	17.3	.4	2608.6
76	148	1.5	32.8	78.0	105.5	122.9	165.4	209.4	209.8	117.7	61.7	62.5	47.3	24.9	15.5	4.2	-.1	1278.9
76	149	-.0	3.1	7.3	11.4	21.8	0.0	48.2	44.9	54.0	60.5	45.4	56.9	36.7	36.9	9.2	.5	436.6*
76	150	1.5	16.4	36.7	60.6	85.5	203.4	263.8	316.5	316.1	280.6	178.4	106.5	93.0	58.4	15.5	1.0	2045.8

HOURLY AVERAGE IRRADIANCE AT ALL HAPS SITES

YR	DOY	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	TOTAL
76	151	-.0	1.4	4.3	3.8	37.8	126.3	175.9	176.3	131.9	137.3	151.6	152.8	51.7	35.8	14.5	.5	1201.8
76	152	.5	25.5	45.5	80.1	148.0	166.3	124.6	153.9	77.0	73.6	50.9	68.8	49.2	14.9	8.5	.5	1107.9
76	153	.7	11.3	49.3	81.6	155.4	188.8	251.2	273.0	235.5	187.9	222.6	187.8	149.9	87.7	30.0	1.5	2114.2
76	154	.7	6.4	21.4	58.4	101.4	131.3	222.2	239.1	265.6	299.3	280.3	223.2	160.4	88.6	29.5	1.0	2108.8
76	155	1.8	31.9	94.1	166.0	231.5	290.1	328.2	344.0	330.0	221.0	86.1	83.6	48.1	29.8	12.1	1.5	2299.7
76	156	.7	8.9	23.9	40.7	84.8	116.7	100.6	146.1	190.3	175.8	200.7	130.7	117.9	68.7	15.5	.7	1422.6
76	157	2.4	26.6	68.6	106.3	133.4	179.0	207.7	263.0	307.0	251.7	230.5	174.2	116.0	67.1	23.9	1.4	2152.9
76	158	2.0	33.7	97.9	170.5	239.4	298.3	340.3	361.8	360.9	337.7	295.7	236.0	167.1	93.5	30.7	1.5	3067.2
76	159	2.0	29.6	88.6	155.6	221.3	272.8	315.3	342.1	341.6	317.8	275.4	214.6	150.1	79.2	26.3	1.2	2833.7
76	160	2.6	26.8	83.6	149.5	217.0	277.4	315.6	322.8	307.4	279.3	251.6	190.1	105.2	64.7	25.4	1.1	2622.0
76	161	2.2	0.0	78.7	146.5	214.4	275.7	319.1	312.7	284.9	272.8	243.9	186.1	127.8	76.8	26.7	1.6	2569.8*
76	162	1.8	24.0	74.8	136.2	201.4	244.7	292.7	278.7	267.9	229.1	186.2	147.7	59.7	20.7	11.6	1.2	2180.4
76	163	1.7	15.4	75.7	151.2	216.1	270.9	312.7	336.9	318.2	0.0	272.4	215.6	151.4	84.0	27.5	1.8	2451.5*
76	164	2.3	27.6	84.5	152.6	219.1	276.6	295.6	321.6	329.1	251.8	185.2	155.1	66.7	34.5	20.3	2.9	2425.7
76	165	1.4	22.3	71.3	106.4	161.7	207.1	291.3	288.1	272.4	294.6	261.6	217.4	158.0	91.9	33.0	1.9	2480.4
76	166	1.6	15.3	54.1	152.3	194.6	255.1	284.9	309.5	327.6	293.4	280.7	221.5	140.7	87.6	24.1	3.4	2646.5
76	167	1.3	12.3	29.8	32.9	93.4	97.8	196.0	239.0	175.5	115.3	95.3	143.4	109.8	60.2	30.1	2.1	1434.3
76	168	1.3	31.8	101.9	173.2	245.4	304.4	339.4	362.6	0.0	345.4	0.0	245.5	176.8	104.5	36.5	1.4	2470.0*
76	169	2.1	35.8	0.0	171.2	230.1	299.6	336.9	0.0	358.0	337.8	295.4	237.4	167.6	91.4	34.6	2.6	2600.6*
76	170	1.1	16.9	45.9	110.5	50.3	64.8	40.8	139.4	144.7	174.7	194.9	177.6	73.4	41.9	22.6	1.0	1304.7
76	171	1.3	21.9	0.0	104.0	230.3	270.3	287.0	300.2	338.5	326.7	268.2	213.0	143.6	105.6	37.1	1.9	2709.5*
76	172	2.2	29.0	92.0	166.6	234.9	276.7	298.7	272.4	237.4	245.9	0.0	0.0	148.4	96.6	33.2	2.1	2136.0*
76	173	1.1	14.7	54.6	71.2	96.9	191.6	221.6	198.4	193.3	143.7	132.1	107.8	92.5	44.9	16.3	2.0	1582.9
76	174	1.3	13.8	42.4	96.9	183.3	248.2	229.2	254.6	310.5	220.4	156.9	116.7	66.6	39.4	10.2	1.7	1991.9
76	175	.2	5.2	27.9	47.0	80.6	207.9	204.6	177.9	126.2	80.8	50.9	42.7	27.3	13.3	4.4	.9	1097.7
76	176	.7	2.8	11.8	47.3	75.1	84.0	90.6	134.6	177.0	194.9	136.4	171.2	113.2	78.9	37.7	2.4	1358.8
76	177	1.3	22.2	50.5	82.8	109.8	162.9	282.7	246.8	190.5	182.0	237.6	228.2	171.3	96.6	36.2	4.2	2105.7
76	178	2.2	32.7	95.0	167.4	233.8	290.8	330.9	350.7	347.9	326.8	290.3	231.4	158.8	89.7	31.6	2.0	2981.9
76	179	2.5	32.3	72.4	157.2	222.6	279.2	297.7	316.2	311.7	294.7	269.3	199.3	129.8	74.7	24.5	1.4	2685.5
76	180	.8	14.3	53.2	80.7	203.6	198.0	191.8	109.0	86.0	62.6	62.9	95.1	152.3	98.8	35.5	2.5	1446.9
76	181	0.0	0.0	56.1	121.2	189.4	197.4	225.8	211.3	206.6	311.5	191.6	201.1	155.4	85.4	33.9	3.1	2189.9*
76	182	1.6	31.0	94.0	149.4	181.3	191.1	151.9	205.2	239.6	223.0	215.6	172.9	100.9	81.2	39.2	2.7	2080.6
76	183	1.6	29.0	89.5	156.4	221.9	265.9	238.8	295.0	300.3	273.4	224.5	162.2	114.1	83.0	32.4	1.9	2490.0
76	184	1.0	29.8	88.7	153.7	153.3	169.1	149.4	70.9	37.4	0.0	51.3	0.0	42.3	25.0	12.5	.5	984.8*
76	185	.4	4.7	15.4	31.6	45.7	52.6	67.4	106.2	130.7	115.9	118.1	85.7	59.4	49.3	24.8	1.3	909.6
76	186	1.5	28.1	74.7	145.6	226.4	270.2	323.0	348.1	313.3	269.8	251.4	212.5	134.4	68.2	36.6	2.0	2711.7
76	187	1.2	24.1	81.1	149.6	217.5	275.4	319.3	344.3	326.6	307.3	291.4	223.1	162.6	104.5	35.8	1.6	2865.3
76	188	1.0	23.3	75.6	143.0	207.8	260.5	292.4	302.4	292.1	205.5	196.6	197.2	142.3	81.0	18.9	1.2	2446.7
76	189	1.2	23.7	78.6	142.2	217.6	0.0	213.8	308.5	319.2	307.0	268.0	154.6	113.9	64.9	26.9	1.8	2242.0*
76	190	1.1	24.0	80.5	148.9	213.5	268.8	313.7	333.8	324.9	0.0	269.1	210.6	123.1	59.2	22.5	2.1	2395.8*
76	191	1.2	19.0	68.5	137.0	199.1	254.7	297.2	328.3	331.4	312.3	0.0	219.1	156.7	87.6	28.7	1.8	2442.6*
76	192	1.1	24.0	83.1	154.6	221.7	278.8	319.0	342.3	342.6	321.5	281.0	227.3	163.8	94.6	33.2	2.3	2890.8
76	193	1.1	25.9	85.7	155.1	220.9	276.0	316.1	342.5	344.9	324.8	283.8	225.2	159.6	94.8	35.9	2.3	2894.6
76	194	.7	19.5	71.6	0.0	212.5	268.0	302.9	295.4	269.3	280.4	0.0	0.0	52.9	36.6	23.8	1.8	1835.4*
76	195	.7	16.6	71.4	127.8	203.7	263.4	306.2	321.2	327.6	309.9	268.4	209.8	142.6	80.5	25.1	1.7	2676.5
76	196	.8	21.4	76.7	144.8	210.2	266.8	309.7	0.0	331.0	275.3	226.6	188.2	143.1	83.7	28.1	1.3	2307.8*
76	197	.6	13.0	36.3	134.6	206.7	250.6	269.6	209.9	316.9	231.6	218.8	206.9	106.0	58.6	15.6	.9	2278.5
76	198	.6	18.5	76.0	151.7	220.7	281.1	325.7	351.9	350.8	332.1	297.6	241.9	176.7	103.2	36.8	1.9	2967.2
76	199	.9	22.9	82.3	154.9	224.7	280.4	320.0	330.9	311.0	276.0	220.7	162.5	117.0	67.8	29.7	2.0	2603.8
76	200	1.0	22.5	81.7	152.4	221.0	276.7	320.5	346.1	346.6	324.0	281.3	227.0	160.3	90.9	30.4	.9	2883.2

HOURLY AVERAGE IRRADIANCE AT ALL RAPS SITES

YR	DOY	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	TOTAL
76	201	.8	24.2	62.9	120.9	212.9	273.8	310.1	339.6	325.6	296.6	257.1	220.5	125.0	70.3	0.0	1.5	2647.9*
76	202	.5	19.4	71.4	139.9	196.6	266.3	296.6	284.5	275.2	266.2	224.1	190.5	127.6	72.0	23.4	.9	2455.2
76	203	.4	16.8	75.9	137.7	175.2	245.3	304.4	331.4	330.8	307.8	267.1	222.6	156.9	74.7	9.0	.6	2656.7
76	204	.9	11.8	50.5	106.0	185.5	266.4	295.3	323.3	325.7	295.1	271.6	214.8	146.3	82.3	28.9	1.1	2605.5
76	205	.4	17.8	72.3	140.8	208.9	267.3	308.2	320.3	317.1	292.8	262.1	220.3	148.6	82.6	26.3	.9	2688.6
76	206	.7	17.7	72.3	141.5	205.4	260.5	301.5	313.2	296.1	285.2	266.9	223.2	144.8	80.7	23.8	1.4	2635.4
76	207	.5	18.0	75.7	146.5	212.0	268.8	308.8	311.2	306.1	298.7	264.0	195.2	140.2	78.2	23.9	.8	2648.6
76	208	.1	14.0	62.1	116.6	190.1	255.9	294.7	307.1	327.3	309.6	261.4	196.2	126.5	36.5	10.9	.4	2515.4
76	209	-.1	0.0	51.0	92.0	133.1	178.6	192.2	268.6	242.1	70.9	76.4	176.7	145.5	86.2	30.5	1.2	1747.4*
76	210	-.0	13.2	61.2	120.4	197.7	251.0	300.3	310.5	308.0	0.0	0.0	0.0	69.1	14.6	8.7	.9	1655.7*
76	211	.4	6.9	37.6	67.0	88.2	118.2	137.5	191.7	186.1	212.4	225.9	184.4	135.1	74.0	19.5	.3	1685.2
76	212	.5	13.7	62.2	110.6	163.1	245.9	257.3	243.6	276.1	197.4	195.2	122.7	96.2	74.2	16.0	.7	2097.3
76	213	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	285.7	284.7	261.1	204.8	137.2	64.1	15.8	.4	1254.0*
76	214	0.0	17.5	75.7	148.4	217.6	275.2	318.8	346.9	328.0	308.9	264.2	211.3	144.1	81.4	23.0	.1	2760.8
76	215	0.0	6.3	37.6	102.9	194.9	276.6	321.5	343.5	339.8	322.4	232.9	169.9	133.3	76.8	20.2	.0	2578.5
76	216	0.0	15.9	68.8	140.5	212.3	273.5	318.3	336.9	338.9	313.6	269.1	217.5	148.0	75.8	19.0	-.3	2747.9
76	217	0.0	17.6	80.7	97.1	198.7	242.1	274.3	319.6	318.7	302.9	266.3	209.7	141.6	73.7	17.1	.2	2560.3
76	218	0.0	10.2	59.8	107.1	169.7	234.7	280.8	294.8	260.2	221.6	193.9	0.0	78.0	35.5	7.1	.0	1953.5*
76	219	0.0	7.1	34.5	43.3	59.4	152.4	65.2	125.5	186.0	292.1	267.4	126.4	55.9	31.3	11.8	.2	1458.3
76	220	0.0	11.2	63.3	133.9	0.0	237.1	223.7	263.1	266.7	299.6	282.8	222.3	151.3	76.6	19.5	.1	2271.5*
76	221	0.0	12.0	66.6	140.4	212.3	273.8	319.2	342.6	343.6	323.3	280.8	219.9	152.4	80.1	18.8	-.1	2785.8
76	222	0.0	13.0	65.8	136.4	202.7	263.3	293.1	328.6	342.6	320.3	272.6	195.6	85.8	45.0	10.2	.3	2575.3
76	223	0.0	10.6	60.9	120.4	190.1	255.5	287.4	308.4	306.5	297.5	256.3	203.9	135.7	69.9	12.5	-.1	2515.6
76	224	0.0	2.5	5.9	24.3	84.2	112.7	209.3	232.4	242.7	131.7	134.2	143.3	124.7	55.4	7.5	-.2	1510.7
76	225	0.0	6.7	42.0	91.8	146.6	234.0	244.7	225.0	181.8	131.6	98.0	72.2	37.6	20.0	14.7	-.2	1546.4
76	226	0.0	7.1	47.3	111.0	175.5	238.0	280.1	280.6	269.2	0.0	236.2	186.7	82.2	40.9	7.9	-.2	1962.6*
76	227	0.0	6.5	47.8	110.8	182.5	194.7	218.7	214.4	263.5	259.8	154.1	83.6	0.0	.6	.1	-.2	1737.1*
76	228	0.0	2.5	15.2	46.5	75.5	79.0	54.0	38.4	52.1	84.1	134.9	91.9	71.7	32.8	8.0	.2	786.8
76	229	0.0	7.9	48.6	97.3	145.8	224.8	288.4	220.8	234.7	237.1	212.8	172.6	113.4	61.7	9.2	0.0	2075.0
76	230	0.0	5.8	38.8	80.7	48.3	82.2	136.7	263.8	241.3	238.3	198.8	130.3	94.6	46.7	10.7	0.0	1617.0
76	231	0.0	8.5	60.2	133.5	204.4	265.8	309.2	333.1	332.7	309.6	261.7	206.7	137.8	66.8	11.4	0.0	2641.5
76	232	0.0	6.8	49.5	118.0	188.9	251.6	298.2	322.7	323.4	302.7	262.3	202.7	136.1	66.2	11.8	0.0	2541.0
76	233	0.0	5.6	42.2	98.3	168.7	228.5	272.3	284.6	285.0	261.0	225.0	177.9	116.5	49.7	8.3	0.0	2223.5
76	234	0.0	4.4	38.4	96.7	166.5	223.2	254.1	277.6	273.3	239.1	203.7	165.3	109.5	51.2	6.6	0.0	2111.5
76	235	0.0	3.7	33.9	69.9	156.4	218.4	266.1	292.4	272.9	263.4	229.3	176.1	114.8	50.9	8.2	0.0	2178.5
76	236	0.0	2.4	32.1	98.9	164.0	221.3	235.7	225.9	181.0	142.8	122.1	151.2	111.0	40.2	6.2	0.0	1734.8
76	237	0.0	3.7	37.1	90.3	151.0	209.5	253.6	269.4	252.7	0.0	205.4	156.9	97.0	36.6	3.4	0.0	1766.6*
76	238	0.0	4.6	36.2	73.4	121.8	198.9	238.9	256.8	189.2	176.1	115.9	110.0	18.1	11.2	6.0	0.0	1559.1
76	239	0.0	3.6	34.4	96.1	162.3	223.5	265.4	283.5	266.3	255.3	201.1	160.2	98.6	40.4	4.7	0.0	2095.4
76	240	0.0	4.3	38.8	98.9	168.2	228.2	269.5	283.8	302.7	222.1	180.9	113.9	80.8	30.7	5.1	0.0	2027.7
76	241	0.0	4.5	41.4	109.3	179.5	233.0	267.7	281.8	267.6	283.2	244.1	185.7	119.8	51.2	4.6	0.0	2273.3
76	242	0.0	3.6	48.3	119.8	189.8	251.0	295.0	320.7	318.4	291.0	244.6	180.8	119.1	51.3	4.8	0.0	2438.2
76	243	0.0	5.2	45.7	114.1	180.9	236.7	273.7	300.7	304.2	261.9	230.0	176.5	100.3	34.8	3.1	0.0	2267.9
76	244	0.0	3.7	37.3	95.4	136.0	167.0	217.8	255.4	250.7	220.8	202.8	160.3	95.4	33.1	2.6	0.0	1878.3
76	245	0.0	1.0	11.6	24.2	77.9	146.7	167.3	140.3	150.0	190.5	155.7	126.2	86.8	26.7	2.0	0.0	1306.8
76	246	0.0	1.7	22.5	82.4	165.3	229.3	271.7	244.6	295.2	252.3	202.7	156.5	97.5	35.7	2.0	0.0	2109.4
76	247	0.0	2.3	21.3	77.2	160.4	229.5	274.0	295.4	283.5	210.1	170.4	133.3	76.9	32.4	2.3	0.0	1968.8
76	248	0.0	2.9	31.4	93.4	163.5	217.1	259.9	288.8	279.6	256.7	224.6	170.1	104.9	38.8	2.1	0.0	2135.8
76	249	0.0	3.4	44.1	113.5	182.1	241.0	285.4	306.5	305.2	279.9	237.5	180.5	110.5	40.5	1.3	0.0	2331.5
76	250	0.0	3.3	43.6	111.9	180.6	239.9	283.4	302.8	301.6	278.2	233.5	175.4	104.4	35.2	1.3	0.0	2295.4

HOURLY AVERAGE IRRADIANCE AT ALL RAPS SITES

YR	DOY	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	TOTAL
76	251	0.0	3.1	42.9	110.6	179.8	239.0	285.5	306.6	304.5	277.2	227.5	166.2	95.6	31.6	.9	0.0	2271.1
76	252	0.0	2.1	32.4	93.0	156.5	213.5	261.5	259.6	245.8	224.5	144.6	47.4	22.1	11.2	.6	0.0	1716.7
76	253	0.0	1.0	6.3	22.0	40.9	89.7	181.4	180.6	290.2	267.8	235.5	180.0	111.3	39.9	1.1	0.0	1647.7
76	254	0.0	2.2	40.2	110.5	181.8	243.3	289.8	312.4	311.3	290.0	244.4	181.6	108.1	35.9	.7	0.0	2352.2
76	255	0.0	1.9	37.1	107.3	180.6	240.9	285.3	308.4	309.2	285.7	239.3	177.9	103.8	34.5	.9	0.0	2312.7
76	256	0.0	2.0	37.6	107.8	180.0	242.6	287.4	310.6	308.9	282.7	234.5	170.1	99.0	30.4	.4	0.0	2294.1
76	257	0.0	2.0	43.2	102.4	167.1	238.0	276.0	296.0	285.4	268.1	218.8	164.7	94.3	27.4	.6	0.0	2186.1
76	258	0.0	1.2	29.7	79.8	163.1	220.2	229.1	282.2	274.4	219.9	210.7	153.5	81.2	18.8	.0	0.0	1963.8
76	259	0.0	1.1	11.7	29.1	71.2	96.4	123.9	104.1	213.4	213.1	175.9	116.8	80.2	24.6	-.2	0.0	1263.0
76	260	0.0	1.6	31.1	92.0	162.5	224.5	254.4	286.0	284.1	269.9	225.2	165.4	93.9	24.2	0.0	0.0	2114.9
76	261	0.0	1.3	26.8	85.3	155.4	223.4	268.3	288.5	287.2	252.8	212.0	152.7	90.2	26.4	0.0	0.0	2070.3
76	262	0.0	1.0	20.4	69.9	138.0	203.4	246.4	270.3	233.7	221.3	173.0	114.1	58.5	18.2	0.0	0.0	1768.2
76	263	0.0	.9	20.8	54.8	113.0	192.2	225.2	260.8	210.3	181.6	184.0	89.1	15.2	6.7	0.0	0.0	1554.5
76	264	0.0	.6	12.7	23.5	22.8	30.1	28.5	38.6	79.8	74.5	45.9	31.8	30.4	11.0	0.0	0.0	430.2
76	265	0.0	1.1	28.5	92.1	162.6	223.0	0.0	289.9	287.9	266.2	220.2	159.6	86.5	20.4	0.0	0.0	1837.8*
76	266	0.0	.9	26.1	89.5	159.2	219.1	264.0	286.4	285.2	261.1	214.5	153.1	80.8	16.5	0.0	0.0	2056.5
76	267	0.0	.5	18.7	43.6	51.9	91.2	126.2	105.2	103.4	136.8	102.9	62.8	29.8	6.4	0.0	0.0	881.3
76	268	0.0	.6	11.6	52.3	101.0	202.0	252.7	269.4	269.0	242.2	191.7	134.8	65.1	11.9	0.0	0.0	1804.3
76	269	0.0	.6	5.3	12.0	10.2	12.1	24.2	30.4	71.8	121.4	128.3	71.1	26.9	4.9	0.0	0.0	519.2
76	270	0.0	.0	4.0	33.0	62.5	106.5	129.2	94.9	69.1	76.2	86.4	41.1	18.2	4.5	0.0	0.0	725.5
76	271	0.0	.3	2.8	13.0	18.5	34.7	77.6	110.1	130.1	145.5	104.4	76.6	46.7	6.0	0.0	0.0	766.2
76	272	0.0	.4	16.3	70.5	135.2	193.9	228.3	223.1	211.8	198.0	127.1	56.1	34.0	7.9	0.0	0.0	1504.5
76	273	0.0	.5	16.1	38.8	87.5	116.2	147.9	174.6	199.6	149.8	89.8	49.3	16.3	1.4	0.0	0.0	1087.8
76	274	0.0	.4	19.9	78.2	146.5	189.7	232.9	271.1	268.5	242.5	197.0	134.8	65.6	10.1	0.0	0.0	1857.2
76	275	0.0	0.0	20.3	83.0	148.5	202.5	244.1	263.2	256.5	230.9	181.4	123.0	58.8	8.8	0.0	0.0	1821.0
76	276	0.0	0.0	17.3	75.4	141.5	196.1	236.0	254.3	255.9	231.8	184.7	124.2	59.0	7.6	0.0	0.0	1783.7
76	277	0.0	0.0	0.0	73.3	138.7	194.0	229.3	251.3	239.1	225.5	173.9	97.9	54.5	8.0	0.0	0.0	1685.5*
76	278	0.0	0.0	16.1	69.5	142.5	189.8	231.3	250.7	226.1	170.3	158.1	67.1	19.4	.8	0.0	0.0	1541.8
76	279	0.0	0.0	9.0	41.8	0.0	61.9	0.0	35.8	27.6	36.4	27.0	11.8	1.7	.5	0.0	0.0	253.3*
76	280	0.0	0.0	16.8	79.1	151.0	210.7	242.1	240.4	228.7	176.2	197.0	113.6	48.7	4.6	0.0	0.0	1708.9
76	281	0.0	0.0	13.6	53.3	121.1	167.5	206.3	184.9	169.7	123.9	104.5	49.0	19.4	3.0	0.0	0.0	1216.1
76	282	0.0	0.0	12.2	73.1	133.8	198.8	219.5	209.7	194.8	221.3	159.2	96.3	42.8	2.9	0.0	0.0	1564.5
76	283	0.0	0.0	12.6	27.4	95.5	154.1	220.7	244.6	224.6	180.0	157.9	79.8	29.9	3.7	0.0	0.0	1430.8
76	284	0.0	0.0	15.1	71.4	137.4	191.5	232.1	245.7	224.5	201.8	171.4	109.9	43.8	2.8	0.0	0.0	1647.4
76	285	0.0	0.0	14.7	71.6	138.2	194.7	234.5	253.7	248.9	220.2	169.5	107.3	42.2	2.8	0.0	0.0	1698.4
76	286	0.0	0.0	15.3	72.6	139.2	194.3	233.6	251.9	249.5	221.7	175.6	111.5	44.7	2.5	0.0	0.0	1712.3
76	287	0.0	0.0	12.7	65.3	134.1	194.0	232.7	250.5	243.6	218.1	163.6	109.3	43.7	2.3	0.0	0.0	1669.9
76	288	0.0	0.0	13.8	71.1	137.5	193.5	0.0	249.4	241.0	211.7	166.1	104.8	40.5	2.8	0.0	0.0	1432.3*
76	289	0.0	0.0	11.2	54.6	122.1	0.0	219.3	239.9	237.6	212.1	169.6	99.6	37.6	1.6	0.0	0.0	1405.1*
76	290	0.0	0.0	7.9	66.3	133.1	186.2	225.5	244.0	239.1	210.2	161.3	97.8	34.9	1.4	0.0	0.0	1609.5
76	291	0.0	0.0	10.3	64.2	133.2	192.4	233.8	253.4	248.4	219.5	173.6	109.1	38.8	1.4	0.0	0.0	1678.1
76	292	0.0	0.0	12.2	65.1	114.1	162.4	226.0	242.4	235.0	199.4	128.3	66.8	22.8	1.4	0.0	0.0	1475.8
76	293	0.0	0.0	1.0	5.9	11.9	16.4	35.1	41.2	28.8	20.5	15.5	7.3	5.7	.6	0.0	0.0	189.8
76	294	0.0	0.0	1.5	8.3	17.9	57.5	113.1	125.9	55.4	60.2	70.3	84.1	31.0	1.0	0.0	0.0	626.3
76	295	0.0	0.0	0.0	59.1	125.6	183.9	221.6	238.0	228.9	197.9	148.3	88.8	31.9	0.0	0.0	0.0	1524.1*
76	296	0.0	0.0	7.6	54.6	118.5	177.0	215.5	233.8	226.7	195.8	154.5	91.4	22.9	.3	0.0	0.0	1498.8
76	297	0.0	0.0	0.0	4.7	10.6	17.8	14.5	18.2	9.3	9.7	10.5	5.5	2.3	-.0	0.0	0.0	103.2*
76	298	0.0	0.0	1.1	10.5	13.2	21.7	27.8	36.6	31.8	28.8	22.2	9.3	3.3	.3	0.0	0.0	206.6
76	299	0.0	0.0	.6	3.7	9.3	16.4	26.8	44.9	56.7	40.4	29.4	0.0	4.3	.3	0.0	0.0	232.7*
76	300	0.0	0.0	5.3	45.8	106.2	163.8	202.0	218.1	147.7	117.5	61.0	36.5	8.3	.2	0.0	0.0	1112.4

HOURLY AVERAGE IRRADIANCE AT ALL RAPS SITES

YR	DOY	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	TOTAL
76	301	0.0	0.0	1.5	9.2	21.7	46.0	58.5	78.9	94.0	57.3	43.6	27.1	13.3	.5	0.0	0.0	451.6
76	302	0.0	0.0	6.9	58.3	113.3	166.3	205.9	222.2	217.5	184.6	145.5	82.8	25.3	-.0	0.0	0.0	1433.5
76	303	0.0	0.0	6.2	39.2	82.4	131.6	0.0	187.8	173.8	121.9	65.4	27.4	6.9	.1	0.0	0.0	844.8*
76	304	0.0	0.0	.3	3.0	6.5	9.1	14.5	17.4	22.1	16.5	11.6	7.3	3.6	.8	0.0	0.0	112.3
76	305	0.0	0.0	0.0	13.7	23.0	46.8	104.5	189.7	190.9	184.5	134.2	77.9	19.6	-.0	0.0	0.0	984.8*
76	306	0.0	0.0	3.3	35.0	95.5	157.3	195.9	211.6	206.7	181.0	136.9	75.8	19.6	0.0	0.0	0.0	1318.6
76	307	0.0	0.0	4.0	27.9	86.3	150.5	181.9	191.1	197.1	169.1	122.7	64.0	11.4	0.0	0.0	0.0	1206.0
76	308	0.0	0.0	4.5	45.9	107.2	166.3	202.3	217.9	209.3	165.2	100.3	64.1	17.9	0.0	0.0	0.0	1301.0
76	309	0.0	0.0	2.0	21.4	37.6	72.6	62.5	78.5	83.0	66.3	83.9	57.8	16.0	0.0	0.0	0.0	601.7
76	310	0.0	0.0	4.7	34.0	85.1	154.7	194.0	211.2	198.2	183.2	119.0	61.1	16.1	0.0	0.0	0.0	1261.2
76	311	0.0	0.0	3.2	39.1	98.9	152.3	191.1	203.2	185.3	167.5	118.6	69.8	13.9	0.0	0.0	0.0	1243.1
76	312	0.0	0.0	2.2	36.9	96.6	154.1	194.1	211.3	207.5	180.5	135.9	78.1	19.4	0.0	0.0	0.0	1316.7
76	313	0.0	0.0	2.7	36.8	92.1	151.3	184.6	192.1	153.6	142.8	87.5	30.9	8.3	0.0	0.0	0.0	1082.6
76	314	0.0	0.0	1.8	36.7	94.7	150.3	185.9	193.9	155.1	139.4	128.6	64.6	12.5	0.0	0.0	0.0	1163.5
76	315	0.0	0.0	1.9	35.4	94.5	150.2	188.1	204.8	196.8	173.6	127.0	67.0	12.4	0.0	0.0	0.0	1253.7
76	316	0.0	0.0	1.0	14.6	44.3	74.7	106.6	103.6	89.3	98.3	108.5	56.9	11.3	0.0	0.0	0.0	709.0
76	317	0.0	0.0	2.2	35.2	93.8	147.2	185.3	199.1	192.2	166.7	117.6	59.2	10.2	0.0	0.0	0.0	1208.7
76	318	0.0	0.0	1.7	32.6	84.0	97.6	120.6	137.4	142.0	125.9	109.9	59.9	8.0	0.0	0.0	0.0	919.3
76	319	0.0	0.0	1.0	17.9	50.8	101.3	159.3	182.1	182.8	144.3	103.0	48.9	9.3	0.0	0.0	0.0	1000.7
76	320	0.0	0.0	1.2	27.1	78.8	136.8	168.6	186.1	180.9	154.2	108.3	50.6	7.9	0.0	0.0	0.0	1100.7
76	321	0.0	0.0	1.1	24.7	76.5	126.4	164.0	184.1	180.4	153.0	108.2	53.5	8.5	0.0	0.0	0.0	1080.5
76	322	0.0	0.0	1.2	11.3	40.4	122.3	172.8	189.5	185.1	159.8	117.7	59.0	10.4	0.0	0.0	0.0	1069.6
76	323	0.0	0.0	1.6	24.5	76.9	129.7	166.0	183.7	177.0	155.2	110.2	55.6	8.0	0.0	0.0	0.0	1088.6
76	324	0.0	0.0	1.1	28.5	80.7	130.2	156.3	169.7	181.0	145.5	103.2	42.6	7.0	0.0	0.0	0.0	1045.8
76	325	0.0	0.0	.6	13.5	50.3	90.1	123.1	149.6	158.9	140.8	100.6	50.9	7.3	0.0	0.0	0.0	885.8
76	326	0.0	0.0	.7	7.8	20.5	73.2	150.3	177.1	175.8	131.2	53.9	22.5	4.5	0.0	0.0	0.0	817.6
76	327	0.0	0.0	.7	21.9	76.8	133.7	163.1	162.3	141.3	140.0	115.5	58.1	9.0	0.0	0.0	0.0	1022.3
76	328	0.0	0.0	-.0	11.4	41.7	41.1	57.8	79.2	54.3	46.4	33.4	18.4	2.8	0.0	0.0	0.0	386.7
76	329	0.0	0.0	.4	10.7	41.5	79.1	137.9	164.9	163.4	144.3	102.5	49.7	7.0	0.0	0.0	0.0	901.3
76	330	0.0	0.0	.5	14.1	57.6	117.4	141.9	174.1	171.0	148.6	103.5	49.2	4.4	0.0	0.0	0.0	982.3
76	331	0.0	0.0	-.2	0.0	14.1	22.6	24.7	29.1	32.9	33.3	12.4	6.8	1.9	0.0	0.0	0.0	177.7*
76	332	0.0	0.0	.3	1.9	8.2	13.8	19.3	31.4	28.4	28.3	37.8	22.4	4.6	0.0	0.0	0.0	196.3
76	333	0.0	0.0	.1	8.8	31.1	84.3	147.8	135.2	91.5	0.0	96.8	45.1	6.0	0.0	0.0	0.0	646.7*
76	334	0.0	0.0	.6	17.4	68.1	124.8	161.9	181.3	179.7	154.8	112.2	55.3	8.0	0.0	0.0	0.0	1064.1
76	335	0.0	0.0	.2	16.4	66.9	118.7	158.2	176.9	171.4	145.9	77.2	16.3	3.0	0.0	0.0	0.0	951.0
76	336	0.0	0.0	0.0	0.0	39.8	63.4	49.1	76.1	90.5	53.8	58.3	30.0	4.3	0.0	0.0	0.0	465.3*
76	337	0.0	0.0	0.0	10.9	52.8	105.6	152.3	159.1	136.2	108.4	69.9	41.1	4.5	0.0	0.0	0.0	840.7
76	338	0.0	0.0	0.0	10.1	37.5	97.2	144.9	163.7	161.7	137.2	91.0	42.7	5.0	0.0	0.0	0.0	891.0
76	339	0.0	0.0	0.0	14.4	60.4	112.6	147.2	161.4	138.4	124.8	92.9	40.3	4.5	0.0	0.0	0.0	897.0
76	340	0.0	0.0	0.0	6.9	36.6	72.6	128.5	131.8	153.8	111.1	78.1	37.6	8.2	0.0	0.0	0.0	765.4
76	341	0.0	0.0	0.0	1.4	7.1	12.0	14.8	22.3	21.6	15.1	9.9	8.0	.5	0.0	0.0	0.0	112.8
76	342	0.0	0.0	0.0	9.0	51.0	110.4	151.5	174.0	168.8	144.6	75.8	34.4	4.2	0.0	0.0	0.0	923.6
76	343	0.0	0.0	0.0	7.8	33.2	82.8	0.0	165.0	151.5	137.6	96.3	45.3	5.7	0.0	0.0	0.0	725.3*
76	344	0.0	0.0	0.0	13.6	60.7	110.7	150.3	167.8	165.1	142.7	97.9	44.8	5.5	0.0	0.0	0.0	959.1
76	345	0.0	0.0	0.0	3.7	18.5	26.4	19.7	15.4	8.1	8.5	5.2	2.8	.9	0.0	0.0	0.0	109.3
76	346	0.0	0.0	0.0	4.9	28.3	39.0	39.4	61.6	87.1	61.1	36.1	17.8	3.0	0.0	0.0	0.0	378.3
76	347	0.0	0.0	0.0	3.9	34.7	95.5	141.7	150.7	156.4	137.2	94.6	46.6	5.4	0.0	0.0	0.0	866.8
76	348	0.0	0.0	0.0	11.5	56.4	106.3	143.2	163.2	164.0	142.9	101.4	48.1	6.4	0.0	0.0	0.0	943.6
76	349	0.0	0.0	0.0	12.4	60.6	111.5	149.9	173.6	172.0	145.4	103.7	50.7	6.5	0.0	0.0	0.0	986.3
76	350	0.0	0.0	0.0	13.6	60.6	0.0	132.8	156.8	158.0	139.0	101.3	49.2	6.5	0.0	0.0	0.0	817.9*

HOURLY AVERAGE IRRADIANCE AT ALL RAPS SITES

YR	DOY	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	TOTAL
76	351	0.0	0.0	0.0	12.9	46.6	85.7	136.6	153.2	166.1	134.9	58.8	42.6	6.9	0.0	0.0	0.0	844.4
76	352	0.0	0.0	0.0	9.5	50.9	101.4	141.3	160.0	158.9	135.6	98.6	47.4	6.2	0.0	0.0	0.0	909.8
76	353	0.0	0.0	0.0	9.4	51.2	101.1	139.9	159.3	158.6	136.4	97.6	46.9	6.2	0.0	0.0	0.0	906.7
76	354	0.0	0.0	0.0	6.5	44.7	82.5	132.8	146.3	130.5	108.6	68.0	19.2	1.8	0.0	0.0	0.0	742.9
76	355	0.0	0.0	0.0	2.8	33.2	93.8	144.4	0.0	169.1	149.3	109.1	56.3	8.9	0.0	0.0	0.0	766.9*
76	356	0.0	0.0	0.0	9.1	55.6	108.9	145.5	165.6	167.7	146.8	107.5	55.1	9.1	0.0	0.0	0.0	970.9
76	357	0.0	0.0	0.0	6.4	46.6	94.4	138.3	151.1	150.3	137.5	104.3	50.3	6.9	0.0	0.0	0.0	886.0
76	358	0.0	0.0	0.0	8.8	53.9	107.1	148.3	169.7	169.5	150.6	109.6	57.4	8.9	0.0	0.0	0.0	983.6
76	359	0.0	0.0	0.0	7.8	51.2	105.2	136.1	135.7	135.7	139.3	99.0	47.7	7.0	0.0	0.0	0.0	866.6
76	360	0.0	0.0	0.0	3.0	23.6	96.3	127.7	124.0	134.3	84.1	65.2	42.4	9.6	0.0	0.0	0.0	710.2
76	361	0.0	0.0	0.0	8.3	55.7	102.0	107.3	97.3	114.7	126.1	93.5	44.9	6.7	0.0	0.0	0.0	754.5
76	362	0.0	0.0	0.0	4.7	27.7	67.4	96.2	108.6	102.0	88.6	64.1	28.8	5.1	0.0	0.0	0.0	593.2
76	363	0.0	0.0	0.0	5.9	50.4	104.7	147.3	167.3	169.1	148.6	109.3	59.0	10.8	0.0	0.0	0.0	972.4
76	364	0.0	0.0	0.0	9.1	55.4	109.2	140.3	169.9	178.3	157.1	114.9	60.7	8.4	0.0	0.0	0.0	1003.2
76	365	0.0	0.0	0.0	8.6	52.2	106.8	150.9	167.4	163.2	134.6	81.7	38.2	6.0	0.0	0.0	0.0	909.6
76	366	0.0	0.0	0.0	7.7	53.5	107.9	149.9	172.0	160.9	149.5	114.8	61.7	11.8	0.0	0.0	0.0	989.8

HOURLY AVERAGE IRRADIANCE AT ALL MAPS SITES

YR	DOY	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	TOTAL
77	1	0.0	0.0	0.0	7.9	53.3	108.4	151.9	174.7	178.4	158.6	117.5	62.7	11.9	0.0	0.0	0.0	1025.4
77	2	0.0	0.0	0.0	1.1	8.7	30.3	44.3	64.3	68.1	60.0	43.7	13.3	2.5	0.0	0.0	0.0	336.4
77	3	0.0	0.0	0.0	4.7	23.2	54.3	76.6	91.5	86.9	70.1	49.3	21.7	3.8	0.0	0.0	0.0	482.0
77	4	0.0	0.0	0.0	2.5	13.8	28.4	29.3	31.5	31.2	25.1	31.2	15.4	4.2	0.0	0.0	0.0	212.7
77	5	0.0	0.0	0.0	1.9	11.9	29.6	51.6	71.4	76.2	60.9	39.3	18.1	2.8	0.0	0.0	0.0	363.8
77	6	0.0	0.0	0.0	2.8	16.2	39.6	52.4	56.4	57.7	63.6	56.1	24.2	6.0	0.0	0.0	0.0	375.0
77	7	0.0	0.0	0.0	8.2	55.2	111.8	157.0	180.3	182.2	160.4	117.7	62.1	13.5	0.0	0.0	0.0	1048.3
77	8	0.0	0.0	0.0	7.9	34.9	75.1	107.5	123.2	128.2	101.6	54.0	19.8	3.4	0.0	0.0	0.0	655.7
77	9	0.0	0.0	0.0	2.5	12.7	34.5	47.9	60.9	35.2	32.0	37.9	22.0	3.8	0.0	0.0	0.0	289.4
77	10	0.0	0.0	0.0	8.2	52.3	112.2	159.9	185.9	186.5	166.2	130.1	72.3	17.9	0.0	0.0	0.0	1091.7
77	11	0.0	0.0	0.0	9.6	39.3	96.0	134.8	179.9	185.2	165.8	123.6	67.6	16.3	0.0	0.0	0.0	1018.4
77	12	0.0	0.0	0.0	8.5	55.7	112.9	158.0	180.8	181.4	159.6	118.9	62.1	11.6	0.0	0.0	0.0	1049.4
77	13	0.0	0.0	0.0	2.0	11.8	27.0	38.0	59.9	63.1	40.3	29.7	22.6	5.9	0.0	0.0	0.0	300.3
77	14	0.0	0.0	0.0	2.6	14.0	32.1	55.3	94.9	118.2	160.6	121.2	47.5	15.6	0.0	0.0	0.0	662.2
77	15	0.0	0.0	0.0	3.7	15.3	42.4	79.4	90.0	92.8	81.0	78.6	47.5	10.3	0.0	0.0	0.0	541.0
77	16	0.0	0.0	0.0	10.2	60.7	122.6	168.4	191.8	194.0	176.3	137.9	81.2	21.8	.3	0.0	0.0	1165.3
77	17	0.0	0.0	0.0	9.9	47.8	89.1	121.3	132.0	135.8	120.1	80.6	46.5	15.2	.9	0.0	0.0	799.2
77	18	0.0	0.0	0.0	5.6	31.3	79.4	112.6	115.7	129.5	123.1	85.3	47.8	14.7	.5	0.0	0.0	745.6
77	19	0.0	0.0	0.0	11.1	47.9	70.6	126.6	0.0	140.5	0.0	51.6	18.4	7.8	.6	0.0	0.0	475.3*
77	20	0.0	0.0	0.0	8.3	56.8	116.3	167.0	192.7	198.6	179.8	140.7	84.7	25.6	.2	0.0	0.0	1172.8
77	21	0.0	0.0	0.0	12.4	55.7	115.3	166.7	192.4	197.1	180.5	142.7	89.3	28.5	.3	0.0	0.0	1181.1
77	22	0.0	0.0	0.0	14.3	77.4	131.8	178.9	204.6	204.2	173.8	122.2	82.8	20.2	.5	0.0	0.0	1210.6
77	23	0.0	0.0	0.0	3.6	21.5	43.7	66.8	86.2	99.5	79.4	61.7	38.4	10.6	.0	0.0	0.0	511.4
77	24	0.0	0.0	0.0	4.4	29.9	87.5	154.4	149.5	104.4	95.5	90.3	45.7	10.3	.9	0.0	0.0	772.9
77	25	0.0	0.0	0.0	5.8	31.8	78.5	143.9	161.4	151.3	120.9	75.9	40.6	15.3	.8	0.0	0.0	826.2
77	26	0.0	0.0	0.0	11.2	42.5	80.3	115.3	181.8	167.8	170.7	150.7	92.5	29.9	.6	0.0	0.0	1043.3
77	27	0.0	0.0	0.0	3.3	28.1	61.1	110.6	154.6	172.6	153.7	137.6	0.0	32.0	1.1	0.0	0.0	854.9*
77	28	0.0	0.0	0.0	12.0	68.5	133.4	183.3	207.7	214.5	195.8	155.2	97.8	35.5	1.4	0.0	0.0	1305.1
77	29	0.0	0.0	0.0	14.7	71.2	138.8	187.8	215.2	220.3	203.7	0.0	106.0	41.2	1.8	0.0	0.0	1200.9*
77	30	0.0	0.0	0.0	14.6	69.0	132.0	178.5	205.2	213.4	197.7	158.0	100.9	37.6	1.5	0.0	0.0	1308.3
77	31	0.0	0.0	0.0	15.8	72.0	139.7	183.8	213.1	219.2	203.9	162.7	94.3	31.2	2.4	0.0	0.0	1338.3
77	32	0.0	0.0	.1	16.0	74.4	140.0	189.5	218.8	224.7	207.3	168.1	108.5	42.3	1.6	0.0	0.0	1391.4
77	33	0.0	0.0	.2	7.6	27.3	55.9	103.2	122.8	102.1	71.3	43.6	27.6	15.0	1.1	0.0	0.0	577.7
77	34	0.0	0.0	.0	14.6	65.0	128.3	178.8	208.0	214.9	197.9	160.0	103.3	40.9	2.3	0.0	0.0	1314.0
77	35	0.0	0.0	.2	9.1	44.7	115.8	129.9	123.1	68.2	63.9	100.6	36.6	11.0	-.1	0.0	0.0	703.0
77	36	0.0	0.0	.2	17.6	77.8	144.1	193.2	221.4	229.0	208.1	167.3	113.9	44.2	3.3	0.0	0.0	1420.0
77	37	0.0	0.0	.4	20.5	72.5	125.2	151.0	195.5	216.3	163.4	163.8	111.6	47.1	3.1	0.0	0.0	1270.4
77	38	0.0	0.0	.6	21.9	81.5	142.7	185.7	212.2	218.5	197.1	159.5	99.0	47.3	3.1	0.0	0.0	1369.2
77	39	0.0	0.0	.4	19.2	77.3	138.5	182.8	209.8	213.1	194.8	156.3	99.2	35.5	2.0	0.0	0.0	1329.0
77	40	0.0	0.0	.4	17.9	71.8	134.0	179.3	210.2	207.1	189.6	158.9	106.9	44.8	3.5	0.0	0.0	1324.5
77	41	0.0	0.0	.5	19.5	75.5	130.1	182.6	211.9	218.6	203.5	166.1	109.4	48.1	4.3	0.0	0.0	1376.2
77	42	0.0	0.0	.3	19.5	73.7	129.7	177.4	204.6	199.7	175.7	114.5	61.1	24.1	2.6	0.0	0.0	1183.2
77	43	0.0	0.0	.3	1.1	7.7	19.9	52.4	91.7	70.5	100.3	119.8	88.6	40.6	3.1	0.0	0.0	595.3
77	44	0.0	0.0	.5	25.7	89.3	153.7	201.0	230.4	236.6	218.9	180.0	122.7	56.2	5.6	0.0	0.0	1520.6
77	45	0.0	0.0	.3	4.0	20.8	95.6	118.8	109.6	136.2	165.3	175.1	89.0	47.6	6.1	0.0	0.0	968.6
77	46	0.0	0.0	.3	11.5	56.6	91.9	157.5	193.8	219.7	199.2	177.8	128.9	59.6	7.7	0.0	0.0	1304.4
77	47	0.0	0.0	.6	28.7	92.6	155.8	206.0	235.2	241.6	222.6	178.6	90.5	43.5	4.4	0.0	0.0	1500.3
77	48	0.0	0.0	.9	19.3	64.0	0.0	153.4	227.9	223.3	207.6	145.8	119.2	58.5	7.0	0.0	0.0	1226.9*
77	49	0.0	0.0	.7	26.9	81.8	0.0	0.0	231.9	238.4	221.3	175.1	79.2	34.7	6.0	0.0	0.0	1096.1*
77	50	0.0	0.0	-.1	9.4	28.0	64.7	122.8	95.4	107.8	98.3	99.7	67.2	49.2	9.6	0.0	0.0	752.0

HOURLY AVERAGE IRRADIANCE AT ALL RAPS SITES

YR	DOY	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	TOTAL
77	51	0.0	0.0	1.1	15.7	83.8	111.0	179.3	232.4	222.3	180.5	83.8	75.9	38.6	6.2	0.0	0.0	1230.7
77	52	0.0	0.0	1.2	38.1	101.0	161.6	208.8	235.3	240.2	226.1	189.5	132.1	67.6	12.1	0.0	0.0	1613.4
77	53	0.0	0.0	1.2	20.4	89.9	153.6	202.8	236.0	220.0	163.7	143.5	88.1	44.9	6.6	0.0	0.0	1371.0
77	54	0.0	0.0	.3	2.4	3.1	4.3	12.9	13.9	66.2	0.0	102.3	99.1	58.4	11.2	0.0	0.0	374.2*
77	55	0.0	0.0	.8	8.1	19.1	38.8	94.9	214.9	0.0	191.5	141.3	117.4	71.1	12.8	0.0	0.0	910.6*
77	56	0.0	0.0	1.6	26.7	54.4	72.4	135.3	213.5	223.6	191.8	146.6	72.2	22.3	4.3	0.0	0.0	1165.1
77	57	0.0	0.0	.3	2.0	5.5	9.9	12.1	31.2	42.6	36.6	33.4	21.4	0.0	0.0	0.0	0.0	194.9*
77	58	0.0	0.0	1.3	20.1	56.1	93.3	131.2	179.2	153.9	84.5	66.8	66.4	32.9	6.7	0.0	0.0	892.4
77	59	0.0	0.0	3.9	35.1	106.9	180.9	223.3	251.5	251.0	240.5	203.8	142.0	55.1	6.4	0.0	0.0	1700.4
77	60	0.0	0.0	4.1	52.7	126.1	191.8	240.0	268.9	276.7	258.6	205.1	145.6	67.8	9.7	0.0	0.0	1847.1
77	61	0.0	0.0	3.1	27.9	43.8	97.3	160.8	230.1	199.4	170.8	137.0	53.4	28.4	6.5	-.1	0.0	1158.4
77	62	0.0	0.0	.9	13.7	25.2	35.9	28.4	30.5	27.3	26.6	17.8	15.3	10.2	2.0	-.1	0.0	233.8
77	63	0.0	0.0	3.0	0.0	87.7	78.0	55.9	122.9	144.8	133.0	107.7	95.7	32.4	5.6	.2	0.0	867.1*
77	64	0.0	0.0	5.1	50.1	114.3	148.3	195.6	252.1	269.6	253.5	213.3	154.0	79.0	19.9	-.5	0.0	1754.2
77	65	0.0	0.0	5.5	53.9	119.4	176.9	226.8	263.3	272.2	254.6	211.5	0.0	86.8	19.9	-.3	0.0	1690.6*
77	66	0.0	0.0	6.6	54.8	121.7	187.7	238.3	267.9	271.5	248.7	210.2	152.4	82.5	19.4	-.3	0.0	1861.3
77	67	0.0	0.0	6.7	56.0	126.5	189.7	237.6	268.7	273.9	253.7	210.2	146.3	81.8	20.4	-.1	0.0	1871.4
77	68	0.0	0.0	7.4	51.7	124.4	164.0	235.0	263.2	235.4	224.0	176.8	140.0	74.9	18.6	.1	0.0	1715.4
77	69	0.0	0.0	5.4	41.9	89.7	104.6	143.0	179.5	209.0	160.9	95.8	66.8	51.4	15.9	.4	0.0	1164.2
77	70	0.0	0.0	3.4	7.6	7.4	17.2	27.4	27.0	43.6	41.4	25.9	13.7	4.5	.7	.0	0.0	220.0
77	71	0.0	0.0	7.7	28.2	75.1	48.6	44.5	45.9	66.1	44.6	34.0	23.6	16.7	3.0	-.2	0.0	437.8
77	72	0.0	0.0	1.7	6.9	19.7	51.8	85.1	78.9	164.3	169.9	129.1	143.2	77.0	23.8	.0	0.0	951.4
77	73	0.0	0.0	10.1	60.9	129.6	192.6	240.6	268.5	273.1	253.2	211.7	153.3	83.8	22.1	.1	0.0	1899.5
77	74	0.0	0.0	10.9	58.1	123.7	188.5	233.3	0.0	0.0	194.9	182.0	134.9	74.6	21.2	.2	0.0	1222.3*
77	75	0.0	0.0	13.7	76.6	151.3	216.6	268.5	292.9	298.0	275.4	220.7	156.6	74.9	16.8	.1	0.0	2061.9
77	76	0.0	0.0	2.8	26.9	41.4	34.2	57.2	25.4	19.8	12.3	30.9	64.5	22.6	5.7	.5	0.0	344.2*
77	77	0.0	.0	2.6	9.7	29.2	37.5	77.7	146.9	190.6	185.9	153.3	145.7	90.1	25.4	.5	0.0	1095.0
77	78	0.0	.1	8.2	63.3	135.8	173.2	213.1	232.3	251.1	166.0	67.9	61.8	15.4	12.7	.5	0.0	1401.2
77	79	0.0	.1	9.5	47.3	105.4	178.3	225.9	283.4	292.7	269.8	207.1	129.7	72.6	21.8	.4	0.0	1844.0
77	80	0.0	-.1	16.3	76.9	142.2	204.4	213.1	273.4	263.8	244.0	166.8	50.5	9.2	2.6	1.2	0.0	1664.5
77	81	0.0	-.2	19.5	85.7	162.4	227.6	278.0	306.0	309.6	286.9	242.3	179.2	101.0	30.3	1.0	0.0	2229.6
77	82	0.0	.5	19.9	83.5	156.1	221.8	270.8	297.5	303.6	280.2	236.6	179.8	107.6	35.2	1.1	0.0	2194.1
77	83	0.0	.7	20.9	84.0	155.8	208.4	229.9	271.3	276.1	253.9	201.2	138.7	76.5	24.1	.9	0.0	1942.3
77	84	0.0	.5	18.9	76.0	146.7	210.4	259.3	287.2	292.2	270.7	228.9	169.5	99.3	31.9	1.2	0.0	2092.7
77	85	0.0	.5	20.5	73.3	94.5	171.4	215.7	258.3	272.3	237.9	189.3	109.0	44.8	18.3	.6	0.0	1706.5
77	86	0.0	3.3	4.6	10.5	20.7	25.9	22.7	29.1	28.4	26.8	37.7	12.8	12.5	4.6	.7	0.0	240.3
77	87	0.0	-.2	1.3	4.0	13.1	21.9	96.7	266.4	227.8	194.6	142.2	49.1	11.1	5.1	1.9	0.0	1035.1
77	88	0.0	.8	23.9	90.2	162.1	219.3	274.2	300.3	304.3	282.6	234.2	173.7	100.3	33.7	1.5	0.0	2201.2
77	89	0.0	1.1	27.1	97.8	175.1	240.8	290.1	316.3	318.4	297.2	254.5	193.5	119.1	43.5	2.0	0.0	2376.7
77	90	0.0	.8	11.9	46.2	124.2	205.2	218.2	295.1	311.7	281.0	243.1	178.4	108.0	37.0	1.5	0.0	2062.3

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