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Publication Date
1977-05-01

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Presented at the 1977 Annual Meeting of the American Section of the International Solar Solar Energy Society, Orlando, Florida, June 6-10, 1977.

LBL-7898

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Energy and Environment Division

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May 1977

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Prepared for the U.S. Department of Energy under Contract No. W-7405-ENG-48

LBL-7898

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LBL-7898

REHABILITATION TECHNIQUES FOR DAILY SOLAR RADIATION DATA

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ABSTRACT

Daily total insolation records are rehabilitated using a "clear-day" analysis technique. This method depends only on the recorded daily data and does not require reference to strip charts or station histories. Final adjustment of data levels is made with the aid of atmospheric transmittance calculations.

INTRODUCTION

A "clear-day" analysis has been used to obtain a corrected solar radiation data base for 19 locations in the State of California. Although a large number of solar measurement stations have been deployed in California for various lengths of time over the past 50 years, very few have produced solar data that are useful for design purposes. Even those data sets that meet minimum requirements for quality and length of record have been found to suffer from prolonged periods without instrument calibration and from inadequate station records of instrument calibration factors. As a result it was necessary to edit all the California data using a technique that required only the raw data. Such an editing technique is the "clear-day" analysis described in this paper. The various stages of this technique were adapted or developed at the Lawrence Berkeley Laboratory during a solar data project.

In the following sections some background information on the Solar Resources Project is followed by a detailed description of the methodology involved in the "clear-day" analysis. Some of the resulting data are presented.

PROJECT DESCRIPTION

The California Solar Resource Project was carried out by the Lawrence Berkeley Laboratory for the California Energy Resources Conservation and Development Commission (ERCDC) and for ERDA. The ten-month project included the collection of all available solar data taken within the state and near

its boundaries and publication of these data in a suitable Solar Data Manual. Extensive user contacts were made to determine both the content and format of this manual. In addition, recommendations were made to ERCDC regarding alternative future data station networks to meet the needs of the state. Approximately 135 solar data measuring sites were identified in California. Many of these sites were temporary in nature and no longer supply solar data. The solar radiometer types encountered included 9 photovoltaic devices, 39 mechanical pyranographs, and 87 thermopile pyranometers. Daily total horizontal insolation data were received from 44 stations and stored in a computer data base developed for this project. All the stored data were subjected to an analysis program designed to evaluate the accuracy of the raw data values. Site visits were made to inspect 23 of these stations. Using the criteria of (a) record length of five years or more and (b) sufficient quality of the data so as to be correctable, data from 19 stations were finally accepted for inclusion in the data manual.

CLEAR-DAY ANALYSIS TECHNIQUE

Daily total insolation values were stored in a computer data base for all available solar data records in California. The data were then processed and plotted in four different ways:

1. Daily plots of percent of extraterrestrial radiation (ETR) received on a horizontal surface
2. Compressed plots of percent of ETR (maximum values for 10-day intervals)
3. Ratio plots of daily insolation received by pairs of stations
4. Insolation frequency histograms for intervals of up to a year

Each of these plots presents the same basic data differently and facilitates evaluation and analysis in a complementary manner. The actual daily insolation values are converted to percent of ETR values by dividing them by the calculated extraterrestrial radiation received on a horizontal surface. This removes most of the seasonal variation in the readings due to changes in the sun's declination throughout the year, and is a direct measure of the transparency of the atmosphere to solar radiation.

Abrupt discontinuities as well as slow instrumental drift over a period of several years can be detected by applying the four graphical techniques listed above. Poor quality data are eliminated. The remaining data are adjusted so that the measured clear-day values coincide with clear-day atmospheric transmittance calculations to be discussed in greater detail below.

The first type of plot is useful for detecting abrupt changes in recorded levels that are indicative of instrument problems or recorder calibration errors. The upper envelope of points plotted in this manner represents the atmospheric transmission of sunlight on clear days. This technique permits sudden jumps in recording levels to be detected but is less capable of indicating slow instrumental drift that can occur over a period of several years.

The second type of plot listed above presents the data so that long-term drifts in instrument calibration levels can readily be detected. This is accomplished by "compressing" the percent of ETR plots so that the maximum value is plotted for each 10-day interval. The tenfold reduction in the length of the computer printout enables many years' worth of data to be examined for trends that typically amount to about 1% per year. Although weather records are not consulted to determine whether days are clear, partially clear, or cloudy, a reduction of this type obviously selects the clearest day occurring during each 10-day interval, and the upper envelope of the points should indicate the maximum atmospheric transmittance achieved over a period of time. A related technique has been used by R. Bahm, who applied it to solar data in New Mexico (unpublished). This technique has the advantage that it is unnecessary to introduce an arbitrary clear-day cutoff value such as would be required if <u>average</u> values were to be taken of clear days over 10- or 15-day intervals. A typical plot of several years' worth of compressed clear day data is reproduced in Fig. 1.

A third type of computer-generated plot (namely, a plot of the ratio of daily total insolation readings from two neighboring stations) was used as an aid in detecting discontinuities in the recorded data levels. Such a plot should yield approximately constant values for each day during which the sky cover conditions are similar at the two stations. Since both stations considered are most frequently located at about the same latitude, residual latitude effects in the percentage of ETR due to seasonal variations in

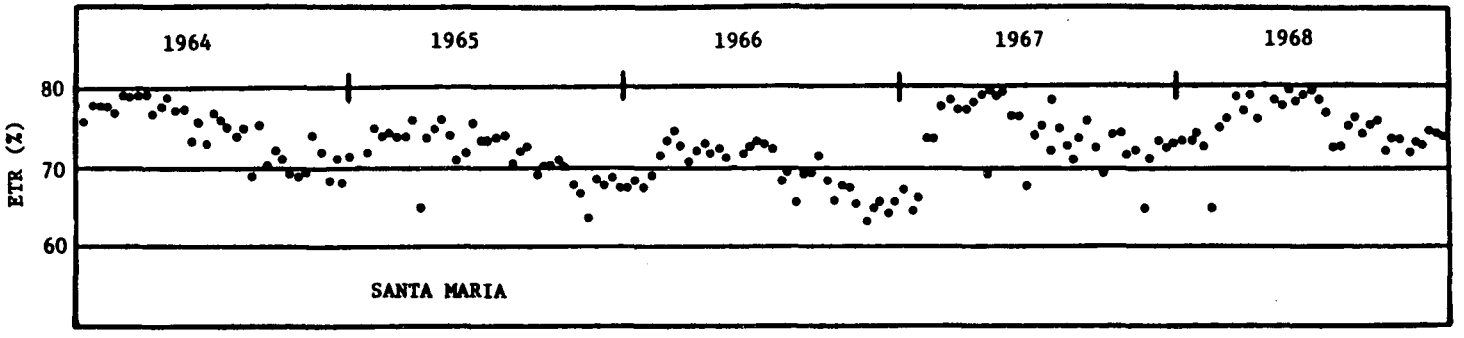


Figure 1. Example of a "compressed" percent of ETR plot for Santa Maria insolation data. Each point on the graph represents the maximum daily percentage of extra-terrestrial radiation recorded during a 10-day interval. An approximately linear downward drift of 3% per year in the instrument calibration factor is observed between 1964 and 1966. Installation of a new pyranometer is responsible for the abrupt increase in the recording level in 1967.

air mass penetrated by the sun's radiation are largely eliminated. Erratic behavior of a data station can often be detected using this type of presentation provided that data from a second nearby station are available for the same period.

This technique was useful in analyzing the data from the 11 stations in the San Francisco Bay Area operated by the Bay Area Air Pollution Control District. Since random insolation fluctuations due to local climatic effects are introduced by both stations for which the ratio is taken, the day-to-day scatter in the ratio is larger on a percentage basis than the scatter in the fraction of ETR plots for either station taken separately. Correlations of daily total insolation values can be quite poor even between close-lying stations during unstable weather conditions. Consequently, this technique is most sensitive in detecting abrupt discontinuities in recording levels during the spring and summer seasons in California. However, even with the above mentioned drawbacks, this technique proved to be a useful tool for detecting changes in calibration levels. If such a change were to occur during a period of low daily correlation between stations, so that a large amount of scatter is observed in the plotted ratios, the difference in the ratios before and after this period would point out the change. For such a case, the percent of ETR plots would then be examined for the same time period to determine which instrument produced the variation. Numerous abrupt shifts were detected in this manner that would probably have been attributed to normal fluctuations if the ratio plots had not been available. Likewise, a number of apparent shifts in the data received by one station were discounted after ascertaining that the ratio plots between it and neighboring stations remained constant.

A fourth and final type of plot used in the analysis is a histogram showing the frequency distribution of daily total insolation values over a period of several months to a year. One purpose of such histograms is to aid in detecting a calibration shift during the year. The measured distributions normally have a single major peak corresponding to clear-day values. If a calibration shift takes place during the year, a double peak may be observable in the distribution. A second purpose of such histograms is to establish the spread between average clear days as determined from the peak of the distribution and the clearest recorded days. This is an important consideration for adjusting the recorded data to a level

determined by an atmospheric clear-day calculation, as will be discussed in the next section. A yearly histogram is presented as an example in Fig. 2.

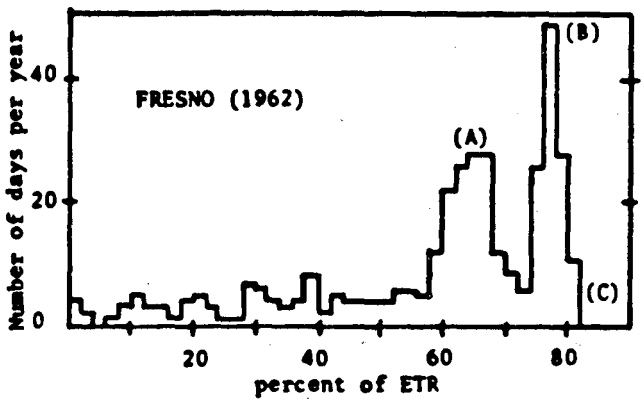
ADJUSTMENT OF THE SOLAR DATA

All data considered for inclusion in the Solar Data Manual were subjected to the foregoing analysis. Excessive short-term fluctuations or intermittent records were eliminated from the data base. No estimates were made of missing data; blank records were simply not counted in constructing long-term averages. Jump discontinuities in the data as determined by the analysis described above were used as boundaries for each data block. The data blocks were then adjusted so that the maximum clear-day insolation levels in each block were normalized to calculated values. The calculations were performed at the NOAA Environmental Research Laboratory by Douglas Hoyt for eight locations and three sets of input parameters: turbidity, precipitable water vapor content, and surface albedo. The calculations yielded the percent of ETR received on a horizontal surface integrated over the day. If necessary, slow instrumental drift within a single data block was accounted for by adjusting data within that block on a yearly basis.

The sensitivity of these calculated values of atmospheric transmittance (expressed as percent of ETR) to turbidity and precipitable water vapor was investigated. Using the latitude-averaged precipitable water vapor values, the turbidity parameter was reduced by a factor of 2; this resulted in an increase in the calculated percent of ETR typically on the order of 1% for inland locations and up to 3% for southern coastal locations (San Diego, Santa Monica). Reducing the precipitable water vapor parameter by 30 to 50% resulted in increases of 2 to 4% in the calculated percent of ETR.

The calculated results were interpreted as the percentage of ETR received on a "typical" clear day since average seasonal water vapor and turbidity parameters were used. A day on which the water vapor content of the atmosphere is lower than normal would lead to higher-than-normal insolation values (clearest days). Such clearest days are indicated by the upper tail of the insolation frequency distribution, as shown in the example in Fig. 2. Reference to the histograms show that the clear days forming the upper

Figure 2. Typical yearly histogram showing uncorrected solar data. This histogram is selected to illustrate the double peaks (A) and (B) that are sometimes observable when the instrument calibration factor changes during the year. Peak (B) represents typical clear days and (C) is the upper tail of the distribution (clearest days).



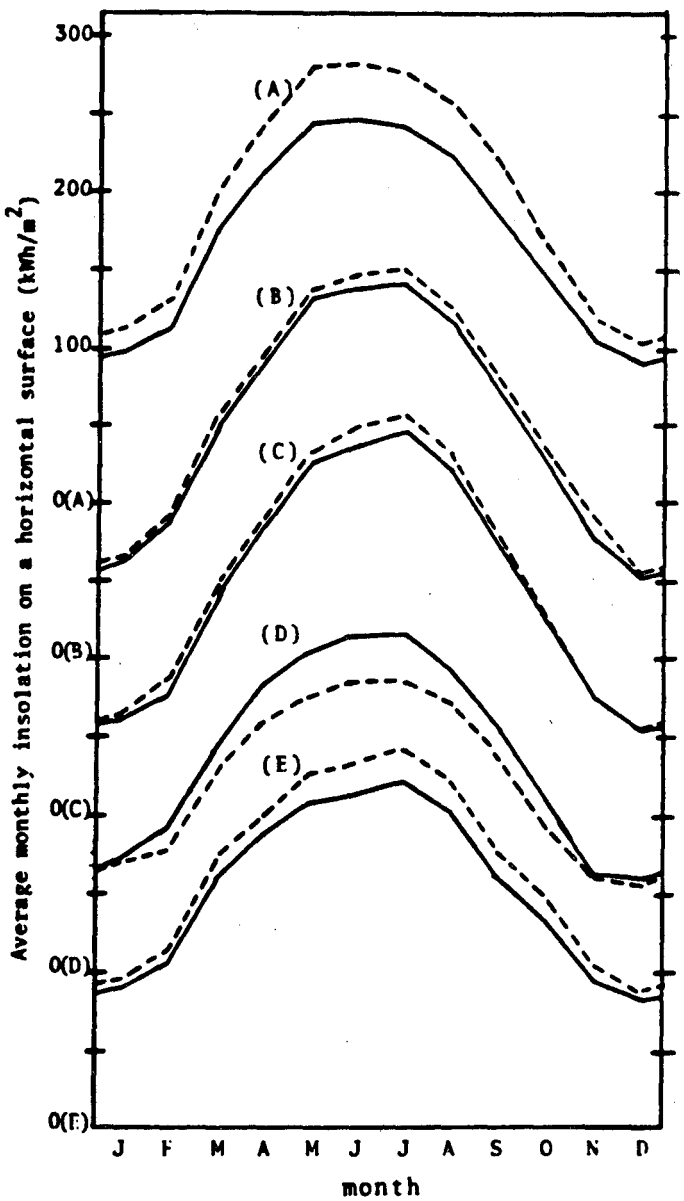


Figure 3. Comparison of average monthly insolation levels on a horizontal surface before and after the data rehabilitation process was carried out. The dashed lines represent uncorrected data and the solid lines are the corrected monthly averages. Key: (A) China Lake/Inyokern, (B) Fresno, (C) Davis, (D) Richmond, (E) Santa Maria. Note that the zero points for each station are displaced on the ordinate.

peak of the distribution fall typically about 3% below the clearest-day maximum value. This number varies somewhat between stations and was taken into consideration in normalizing the experimental data to the calculated insolation values.

RESULTS OF THE ANALYSIS

Average monthly insolation values were obtained from the corrected data sets. A comparison of such averages made before and after application of the rehabilitation process is presented in Figure 3 for 5 of the 19 stations analyzed. The maximum differences between the values amount to about 15% for summertime insolation levels (Richmond and China Lake/Invokern). Another significant characteristic of the corrected data is that insolation frequency histograms tend to show less spread and sharper peaks than their uncorrected counterparts, even when the average values do not change significantly.

This work was supported by the U. S. Department of Energy.

This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

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