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NBSIR 84-2859

The NBS Daylight Availability Database

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
Building Physics Division
Gaithersburg, Maryland 20899

July 1984

Prepared for
Naval Civil Engineering Laboratory
Port Hueneme, California 93043

National Fenestration Council
3310 Harrison St.
Topeka, KS 66611

Naval Facilities Engineering Command
U.S. Navy
Washington, DC 20390

Directorate of Civil Engineering
U.S. Air Force
Washington, DC 20330

and

Office of Chief of Engineers
U.S. Army
Washington, DC 20314

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NBSIR 84-2859

THE NBS DAYLIGHT AVAILABILITY DATABASE

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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

ABSTRACT

This report presents a database containing hourly measurements of solar radiation, illumination, sky luminance and ambient air temperature for an entire composite year. The measurements were made at the National Bureau of Standards, Gaithersburg, Maryland (77° west longitude, 38°5 north latitude). Both instantaneous hourly and integrated average hourly measurements are included, as are daily, monthly and annual averages and totals. For each measured quantity, a histogram of the distribution of the data is presented for the year. The data measurement, collection and analysis system is described.

Key words: daylight availability, irradiance, luminance, sky illuminance, solar radiation, weather data

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1. INTRODUCTION

Weather data has been collected and compiled at many locations, for many years. Such information is used for a variety of purposes, including weather predictions, aviation and agricultural forecasts. However, building designers need special types of weather data to evaluate the thermal and energy performance of buildings. Information regarding solar radiation, daylight illumination and outdoor air temperature is essential for the effective analysis of building envelopes, the optimum use of fenestration, and accurate analyses of building energy performance. In some instances, typically for worst-case or design day purposes, single values are used for the pertinent weather parameters. Examples of this would be a minimum or average outdoor air temperature to calculate heat transfer through a portion of a building envelope or calculating interior daylight levels assuming an overcast sky. While single-valued weather data are useful, accurate analysis of building energy performance and optimum design of building components requires data which describes the dynamic nature of weather parameters over an annual period. Hourly data is frequently sufficient for this purpose.

Most standard weather stations collect a limited menu of climatic parameters, some including global total solar irradiance on a horizontal surface, outdoor air temperature, relative humidity, barometric pressure, wind speed and amount of cloud cover [1]. These weather data are available from the National Climatic Center [2] and various other sources including computer time-sharing services. The standard weather data sources lack some detailed information required for building design, such as data for radiant and visible energy incident upon horizontal and vertical surfaces, luminance distribution of the sky dome, and measurements of cloud conditions. In particular, sky luminance and illuminance data are required for calculating interior daylight levels, and vertical irradiance data is required for determining fenestration heat transfer. Only by considering the heating, cooling and lighting effects of fenestration options can building designers determine the most effective utilization of fenestration.

This report contains a record of irradiance, sky illuminance, luminance and outdoor air temperature measurements over a one-year period. Twenty eight climate and solar parameters are presented on an hourly basis. Two groups of data are presented: integrated average hourly data and the corresponding instantaneous hourly data. Also included are daily totals and averages, monthly averages and annual averages. For each measured quantity, a histogram of the distribution of the data is presented for the year.

The majority of the data was collected during 1982, however entire days with missing data due to equipment failure have been replaced with data from the same date from either 1981, 1983, or 1984. The measurements were made at the Daylight Laboratory, National Bureau of Standards, Gaithersburg, Maryland (suburb of Washington, D.C.), 77° west longitude 38°5' north latitude (see figure 1.).

The following sections describe the measured parameters, data measurement and analysis system, followed by the database.

2. DESCRIPTION OF MEASUREMENTS

2.1 MEASURED PARAMETERS

Measurements were made of diffuse and global irradiance, and diffuse and global illuminance on a horizontal surface, global irradiance and illuminance on vertical surfaces (north-, south-, east- and west-facing), sky luminance at five locations (15° solid angle spots), and exterior air temperature. Table 1 describes the sensors used for the measurements. A complete list of the measured parameters, sensor types and related information is shown in table 2.

It should be noted that the alphanumeric codes associated with each measured parameter do not correspond to any particular nomenclature but rather are taken directly from the names of the FORTRAN variables used for data processing. This provides for consistency among the equations in the text of the report and the printout of the database. FORTRAN is limited to upper-case variable names, with no provisions for subscripts. Table 2 includes a description of each measured parameter and the associated code.

A general description of sensor types and characteristics follows.

- a) Sky Luminance - Luminance is the luminous intensity of a surface in a given direction per unit of projected area of the surface as viewed from that direction. Luminance was measured using photovoltaic silicon cells, with photometric filters and 15° solid angle field-of-view. One sensor was centered on zenith (LZ) and each of four other sensors was centered at 42° elevation, due north (LN), east (LE), south (LS) and west (LW). A photograph of the luminance sensor array is shown in figure 3.
- b) Illuminance - Illuminance is the density of luminous flux (weighted by eye response) incident on a surface. Illuminance was measured using photovoltaic silicon cells, with photometric filters and cosine diffusers. Global illuminance (IZ) was measured on a horizontal surface from an unobstructed sky hemisphere. Diffuse illuminance (ID) on a horizontal surface was measured using a shading band (see figure 3). Corrections for the portion of sky obstructed by the shading band were made using manufacturer's data. Direct normal illuminance (IBN) was determined by subtracting diffuse from global illuminance and dividing by the sine of the solar altitude,

$$IBN = \frac{IZ-ID}{\sin(SALT)} \quad (1)$$

where

SALT = solar altitude

$$SALT = \arcsin[\sin L \sin D + \cos L \cos D \cos(12-T)15] \quad (2)$$

L = site latitude

$$D = \text{solar declination} = 0.4093 \sin\left[\frac{2\pi}{365}(J+284)\right] \quad (3)$$

Table 1. Sensor Types

Type A)	Luminance - Photovoltaic silicon cell with 15° solid angle lens and photometric filter (which follows the standard spectral eye response curve [3])
Type B)	Irradiance - Photovoltaic silicon cell with cosine corrected diffuser and radiometric filter (flat response 450-950 nm spectral range), hemispherical field-of-view
Type C)	Illuminance - Photovoltaic silicon cell with cosine corrected diffuser and photometric filter, hemispherical field-of-view
Type D)	Irradiance - Pyranometer, thermopile type (flat response 300-3000 nm spectral range), hemispherical field-of-view
Type E)	Temperature - Copper-constantan thermocouple, with radiation shield

Table 2. List of Database Parameters

Code	Parameter	Sensor Type*	Measurement ⁺ Units	Maximum Uncertainty	
1	LZ	Zenith luminance	A	cdm ⁻²	+ 3%
2	LN	North luminance	A	cdm ⁻²	+ 3%
3	LE	East luminance	A	cdm ⁻²	+ 3%
4	LS	South luminance	A	cdm ⁻²	+ 3%
5	LW	West luminance	A	cdm ⁻²	+ 3%
6	SALT	Solar altitude	-	degrees	-
7	SAZ	Solar azimuth	-	degrees	-
8	STIM	Solar time	-	hours	-
9	SN	North vertical irradiance	B	wm ⁻²	+ 8%
10	SS	South vertical irradiance	B	wm ⁻²	+ 8%
11	SE	East vertical irradiance	B	wm ⁻²	+ 8%
12	SW	West vertical irradiance	B	wm ⁻²	+ 8%
13	IZ	Global horizontal illuminance	C	lux	+ 3%
14	IS	South vertical illuminance	C	lux	+ 3%
15	IE	East vertical illuminance	C	lux	+ 3%
16	IW	West vertical illuminance	C	lux	+ 3%
17	IN	North vertical illuminance	C	lux	+ 3%
18	ID	Diffuse horizontal illuminance	C	lux	+ 5%
19	SRT	Global horizontal irradiance	D	wm ⁻²	+ 4%
20	SRD	Diffuse horizontal irradiance	D	wm ⁻²	+ 6%
21	CR	Cloud ratio	-	-	+10%
22	TO	Ambient air temperature	E	°F	+ 0.8°F
23	IBN	Direct normal illuminance	-	lux	+ 8%
24	SBN	Direct normal irradiance	-	wm ⁻²	+10%
25	E1	Atmospheric extinction coefficient 1	-	-	-
26	E2	Atmospheric extinction coefficient 2	-	-	-
27	TR1	Downward transfer ratio 1	-	-	-
28	TR2	Downward transfer ratio 2	-	-	-

* From Table 1.

+ cdm⁻² = candelas per square meter

wm⁻² = watts per square meter

lux = lumens per square meter

J = Julian Date $1 \leq J \leq 365$
 T = Solar time.

Illuminances on vertical planes (north, east, south and west) were measured using an array shielded from ground reflections (see figure 4).

- c) Irradiance - Irradiance is the density of radiant flux (equally weighted for all wavelengths) incident on a surface. Global irradiance (SRT) on a horizontal surface was measured using a thermal-type pyranometer exposed to the unobstructed sky dome (see figure 5). Diffuse irradiance (SRD) was measured with a similar instrument and a shading band. Corrections for the portion of the sky obstructed by the shading band were made using manufacturer's data. Direct normal irradiance (SBN) was also determined by subtracting diffuse from global irradiance and dividing by the sine of the solar altitude.

$$SBN = \frac{SRT - SRD}{\sin(SALT)} \quad (4)$$

- d) Air temperature - Outdoor air temperature was measured using a type-T (copper-constantan) thermocouple, with a radiation shield.

The database also contains the derived quantities of solar altitude, solar azimuth, solar time, atmospheric extinction coefficient and downward transfer ratio. Figure 6 shows the definitions of the solar angles.

- e) Solar altitude - Calculated using equation 2.
 f) Solar azimuth - Calculated using equation 5a, b, or c.

$$W = (12-T) \times 15 \quad (5)$$

If $\cos W < \tan D/\tan L$

$$SAZ = \arcsin (\cos D \sin W/\cos SALT) \quad (5a)$$

If $\cos W > \tan D/\tan L$

$$SAZ = \pi - \arcsin (\cos D \sin W/\cos SALT) \quad (5b)$$

$$\text{If } SAZ < 0, SAZ = SAZ + 2\pi \quad (5c)$$

Solar azimuth is zero due north, 90° due east, 180° due south, and 270° due west.

- g) Solar time - Calculated from equation 6.

$$STIM = TS + (1 \text{ if daylight time}) + ET - 2/15 \quad (6)$$

where TS = standard time (decimal hours)

ET = equation of time

$$= 0.170 \sin \frac{4\pi}{373} (J-80) - 0.129 \sin \frac{2\pi}{355} (J-8) \quad (7)$$

h) Cloud ratio = The ratio of diffuse to global irradiance.

$$CR = \frac{SRD}{SRT} \quad (8)$$

i) Atmospheric extinction coefficient - Two versions (E1,E2) were determined from measurements, based on direct illuminance or irradiance, as follows:

E1 (direct illuminance)

$$E1 = - \sin (SALT) \ln \frac{IBN}{IXT} \quad (9)$$

$$\text{where } IXT = 127,500 \left\{ 1 + 0.034 \cos \frac{2\pi}{365} (J-2) \right\} \quad (10)$$

E2 (direct irradiance)

$$E2 = - \sin (SALT) \ln \frac{SBN}{SXT} \quad (11)$$

$$\text{where } SXT = 1353 \left\{ 1 + 0.034 \cos \frac{2\pi}{365} (J-2) \right\} \quad (12)$$

j) Downward transfer ratio - Two versions (TR1 and TR2) were computed, one from irradiance and one from illuminance. The downward transfer ratio is defined as the portion of solar energy scattered out of the direct beam reaching the ground [7]. Therefore one minus the downward transfer ratio is reflected back into space, or absorbed by the atmosphere.

TR1 (illuminance)

$$TR1 = \frac{ID}{IXT \sin(SALT) [1 - \text{EXP}(-E1/\sin(SALT))]} \quad (13)$$

TR2 (irradiance)

$$TR2 = \frac{SRD}{SXT \sin(SALT) [1 - \text{EXP}(-E2/\sin(SALT))]} \quad (14)$$

2.2 MEASUREMENT SYSTEM

The data acquisition system consisted of a microcomputer-controlled data logger which monitored the measurement sensors. All sensors were configured to provide voltage inputs to the data logger, which performed analog-to-digital conversion and voltage measurement. The data logger also provided temperature compensation for the thermocouple readings. Under control of the microcomputer, sensor

readings were continuously and sequentially scanned. At the beginning of each hour, a data file for that hour was assembled consisting of the current reading for each sensor (instantaneous value) and the average of all the readings for each sensor over the previous one hour period (average value). Each average value is calculated from fifteen readings during the hour. The letter "A" preceding a measured parameter name indicates an average value.

Data were stored on 0.133 m (5.25 in.) floppy disks, and transferred to a larger computer for subsequent processing, analysis and storage.

2.3 DATA ANALYSIS AND CHECKING

The database contains measurements of eighteen parameters, and ten derived quantities. Over the period of a year, this amounts to approximately 2.5 million readings, including average and instantaneous values. Each annual average parameter is a result of 131,400 readings, and each instantaneous parameter is represented by 8760 readings. The initial raw data files were processed to check for errors and inconsistencies. A careful review of the data was conducted to identify erroneous data, however, data were only removed from the database if a clear justification, as described below could be made for such removal. Consequently, if a datum passed all the checking routines and was not associated with any known measurement problems, it was included in the database. Even though the checking routines were considered a successful technique for controlling erroneous data, from time to time questionable data still appeared and were flagged accordingly. The sheer volume of data processed could have resulted in a small portion of inaccurate data remaining in the database undetected.

Potential inaccuracies can be grouped into two general categories. The first category includes what could be described as measurement errors. In this category would fall calibration errors, sensor non-linearity and errors in voltage measurement or analog-to-digital conversion. The second category includes measurements which are accurate, but not measuring the parameter of interest properly. Prime examples of this would be a sky luminance measurement when the solar disk is visible in the field of view of the luminance sensor, or when snow is present on sensors. In these cases, the measurement system may be working properly, but the reading would not be representative of sky luminance as assumed.

The first stage of data checking included adjusting each reading for any zero offset, setting to zero any slight non-zero readings known to be zero (i.e., irradiance after dark), and setting diffuse irradiance and illuminance equal to total irradiance and illuminance, respectively, if the respective diffuse component reading exceeded the reading for total. This second correction is occasionally necessary on overcast days due to the average nature of the shading band correction factor, but is usually a small effect.

The second stage of data checking involved comparing each reading to an acceptable range for each parameter, and intercomparing related readings as a group. Maximum and minimum levels were established for each parameter, based on the expected range of theoretically possible readings. Readings outside of

this range were flagged with an asterisk (*) and set to 999999. For the luminance channels, a reading in excess of 15,000 cdm^{-2} was assumed to be due to interference from the solar disk, and therefore flagged with an asterisk but not set to 999999 unless the reading exceeded 75,000 cdm^{-2} . Three groups of parameters were assembled for intercomparison. The five luminance sensors were one group, the four vertical irradiance sensors the second group and the four vertical illuminance sensors the third group. Within each group an average of each hour's readings was computed, and if any individual reading differed from the average by more than a factor of ten (or 1/10) that reading was flagged with a plus sign (+) and set to 999999.

The averaged hourly data should be more accurate than the instantaneous hourly data for two reasons. First, any random errors (electronic noise, analog to digital conversion, etc.) should cancel out when multiple readings are averaged. Second, an occasional false reading due to intermittent malfunctions or conditions will have a small effect on the average reading. Both instantaneous and average readings are of value. In many daylighting applications, the instantaneous conditions are of interest. However, a one hour average is nearly "instantaneous" in relation to an annual file containing 8760 hourly readings. Since many energy calculations are done on an hourly basis, perhaps hourly averaged daylighting data are appropriate to use for these applications.

When data were unavailable for 1982, due to equipment down time, data were substituted from 1983, 1984 or 1981 for the same julian date. While this changes the distribution of the data and affects the average slightly, the usefulness of the annual data is not compromised, since 1982 should not be considered a special year. Thus, the database reflects reasonable conditions for a possible year, but not necessarily a typical year.

3. DISCUSSION OF DATABASE

The primary objective of the publication of this database is to provide a comprehensive set of reference, concurrent measurements of illuminance, irradiance and sky luminance for a one-year period. These data are critically needed for building design purposes and daylighting analyses, but are virtually unavailable.

All or portions of the database might be used as driving parameters for energy or daylighting calculations, or for other purposes such as sky and solar modeling. Detailed analysis of the relationships between the measured parameters, or their dynamic behavior, may enable new correlations to be developed for improved sky and solar modeling. Since the annual database contains such a vast quantity of information, it would be useful to analyze the hourly data and determine means to characterize the measurements in a more general manner.

Two methods were used to characterize and summarize the measurements. One method involved computing averages for each of the parameters on a daily, a monthly and an annual basis. The second method consisted of determining the mean and standard deviation of each parameter and plotting a histogram showing the distribution of the data over the year.

The computed averages of each parameter provide a means for making an assessment of the general magnitude of that parameter, and allow comparison of different day's data. For example, a very bright day will have a much higher average illuminance than a dark overcast day. In addition to the daily average for each parameter, which is computed using only the non-zero readings, the daily total of each measured parameter was tabulated. This quantity indicates the total of all readings for each parameter, thereby including the effects of longer or shorter daylight periods throughout the year. Note that averages based on 24 hours can easily be computed by dividing each daily total by 24.

Monthly averages were also calculated for each parameter. The monthly average is defined as the average daily total for the month (not the average hourly reading). Annual averages were calculated for each parameter, being equal to the average daily total for the year and the hourly average of non-zero readings. Exceptions to the above criteria were required for the atmospheric extinction coefficients and downward transfer ratios, since a total atmospheric extinction coefficient for the day would have no meaning. Here only hourly averages for each month and the annual average were tabulated.

While the daily, monthly and annual averages provide much useful information, they do not give an indication of the variability or distribution of the values of each parameter. An effective way of presenting the distribution of each parameter is through a histogram of the readings showing the percentage of the entire annual data set falling into various intervals. Such histograms were developed from the data to show the spread of the readings for each parameter, along with the probability of an individual reading falling within a certain range. The mean and standard deviation of the annual set of data for each

parameter were also calculated. For this usage, the standard deviations do not represent an uncertainty, but rather indicate the variability of each parameter throughout the year.

Before discussing the individual histograms, a general examination of the dynamic nature of the database parameters is appropriate. The behavior of each of the parameters through the year is governed by the superposition of several cycles. The irradiance, illuminance and luminance data follow a strong diurnal (daily) cycle in which maximum values typically occur near a certain set of solar angles. For example, energy incident on east-facing vertical surfaces is typically maximum in the morning, while horizontal and south-facing surfaces typically receive maximum incident energy at solar noon. However, this does not mean that south vertical irradiance is always maximum at solar noon, since considerable hourly variations can occur due to a randomly fluctuating cycle superimposed on the diurnal cycle. This random cycle is a function of the local weather conditions as influenced by cloud cover, atmospheric water vapor and other factors. A third significant cycle is due to seasonal effects. Many geographical locations exhibit observable differences in available solar radiation or cloud conditions on a seasonal basis, whereby more overcast days occur in winter than in summer (or vice versa). Outdoor air temperature follows a strong seasonal cycle and a strong diurnal cycle. Direct normal irradiance and illuminance are less sensitive to a daily cycle, except for the effects of low solar elevations.

3.1 DATA DISTRIBUTION HISTOGRAMS

A pair of histograms is presented for each parameter, the first based on instantaneous readings, the second based on average readings. Figures 7 through 11 present the distribution of readings for each of the sky luminance sensors. Sky luminance shows a wide range in the data, but a fairly narrow band of probable intensity. Readings greater than $15,000 \text{ cdm}^{-2}$, which are due to the solar disk being present in the luminance measurement area, are excluded from these figures.

Figures 12 through 15 present the distribution of vertical irradiance readings. As would be expected, north vertical irradiance is significantly lower than the other vertical planes averaging only one third of south vertical irradiance. East and west vertical irradiances are about two thirds of the south vertical readings.

Figures 16 through 21 present the distribution of the illuminance readings. Considerable variation is apparent for all surfaces, graphically illustrating the wide dynamic range of daylight availability. Diffuse horizontal illuminance and east, south and west vertical illuminance range from 66 to 50 percent of global horizontal illuminance, while north vertical is less than 25 percent.

The distributions global horizontal irradiance and diffuse horizontal irradiance are presented in figures 22 and 23, respectively. Diffuse irradiance average about 50 percent of global irradiance. The ratio of diffuse to global irradiance, cloud ratio, is shown in figure 24. The average cloud ratio was 68 percent, but a wide range occurred.

Figure 25 shows the distribution of outdoor air temperatures. The mean air temperature was 10.6 C (51.1°F).

Direct normal illuminance and irradiance are presented in figures 26 and 27, respectively. They exhibit a fairly even distribution. The computed atmospheric extinction coefficients are shown in figures 28 and 29. Over half of the readings were less than one or greater than 5.75. The downward transfer ratios are presented in figures 30 and 31. TR1 (illuminance) averages 36 percent, while TR2 (irradiance) averages 31 percent.

3.2 DATABASE PRINTOUT

Appendix A contains the printout of the daylighting database. Each parameter is labeled with an alpha code as listed in table 2. One day's worth of data is on each page, with adjacent pages containing hourly average data for the day, and instantaneous hourly data for the day. The julian date and calendar date are listed at the top of each page. Each page is divided into two sections with twelve hour's data in each section. Hours are indicated by column headings. The units of measurement are listed, along with daily totals and non-zero averages for each parameters. The last page of the appendix contains the daily or hourly averages (as appropriate) on a monthly and annual basis, for each parameter.

Missing or defective data were represented by 999999. Uncertain or questionable data were flagged with an asterisk (*) or plus sign (+). No attempt was made to synthesize replacement data for missing or bad data, because the intent of this paper is to provide measured data, rather than calculated. However, the user can use whatever means they feel is appropriate to fill in for missing data. Procedures such as interpolating between available data points [1], or calculating based on other parameters [4] or models [5,6] would be useful for that purpose.

4. SUMMARY

An annual database is presented including irradiance, illuminance, sky luminance, sky condition and temperature measurements. The database is intended for use in daylighting design and calculations, building energy analyses, and sky and solar modeling. The measurement system is described. The data is analyzed and processed including examination of reading averages, distribution and variability over a one year period.

5. REFERENCES

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Figure 1. NBS Daylighting Laboratory

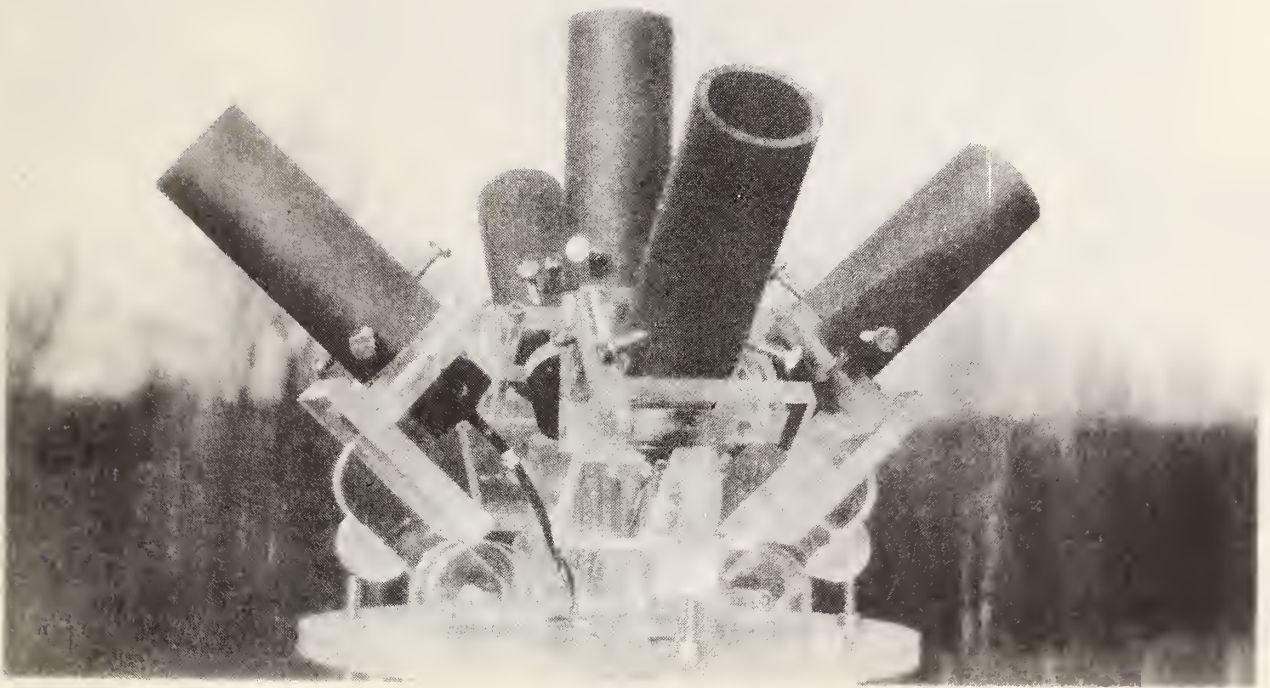


Figure 2. Luminance sensor array



Figure 3. Diffuse illuminance and irradiance sensors

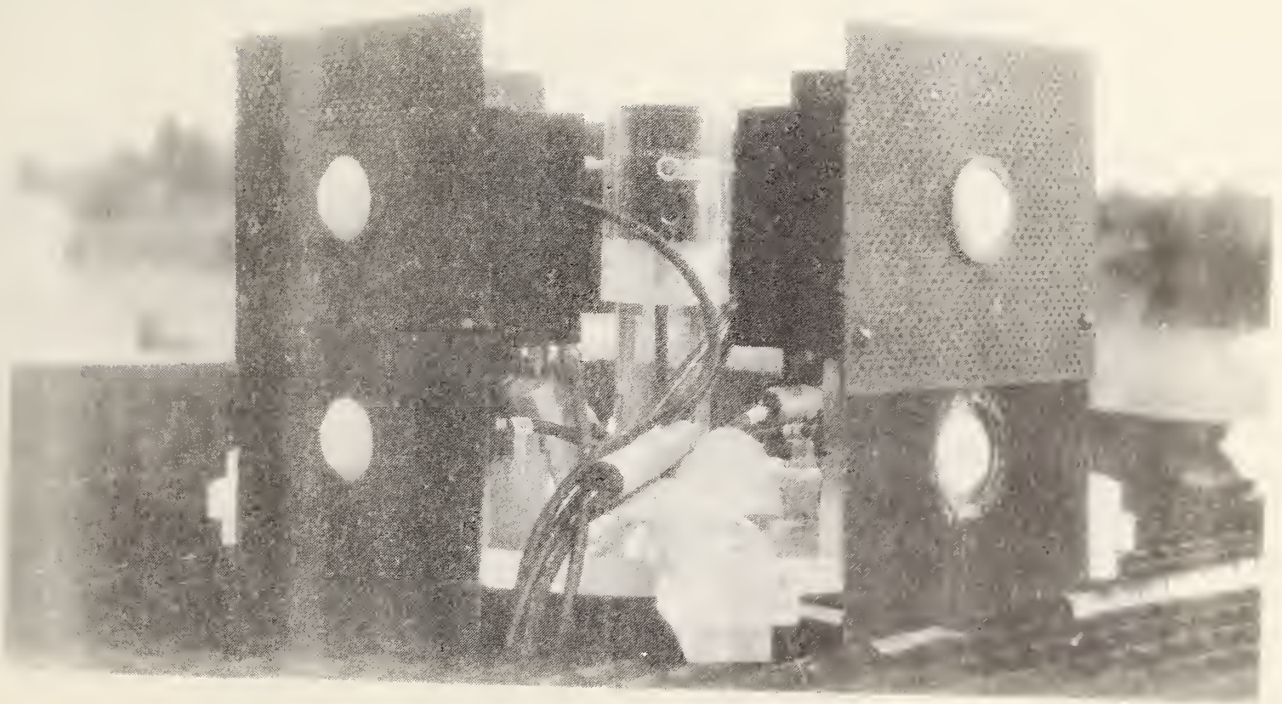


Figure 4. Vertical illuminance and irradiance sensors



Figure 5. Global irradiance sensor

a_t = solar altitude

a_s = solar azimuth

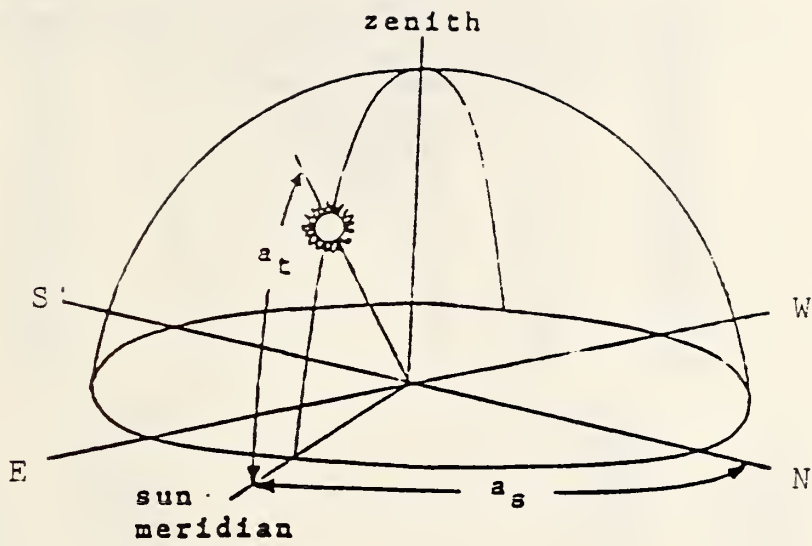


Figure 6. Definitions of solar angles

AV. LZ
EACH * REPRESENTS 20 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	636	*****
1000	768	*****
2000	604	*****
3000	435	*****
4000	335	*****
5000	253	*****
6000	210	*****
7000	141	*****
8000	123	*****
9000	114	*****
10000	77	***
11000	69	**
12000	55	**
13000	57	**
14000	29	*
15000	11	*

AV. LZ
N 3917
MEAN 3492.2
MEDIAN 2418.5
TMEAN 3183
STDEV 3349.7
SEMEAN 54
MAX 14939
MIN .06
Q3 5154
Q1 915

IV. LZ
EACH * REPRESENTS 20 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	646	*****
1000	796	*****
2000	634	*****
3000	420	*****
4000	307	*****
5000	246	*****
6000	211	*****
7000	125	*****
8000	92	****
9000	95	****
10000	75	***
11000	65	**
12000	51	**
13000	41	**
14000	35	*
15000	16	*

IV. LZ
N 3851
MEAN 3350.2
MEDIAN 2244.2
TMEAN 3023
STDEV 3313.3
SEMEAN 53
MAX 14983
MIN 2.03
Q3 4861
Q1 897

Figure 7. Data distribution histogram for zenith luminance (LZ)

AV. LN
EACH * REPRESENTS 20 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	527	*****
1000	690	*****
2000	835	*****
3000	542	*****
4000	392	*****
5000	313	*****
6000	245	*****
7000	171	*****
8000	155	*****
9000	96	*****
10000	66	****
11000	27	**
12000	24	**
13000	3	*
14000	2	*

AV. LN
N 4086
MEAN 3244.5
MEDIAN 2487.1
TMEAN 3046
STDEV 2659.4
SEMEAN 42
MAX 13844
MIN 0.01
Q3 4732
Q1 1314

IN. LN
EACH * REPRESENTS 20 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	522	*****
1000	713	*****
2000	866	*****
3000	523	*****
4000	373	*****
5000	266	*****
6000	235	*****
7000	156	*****
8000	123	*****
9000	81	****
10000	69	****
11000	35	**
12000	33	**
13000	13	*
14000	6	*
15000	1	*

IN. LN
N 4039
MEAN 3195.5
MEDIAN 2368.2
TMEAN 2958
STDEV 2741.1
SEMEAN 43
MAX 14840
MIN 2.01
Q3 4529
Q1 1270

Figure 8. Data distribution histogram for north luminance (LN)

AV. LE
EACH * REPRESENTS 10 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	476	*****
1000	501	*****
2000	619	*****
3000	470	*****
4000	334	*****
5000	260	*****
6000	233	*****
7000	234	*****
8000	142	*****
9000	113	*****
10000	113	*****
11000	81	*****
12000	52	****
13000	55	****
14000	46	****
15000	17	**

AV. LE
N 3740
MEAN 4083.1
MEJIAN 3075.2
TMEAN 3815
STDEV 3465.9
SEMEAN 57
MAX 14940
MIN 0.13
Q3 6118
Q1 1443

IV. LE
EACH * REPRESENTS 10 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	485	*****
1000	546	*****
2000	637	*****
3000	434	*****
4000	346	*****
5000	251	*****
6000	201	*****
7000	170	*****
8000	156	*****
9000	111	*****
10000	69	*****
11000	77	*****
12000	56	****
13000	54	****
14000	42	***
15000	13	*

IV. LE
N 3672
MEAN 3916.7
MEJIAN 2890.2
TMEAN 3636
STDEV 3449.5
SEMEAN 57
MAX 14999
MIN 2.04
Q3 5756
Q1 1345

Figure 9. Data distribution histogram for east luminance (LE)

AV. LS
EACH * REPRESENTS 15 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	528	*****
1000	521	*****
2000	435	*****
3000	406	*****
4000	317	*****
5000	253	*****
6000	196	*****
7000	165	*****
8000	197	*****
9000	143	*****
10000	115	*****
11000	111	*****
12000	124	*****
13000	75	*****
14000	72	*****
15000	29	**

AV. LS
N 3709
MEAN 4524.2
MEDIAN 3385.7
TMEAN 4270
STDEV 3940.6
SEMEAN 65
MAX 14996
MIN 0.01
Q3 7206
Q1 1235

IN. LS
EACH * REPRESENTS 15 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	543	*****
1000	499	*****
2000	506	*****
3000	403	*****
4000	297	*****
5000	219	*****
6000	220	*****
7000	166	*****
8000	146	*****
9000	139	*****
10000	107	*****
11000	100	*****
12000	62	*****
13000	84	*****
14000	77	*****
15000	26	**

IN. LS
N 3610
MEAN 4332.2
MEDIAN 3125.6
TMEAN 4054
STDEV 3892.8
SEMEAN 65
MAX 14992
MIN 2.04
Q3 6630
Q1 1224

Figure 10. Data distribution histogram for south luminance (LS)

AV. LW
EACH * REPRESENTS 15 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	486	*****
1000	564	*****
2000	585	*****
3000	482	*****
4000	361	*****
5000	267	*****
6000	192	*****
7000	190	*****
8000	157	*****
9000	113	*****
10000	92	*****
11000	93	*****
12000	66	*****
13000	56	****
14000	46	****
15000	20	**

	AV. LW
N	3776
MEAN	4033
MEDIAN	3007
TMEAN	3754
STDEV	3539
SEMEAN	50
MAX	14990
MIN	0
Q3	5983
Q1	1341

IN. LW
EACH * REPRESENTS 15 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	478	*****
1000	573	*****
2000	641	*****
3000	413	*****
4000	346	*****
5000	250	*****
6000	201	*****
7000	167	*****
8000	129	*****
9000	107	*****
10000	96	*****
11000	66	*****
12000	65	*****
13000	52	****
14000	42	****
15000	13	*

	IN. LW
N	3641
MEAN	3864.4
MEDIAN	2750.9
TMEAN	3577
STDEV	3444.7
SEMEAN	57
MAX	14994
MIN	1.99
Q3	5610
Q1	1322

Figure 11. Data distribution histogram for west luminance (LW)

AV. SN
EACH * REPRESENTS 30 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	922	*****
40	1311	*****
80	1164	*****
120	469	*****
160	205	*****
200	50	**
240	10	*
280	4	*
320	4	*
360	1	*
400	1	*

	AV. SN
N	4161
MEAN	51.62
MEDIAN	55.73
TMEAN	58.33
STDEV	47.10
SEMEAN	0.73
MAX	397.10
MIN	0.01
Q3	88.54
Q1	24.15

IN. SN
EACH * REPRESENTS 30 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	957	*****
40	1336	*****
80	1106	*****
120	467	*****
160	170	*****
200	54	**
240	2	*
280	1	*
320	2	*
360	9	*
400	1	*

	IN. SN
N	4125
MEAN	60.10
MEDIAN	54.20
TMEAN	56.61
STDEV	47.39
SEMEAN	0.74
MAX	396.87
MIN	0.02
Q3	87.09
Q1	23.00

Figure 12. Data distribution histogram for north irradiance (SN)

AV. SS
EACH * REPRESENTS 20 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	623	*****
50	603	*****
100	393	*****
150	320	*****
200	294	*****
250	265	*****
300	219	*****
350	273	*****
400	190	*****
450	131	*****
500	100	*****
550	93	*****
600	70	*****
650	45	*****
700	54	*****
750	44	*****
800	18	*****

AV. SS
N 4135
MEAN 196.0
MEDIAN 132.64
TMEAN 179.0
STDEV 192.05
SEMENV 3.0
MAX 799.3
MIN 0.01
Q3 323.7
Q1 36.0

IN. SS
EACH * REPRESENTS 20 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	874	*****
50	781	*****
100	420	*****
150	349	*****
200	260	*****
250	230	*****
300	185	*****
350	200	*****
400	184	*****
450	139	*****
500	97	*****
550	89	*****
600	72	*****
650	67	*****
700	43	*****
750	64	*****
800	24	*****

IN. SS
N 4092
MEAN 193.80
MEDIAN 120.54
TMEAN 176.1
STDEV 199.2
SEMENV 3.1
MAX 799.6
MIN 0.04
Q3 312.0
Q1 32.8

Figure 13. Data distribution histogram for south irradiance (SS)

AV. SE
EACH * REPRESENTS 25 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	972	*****
50	1199	*****
100	622	*****
150	322	*****
200	216	*****
250	141	*****
300	170	*****
350	123	*****
400	121	*****
450	76	****
500	66	***
550	19	*
600	35	**
650	35	**
700	25	*
750	12	*
800	5	*

AV. SE
N 4159
MEAN 131.0
MEDIAN 70.24
TMEAN 113.3
STDEV 154.5
SEMEAN 2.4
MAX 799.63
MIN 0.01
Q3 175.7
Q1 27.6

AV. SE
EACH * REPRESENTS 25 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	1015	*****
50	1202	*****
100	587	*****
150	300	*****
200	176	*****
250	165	*****
300	123	*****
350	127	*****
400	126	*****
450	99	****
500	48	**
550	37	**
600	44	**
650	25	*
700	23	*
750	20	*
800	6	*

AV. SE
N 4125
MEAN 131.71
MEDIAN 66.0
TMEAN 113.0
STDEV 158.21
SEMEAN 2.5
MAX 797.05
MIN 0.03
Q3 171.7
Q1 25.6

Figure 14. Data distribution histogram for east irradiance (SE)

AV. SW
EACH * REPRESENTS 25 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	1003	*****
50	1216	*****
100	655	*****
150	277	*****
200	261	*****
250	171	*****
300	160	*****
350	95	****
400	126	*****
450	79	****
500	56	***
550	22	*
600	2	*
650	1	*
700	6	
750	1	*

AV. SW
N 4149
MEAN 116.79
MEDIAN 68.20
TMEAN 103.0
STDEV 126.72
SEMEAN 2.0
MAX 747.62
MIN 0.01
Q3 165.1
Q1 26.1

IN. SW
EACH * REPRESENTS 50 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	1025	*****
50	1255	*****
100	590	*****
150	327	*****
200	174	*****
250	155	*****
300	122	*****
350	164	*****
400	115	****
450	86	***
500	64	***
550	36	**
600	1	*

IN. SW
N 4116
MEAN 116.99
MEDIAN 64.66
TMEAN 103.2
STDEV 131.54
SEMEAN 2.1
MAX 577.13
MIN 0.03
Q3 154.0
Q1 25.3

Figure 15. Data distribution histogram for west irradiance (SW)

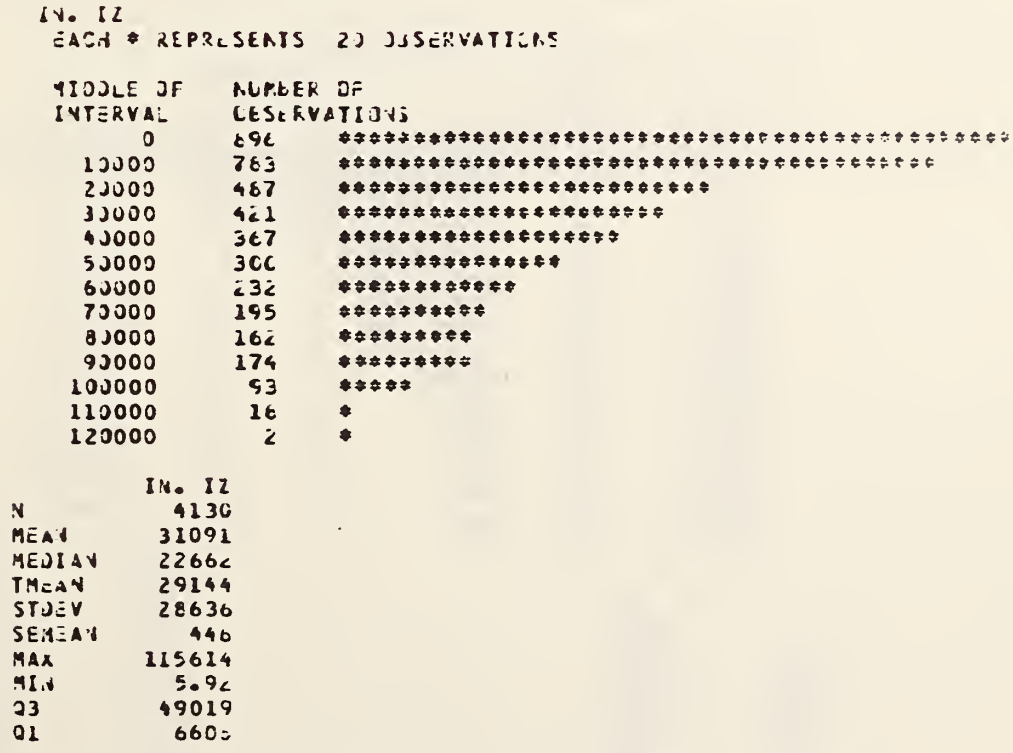
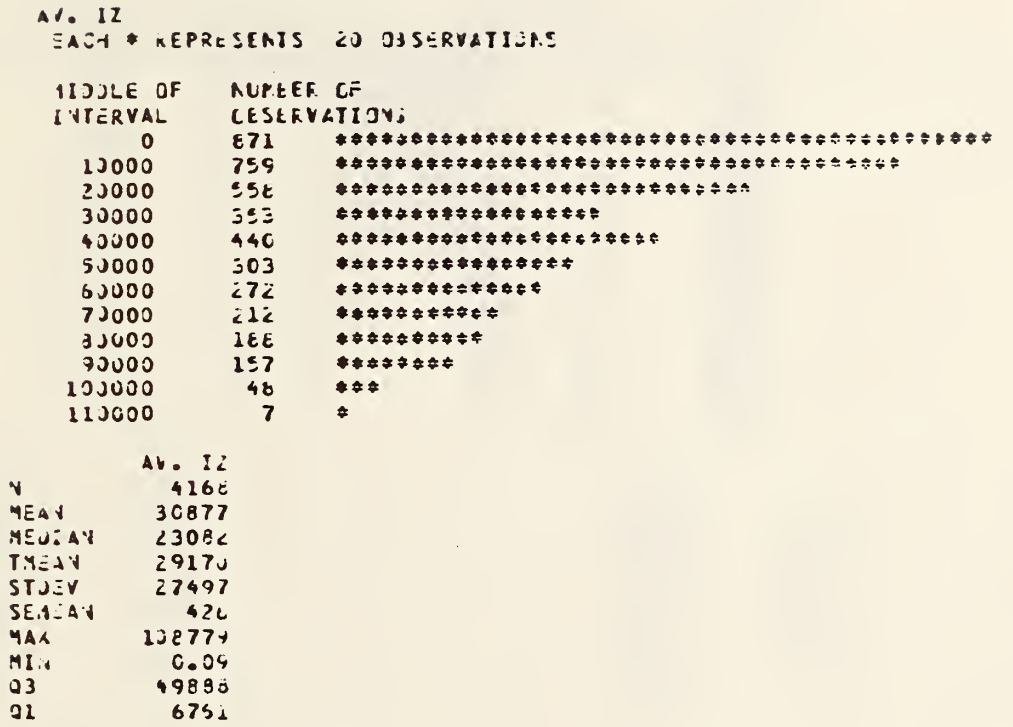


Figure 16. Data distribution histogram for global illuminance (IZ)

AV. IS
EACH * REPRESENTS 20 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	867	*****
5000	801	*****
10000	367	*****
15000	298	*****
20000	270	*****
25000	231	*****
30000	217	*****
35000	262	*****
40000	199	*****
45000	147	*****
50000	90	*****
55000	97	*****
60000	60	****
65000	50	***
70000	62	****
75000	45	***
80000	10	*

	AV. IS
N	4113
MEAN	19606
MEDIAN	12527
TMEAN	17970
STDEV	19522
SEMEAN	304
MAX	79927
MIN	0.19
Q3	32611
Q1	3327

IV. IS
EACH * REPRESENTS 20 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	886	*****
5000	794	*****
10000	422	*****
15000	309	*****
20000	238	*****
25000	230	*****
30000	189	*****
35000	166	*****
40000	194	*****
45000	129	*****
50000	107	*****
55000	81	****
60000	98	****
65000	67	***
70000	57	***
75000	66	****
80000	17	*

	IV. IS
N	4068
MEAN	19591
MEDIAN	11440
TMEAN	17834
STDEV	20331
SEMEAN	319
MAX	79866
MIN	4.27
Q3	32084
Q1	3146

Figure 17. Data distribution histogram for south illuminance (IS)

AV. IE
EACH * REPRESENTS 25 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	895	*****
5000	1129	*****
10000	864	*****
15000	503	*****
20000	203	*****
25000	191	*****
30000	101	*****
35000	91	****
40000	109	****
45000	125	****
50000	77	***
55000	70	***
60000	80	***
65000	40	**
70000	40	**
75000	11	*

AV. IE
N 4137
MEAN 14863
MEDIAN 7689
TMEAN 12997
STDEV 17265
SEMEAN 266
MAX 75966
MIN .03
Q3 20377
Q1 3197

IN. IE
EACH * REPRESENTS 25 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	903	*****
5000	1190	*****
10000	607	*****
15000	530	*****
20000	166	*****
25000	97	***
30000	96	***
35000	137	****
40000	105	****
45000	59	**
50000	115	****
55000	82	****
60000	55	**
65000	75	**
70000	52	**
75000	16	*
80000	1	*

IN. IE
N 4058
MEAN 14907
MEDIAN 7223
TMEAN 12936
STDEV 17959
SEMEAN 291
MAX 78168
MIN 4.34
Q3 18506
Q1 2981

Figure 18. Data distribution histogram for east illuminance (IE)

AV. IW
EACH * REPRESENTS 25 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	931	*****
5000	1154	*****
10000	681	*****
15000	305	*****
20000	220	*****
25000	162	*****
30000	102	*****
35000	134	*****
40000	120	*****
45000	72	***
50000	68	***
55000	96	****
60000	50	**
65000	30	**
70000	39	**
75000	11	*

Av. IW
N 4177
MEAN 14151
MEDIAN 7525.4
TMEAN 12300
STDEV 16457
SEMMEAN 250
MAX 76007
MIN .05
Q3 18892
Q1 3110

IN. IW
EACH * REPRESENTS 25 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	905	*****
5000	1216	*****
10000	642	*****
15000	345	*****
20000	160	*****
25000	106	*****
30000	118	*****
35000	102	*****
40000	60	***
45000	89	****
50000	104	*****
55000	69	***
60000	53	***
65000	61	***
70000	42	**
75000	19	*

IN. IW
N 4113
MEAN 14289
MEDIAN 7189
TMEAN 12313
STDEV 17230
SEMMEAN 269
MAX 76984
MIN 4.39
Q3 17080
Q1 3047

Figure 19. Data distribution histogram for west illuminance (IW)

AV. IN
EACH * REPRESENTS 25 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	803	*****
4000	1115	*****
8000	1150	*****
12000	696	*****
16000	331	*****
20000	59	***
24000	12	*
28000	4	*
32000	1	*
36000	3	*
40000	1	*

	AV. IN
N	4175
MEAN	6984.4
MEDIAN	6396
TMEAN	6726
STDEV	5030.3
SEMEAN	76
MAX	38579
MIN	.11
Q3	10323
Q1	3076

IN. IN
EACH * REPRESENTS 33 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	936	*****
5000	1536	*****
10000	1029	*****
15000	516	*****
20000	96	***
25000	2	*
30000	0	
35000	2	*
40000	0	
45000	2	*
50000	9	*
55000	2	*
60000	0	
65000	2	*
70000	2	*

	IN. IN
N	4136
MEAN	7072.6
MEDIAN	6362.3
TMEAN	6682
STDEV	5794.6
SEMEAN	90
MAX	70429
MIN	4.37
Q3	10021
Q1	2925

Figure 20. Data distribution histogram for north illuminance (IN)

AV. ID
EACH * REPRESENTS 20 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	652	*****
5000	659	*****
10000	751	*****
15000	707	*****
20000	443	*****
25000	320	*****
30000	206	*****
35000	152	*****
40000	94	*****
45000	64	*****
50000	42	***
55000	24	**
60000	4	*
65000	1	*

	AV. ID
N	4139
MEAN	14817
MEDIAN	12528
TMEAN	13897
STDEV	12033
SEMEAN	187
MAX	63334
MIN	0.09
Q3	20969
Q1	5564

IN. ID
EACH * REPRESENTS 20 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	645	*****
5000	647	*****
10000	775	*****
15000	685	*****
20000	446	*****
25000	294	*****
30000	176	*****
35000	145	*****
40000	110	*****
45000	75	****
50000	40	**
55000	31	**
60000	6	*
65000	2	*

	IN. ID
N	4079
MEAN	14736
MEDIAN	12303
TMEAN	13749
STDEV	12215
SEMEAN	191
MAX	63291
MIN	1.88
Q3	20697
Q1	5544

Figure 21. Data distribution histogram for diffuse illuminance (ID)

AV. SRT
EACH * REPRESENTS 20 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	873	*****
100	792	*****
200	533	*****
300	388	*****
400	408	*****
500	330	*****
600	280	*****
700	239	*****
800	188	*****
900	133	*****
1000	19	*

AV. SRT
N 4183
MEAN 301.55
MEDIAN 225.54
TMEAN 285.9
STDEV 264.5
SEMEAN 4.1
MAX 1009.4
MIN .01
Q3 492.3
Q1 67.7

IN. SRT
EACH * REPRESENTS 20 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	914	*****
100	819	*****
200	498	*****
300	430	*****
400	351	*****
500	294	*****
600	240	*****
700	216	*****
800	171	*****
900	179	*****
1000	48	***
1100	6	*
1200	2	*

IN. SRT
N 4168
MEAN 301.2
MEDIAN 210.9
TMEAN 282.9
STDEV 277.4
SEMEAN 4.3
MAX 1185.6
MIN 0.1
Q3 481.4
Q1 62.7

Figure 22. Data distribution histogram for global irradiance (SRT)

AV. SRD
EACH * REPRESENTS 20 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	629	*****
50	757	*****
100	863	*****
150	593	*****
200	392	*****
250	317	*****
300	234	*****
350	172	*****
400	123	*****
450	65	*****
500	24	**
550	6	*
600	1	*

	AV. SRD
N	4176
MEAN	143.13
MEDIAN	114.12
TMEAN	135.0
STDEV	115.8
SEMEAN	1.8
MAX	590.5
MIN	0.01
Q3	211.6
Q1	54.2

IN. SRD
EACH * REPRESENTS 20 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	650	*****
50	759	*****
100	879	*****
150	578	*****
200	383	*****
250	298	*****
300	219	*****
350	165	*****
400	114	*****
450	54	***
500	39	**
550	14	*
600	4	*

	IN. SRD
N	4156
MEAN	141.49
MEDIAN	110.6
TMEAN	132.5
STDEV	117.96
SEMEAN	1.8
MAX	580.44
MIN	0.09
Q3	205.9
Q1	52.4

Figure 23. Data distribution histogram for diffuse irradiance (SRD)

AV. CR
EACH * REPRESENTS 30 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0.0	1	*
0.1	106	****
0.2	445	*****
0.3	361	*****
0.4	334	*****
0.5	323	*****
0.6	269	*****
0.7	285	*****
0.8	265	*****
0.9	267	*****
1.0	1352	*****

AV. CR
N 4126
MEAN 0.6655
MEDIAN 0.7200
TMEAN 0.6760
STDEV 0.3072
SEMEAN 0.0048
MAX 1.0000
MIN 0.0400
Q3 1.0000
Q1 0.3700

IN. CR
EACH * REPRESENTS 35 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0.0	2	*
0.1	117	****
0.2	466	*****
0.3	394	*****
0.4	330	*****
0.5	266	*****
0.6	211	*****
0.7	168	*****
0.8	187	*****
0.9	304	*****
1.0	1600	*****

IN. CR
N 4069
MEAN 0.6767
MEDIAN 0.7700
TMEAN 0.6886
STDEV 0.3215
SEMEAN 0.0050
MAX 1.0000
MIN 0.0400
Q3 1.0000
Q1 0.3600

Figure 24. Data distribution histogram for cloud ratio (CR)

AVER. TO
EACH * REPRESENTS 30 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
-10	16	*
0	431	*****
10	127	*****
20	425	*****
30	908	*****
40	1202	*****
50	1111	*****
60	1325	*****
70	1376	*****
80	845	*****
90	321	*****
100	25	*

AVER. TO
N 8112
MEAN 51.13
MEDIAN 53.54
TMEAN 51.91
STDEV 22.64
SEMEAN 0.25
MAX 99.21
MIN -14.04
Q3 68.67
Q1 35.95

INST. TO
EACH * REPRESENTS 30 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
-10	14	*
0	430	*****
10	125	*****
20	414	*****
30	906	*****
40	1200	*****
50	1106	*****
60	1317	*****
70	1394	*****
80	836	*****
90	336	*****
100	29	*

INST. TO
N 8107
MEAN 51.22
MEDIAN 53.60
TMEAN 52.00
STDEV 22.59
SEMEAN 0.25
MAX 99.10
MIN -10.30
Q3 68.70
Q1 36.10

Figure 25. Data distribution histogram for outdoor temperature (TO)

AV. IBN
EACH * REPRESENTS 15 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	416	*****
10000	505	*****
20000	333	*****
30000	267	*****
40000	316	*****
50000	298	*****
60000	297	*****
70000	289	*****
80000	197	*****
90000	82	*****
100000	16	**
110000	4	*
120000	0	
130000	1	*

AV. IBN
N 3021
MEAN 36720
MEDIAN 34672
TMEAN 35821
STDEV 27053
SEMEAN 492
MAX 128086
MIN 0.42
Q3 59902
Q1 11150

IV. IBN
EACH * REPRESENTS 15 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	516	*****
10000	464	*****
20000	236	*****
30000	216	*****
40000	242	*****
50000	276	*****
60000	296	*****
70000	296	*****
80000	219	*****
90000	104	*****
100000	32	**
110000	2	*
120000	1	*

IV. IBN
N 2920
MEAN 37399
MEDIAN 35676
TMEAN 36455
STDEV 28976
SEMEAN 536
MAX 118333
MIN 3
Q3 62364
Q1 9597

Figure 26. Data distribution histogram for direct normal (beam) illuminance (IBN)

AV SBN
EACH * REPRESENTS 15 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	530	*****
100	359	*****
200	296	*****
300	289	*****
400	306	*****
500	281	*****
600	266	*****
700	271	*****
800	256	*****
900	120	*****
1000	4	*
1100	1	*

	AV SBN
N	2981
MEAN	374.8
MEDIAN	356.5
TMEAN	367.3
STDEV	280.6
SEMEAN	5.1
MAX	1118.2
MIN	0.03
Q3	614.7
Q1	103.7

IN SBN
EACH * REPRESENTS 15 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0	640	*****
100	266	*****
200	186	*****
300	223	*****
400	226	*****
500	240	*****
600	289	*****
700	310	*****
800	305	*****
900	123	*****
1000	3	*
1100	1	*
1200	0	
1300	1	*

	IN SBN
N	2817
MEAN	390.6
MEDIAN	391.1
TMEAN	384.7
STDEV	300.0
SEMEAN	5.7
MAX	1268.8
MIN	0.01
Q3	561.8
Q1	67.5

Figure 27. Data distribution histogram for direct normal (beam) irradiance (SBN)

AV. E1
EACH * REPRESENTS 35 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0.0	330	*****
0.5	1602	*****
1.0	532	*****
1.5	245	*****
2.0	125	****
2.5	76	***
3.0	46	**
3.5	28	*
4.0	11	*
4.5	4	*
5.0	5	*
5.5	2	*
6.0	1056	*****

AV. E1
N 4064
MEAN 2.153
MEDIAN 0.820
TMEAN 2.052
STDEV 2.365
SEMEAN 0.037
MAX 5.000
MIN 0.010
Q3 6.000
Q1 0.400

IV. E1
EACH * REPRESENTS 35 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0.0	303	*****
0.5	1585	*****
1.0	431	*****
1.5	225	*****
2.0	133	****
2.5	91	***
3.0	61	**
3.5	29	*
4.0	21	*
4.5	10	*
5.0	13	*
5.5	7	*
6.0	1143	*****

IV. E1
N 4052
MEAN 2.305
MEDIAN 0.850
TMEAN 2.220
STDEV 2.428
SEMEAN 0.038
MAX 5.000
MIN 0.010
Q3 5.000
Q1 0.390

Figure 28. Data distribution histogram for atmospheric extinction coefficient E1

AV. E2
EACH * REPRESENTS 30 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0.0	323	*****
0.5	1497	*****
1.0	536	*****
1.5	241	*****
2.0	124	*****
2.5	73	***
3.0	67	***
3.5	37	**
4.0	35	**
4.5	13	*
5.0	10	*
5.5	10	*
6.0	1107	*****

	AV. E2
N	4075
MEAN	2.277
MEDIAN	0.900
TMEAN	2.189
STDEV	2.398
SEMEAN	0.038
MAX	6.000
MIN	0.010
Q3	6.000
Q1	0.400

IN. E2
EACH * REPRESENTS 35 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0.0	277	*****
0.5	1542	*****
1.0	411	*****
1.5	149	*****
2.0	115	****
2.5	92	***
3.0	66	**
3.5	45	**
4.0	32	*
4.5	35	*
5.0	21	*
5.5	11	*
6.0	1287	*****

	IN. E2
N	4083
MEAN	2.523
MEDIAN	0.930
TMEAN	2.462
STDEV	2.504
SEMEAN	0.039
MAX	6.000
MIN	0.010
Q3	6.000
Q1	0.390

Figure 29. Data distribution histogram for atmospheric extinction coefficient E2

AV. TRI
EACH * REPRESENTS 20 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0.0	39	**
0.1	450	*****
0.2	474	*****
0.3	573	*****
0.4	566	*****
0.5	631	*****
0.6	305	*****
0.7	96	*****
0.8	20	*
0.9	10	*
1.0	4	*

	AV. TRI
N	3770
MEAN	0.3646
MEDIAN	0.3900
TMEAN	0.3631
STDEV	0.1644
SEMEAN	0.0027
MAX	0.9900
MIN	0.0100
Q3	0.4700
Q1	0.2400

IN. TRI
EACH * REPRESENTS 20 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0.0	72	****
0.1	484	*****
0.2	500	*****
0.3	606	*****
0.4	912	*****
0.5	669	*****
0.6	285	*****
0.7	136	*****
0.8	50	***
0.9	26	**
1.0	5	*

	IN. TRI
N	3749
MEAN	0.3593
MEDIAN	0.3700
TMEAN	0.3544
STDEV	0.1796
SEMEAN	0.0029
MAX	0.9900
MIN	0.0100
Q3	0.4700
Q1	0.2200

Figure 30. Data distribution histogram for downward transfer ratio TRI

AV. TR2
EACH * REPRESENTS 30 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0.0	70	***
0.1	462	*****
0.2	524	*****
0.3	1271	*****
0.4	1067	*****
0.5	379	*****
0.6	46	**
0.7	12	*
0.8	8	*
0.9	7	*
1.0	2	*

AV. TR2
N 3870
MEAN 0.3080
MEDIAN 0.3200
TMEAN 0.3078
STDEV 0.1296
SEMEAN 0.0021
MAX 0.9900
MIN 0.0100
Q3 0.3900
Q1 0.2300

IN. TR2
EACH * REPRESENTS 30 OBSERVATIONS

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0.0	102	***
0.1	496	*****
0.2	561	*****
0.3	1261	*****
0.4	909	*****
0.5	341	*****
0.6	128	****
0.7	46	**
0.8	16	*
0.9	3	*
1.0	3	*

IN. TR2
N 3868
MEAN 0.3053
MEDIAN 0.3100
TMEAN 0.3012
STDEV 0.1439
SEMEAN 0.0023
MAX 0.9900
MIN 0.0100
Q3 0.3900
Q1 0.2200

Figure 31. Data distribution histogram for downward transfer ratio TR2

Abbreviated Appendix A

NBSIR 84-2859

The NBS Daylight Availability Database

INSTANTANEOUS DATA

	DAILY AVERAGE FOR MONTH												ANNUAL		UNIT
	MONTHS												HOURLY AVERAGE	DAILY AVERAGE TOTAL	
	1	2	3	4	5	6	7	8	9	10	11	12			
LZ	13247.	23223.	37680.	47324.	67594.	100481.	100381.	77075.	41120.	28211.	26545.	14385.	3932.	48012.	CD/M2
LN	19174.	25092.	35476.	45408.	49165.	66402.	60378.	50728.	30036.	23953.	22596.	14702.	3029.	36856.	CD/M2
LE	18494.	33070.	51192.	91185.	83906.	88485.	107318.	106075.	56733.	35284.	30761.	19357.	5047.	60032.	CD/M2
LS	32022.	47530.	62155.	81814.	78880.	85081.	90921.	92978.	64078.	60212.	62801.	47155.	5585.	67123.	CD/M2
LW	22194.	34971.	52138.	75187.	84498.	91539.	91413.	99393.	50980.	36600.	30284.	15736.	4857.	56939.	CD/M2
SN	343.	448.	595.	867.	1051.	1064.	1284.	933.	472.	373.	475.	379.	56.	689.	W/M2
SS	1583.	2382.	2151.	2663.	2365.	1967.	2383.	2385.	2129.	2086.	2245.	2129.	179.	2203.	W/M2
SE	739.	1087.	1166.	2148.	2242.	1892.	2519.	2012.	1309.	1054.	1001.	981.	122.	1509.	W/M2
SW	700.	966.	1329.	1897.	2006.	1764.	2066.	1705.	1169.	888.	861.	732.	108.	1338.	W/M2
IZ	149477.	240379.	299038.	483863.	562579.	497937.	619191.	516098.	344789.	242275.	184142.	152054.	28694.	356680.	LUX
IS	158564.	248353.	228794.	281864.	228644.	202220.	210082.	240325.	212756.	208176.	220311.	218742.	18059.	221376.	LUX
IE	87001.	138337.	141263.	239348.	259400.	230534.	244138.	229922.	167174.	123918.	96218.	80457.	13747.	169280.	LUX
IW	84473.	125834.	169686.	230119.	245303.	218631.	253040.	202613.	142624.	113420.	101879.	76059.	13184.	163257.	LUX
IN	41604.	60993.	79875.	109451.	119269.	140773.	139218.	103829.	61352.	43521.	43253.	34715.	6528.	81256.	LUX
ID	90319.	130904.	161452.	198378.	255844.	263780.	254505.	205985.	150506.	105761.	106849.	84843.	13587.	166967.	LUX
SRT	1449.	2392.	3140.	4894.	5632.	4990.	5747.	4658.	3014.	2549.	1986.	1503.	278.	3487.	W/M2
SRD	769.	1148.	1562.	1999.	2241.	2678.	2553.	2304.	1404.	1139.	1092.	750.	131.	1633.	W/M2
CR	682.	758.	873.	793.	745.	983.	850.	807.	661.	584.	777.	669.	62.	765.	PCT
TO	559.	757.	991.	1035.	1325.	1668.	1765.	1545.	1193.	1121.	1135.	748.	51.	1154.	DEG.F
IBN	151218.	222293.	240408.	416481.	407868.	313121.	493377.	449448.	327685.	268035.	178217.	177525.	37399.	303344.	LUX
SBN	1699.	2575.	2605.	4412.	4818.	3243.	4315.	3421.	2689.	2889.	2093.	2001.	391.	3056.	W/M2

HOURLY AVERAGES

E1	3.29	3.17	2.85	2.37	1.93	2.87	0.95	1.15	2.10	2.57	2.51	2.85	2.38
E2	2.71	3.03	3.12	2.29	1.71	2.69	1.88	2.24	3.26	2.74	2.39	2.02	2.51
TR1	0.29	0.31	0.29	0.34	0.42	0.34	0.39	0.37	0.31	0.26	0.31	0.29	0.33
TR2	0.24	0.27	0.28	0.31	0.35	0.31	0.34	0.31	0.24	0.25	0.29	0.24	0.28

	AVERAGE DATA												ANNUAL		
	MONTHS												HOURLY AVERAGE	DAILY TOTAL	
	1	2	3	4	5	6	7	8	9	10	11	12			
ALZ	12786.	23912.	36174.	47008.	67748.	98169.	98586.	78456.	41813.	28958.	25785.	14032.	3864.	47676.	CD/M2
ALN	17472.	24747.	38090.	46347.	49588.	66369.	60057.	52513.	29982.	23490.	22339.	14387.	3008.	37051.	CD/M2
ALE	17527.	32198.	52454.	83808.	87946.	100171.	99770.	107110.	56288.	36397.	30633.	18905.	4940.	60143.	CD/M2
ALS	33058.	51912.	68386.	84067.	79389.	85657.	90679.	94846.	66385.	57084.	66098.	45186.	5546.	68527.	CD/M2
ALW	22385.	32766.	51373.	72038.	89218.	94932.	97586.	99958.	51706.	35484.	30040.	15697.	4749.	57620.	CD/M2
ASN	406.	492.	661.	1002.	1044.	1070.	1273.	929.	470.	374.	468.	378.	57.	712.	W/M2
ASS	1696.	2481.	2333.	2773.	2379.	1992.	2374.	2381.	2096.	2044.	2283.	2207.	181.	2251.	W/M2
ASE	752.	1098.	1185.	2167.	2305.	1890.	2571.	2037.	1267.	1096.	981.	964.	122.	1523.	W/M2
ASW	706.	975.	1401.	1905.	1955.	1813.	2040.	1722.	1171.	927.	835.	732.	108.	1346.	W/M2
AIZ	146876.	240880.	313385.	494328.	558900.	508146.	616416.	517671.	338459.	236166.	178574.	151347.	28516.	357485.	LUX
AIS	165705.	254738.	241016.	289410.	228003.	204849.	210571.	240549.	207941.	201833.	226200.	219693.	18097.	224001.	LUX
AIE	88119.	141052.	154173.	246726.	260267.	232411.	244681.	230194.	162668.	120045.	95240.	80344.	13725.	170805.	LUX
AIW	85783.	123538.	179782.	238792.	240094.	224975.	248545.	205113.	141607.	108394.	101105.	76678.	13072.	164194.	LUX
AIN	41857.	59608.	80086.	111493.	118246.	140657.	137296.	103555.	61274.	42911.	43028.	34645.	6454.	80999.	LUX
AID	90898.	132594.	172379.	213583.	257457.	271574.	257810.	207022.	150544.	107247.	105222.	83183.	13677.	170349.	LUX
ASRT	1523.	2482.	3181.	5047.	5549.	5120.	5716.	4652.	2940.	2565.	1891.	1490.	279.	3504.	W/M2
ASRD	792.	1154.	1704.	2152.	2263.	2881.	2559.	2309.	1422.	1133.	1054.	734.	132.	1660.	W/M2
ACR	689.	743.	856.	807.	717.	940.	822.	799.	663.	609.	802.	712.	61.	763.	PCT
ATC	561.	754.	980.	1030.	1325.	1667.	1768.	1543.	1191.	1123.	1134.	748.	51.	1152.	DEG.F
AIBN	151278.	227401.	264580.	434456.	416455.	320328.	492444.	455590.	312476.	259778.	174770.	193306.	36720.	308145.	LUX
ASBN	1712.	2784.	2691.	4465.	4743.	3404.	4338.	3466.	2577.	2948.	2011.	2185.	375.	3103.	W/M2

HOURLY AVERAGES

AE1	3.06	2.94	2.57	2.01	1.75	2.54	0.92	1.12	2.15	2.56	2.46	2.66	2.23
AE2	2.76	2.66	2.87	1.94	1.53	2.24	1.58	1.97	3.17	2.53	2.48	2.06	2.32
ATR1	0.29	0.33	0.32	0.36	0.41	0.35	0.39	0.37	0.30	0.27	0.30	0.31	0.33
ATR2	0.24	0.28	0.29	0.33	0.34	0.32	0.33	0.31	0.23	0.25	0.28	0.26	0.29

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET (See instructions)	1. PUBLICATION OR REPORT NO. NBSIR 84-2859	2. Performing Organ. Report No.	3. Publication Date July 1984
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4. TITLE AND SUBTITLE
The NBS Daylight Availability Database

5. AUTHOR(S)
S. Treado, G. Gillette, W. Remmert and J. Bean

6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions) NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234	7. Contract/Grant No. 8. Type of Report & Period Covered
---	---

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (Street, City, State, ZIP) Naval Civil Eng. Lab, Port Hueneme, CA 93043 - Nat'l Fenestration Council, 3310 Harrison St., Topeka, KS 66611 - Naval Facilities Eng. Command, U.S. Navy, Washington, DC 20390 - Directorate of Civil Eng., U.S. Air Force, Washington, DC 20330 - Office of Chief of Engineers, U.S. Army, Washington, DC 20314

10. SUPPLEMENTARY NOTES

 Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

This report presents an annual database containing hourly measurements of solar radiation, illumination, sky luminance and ambient air temperature. The measurements were made at the National Bureau of Standards, Gaithersburg, Maryland (77° west longitude, 38.5° north latitude). Both instantaneous hourly and integrated average hourly measurements are included, as are daily, monthly and annual average and totals. For each measured quantity, a histogram of the distribution of the data is presented for the year. The data measurement, collection and analysis system is described.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)
daylight availability; irradiance; luminance; sky illuminance, solar radiation, weather data

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