Title

Analysis of the California Solar Resource--Volume 3: Appendices

Author

erdahl, P.

Publication Date

2011-03-18

LBL-7860 c2
3/3
November 1978

Energy and Environment Division

ANALYSIS OF THE CALIFORNIA SOLAR RESOURCE
Volume 3: Appendices

P. Berdahl, D. Grether,
M. Martin, and M. Wahlig

Lawrence Berkeley Laboratory University of California/Berkeley

Prepared for the U.S. Department of Energy, Division of Solar Energy,
under Contract No. W-7405-ENG-48 and for the California Energy Commission

Printed in the United States of America
Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price: Printed Copy, \$ 8.00 Domestic; \$16.00 Foreign
Microfiche, \$ 3.00 Domestic; \$ 4.50 Foreign

LBL-7860
UC-62

ANALYSIS OF THE CALIFORNIA SOLAR RESOURCE

VOLUME 3: APPENDICES

P. Berdahl, D. Grether, M. Martin, and M. Wahlig

ENERGY AND ENVIRONMENT DIVISION
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA

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Analysis of the California Solar Resource is a three-volume work:

Volume 1: Executive Summary

Volume 2: Final Report

Volume 3: Appendices

All three volumes are available from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

Contents

Appendix A
SUMMARIES OF CONFERENCES WITH SOLAR DATA USERS

INTRODUCTION

Seven meetings were held with users of solar data who represent a broad sample of individuals active in solar energy in California. The primary purpose of these meetings was to obtain advice regarding the form and content of the solar data manual(s) and regarding a questionnaire for polling a wide sample of individuals. A secondary purpose of these meetings was to enable LBL personnel to establish closer contact with the solar energy community in California. This contact facilitated later cooperation in the tasks of data collection and management.

The meetings are summarized below and a list of the meeting participants is presented in Table A-1.

MEETING #1, 10 MAY 1976, LAWRENCE BERKELEY LABORATORY, BERKELEY

Suggested Solar Data

1. Direct insolation--for computations for tilted surfaces, concentrating collectors, and analysis of central power stations.
2. Distributions of 1, 2, 3 cloudy days.
3. Correlations of solar radiation vs. temperature and solar radiation vs. cloudiness.
4. Hourly solar data averaged over days of the month or season. (This gives an idea what a typical day is like.)
5. Generalized graph showing the sensitivity of radiation received on a surface to slight eastward and westward tilts.
6. Insolation values for cloudless days.
7. Number of hours of daylight.
8. Sun charts (giving location of the sun as a function of time).

Suggested Nonsolar Data

1. Frequency distributions of daytime temperature, nighttime temperature, and wind speed.
2. Ground temperature.
3. Albedo of various types of terrain.

Table A-1. Conferences with solar data users (1976).

Date	Location	Attendees/Affiliation
10 May	LBL	Bruce Wilcox, Berkeley Solar Group
		Marshal Merriam, U. C. Berkeley
		Dale Sartor, Interactive Resources
		Richard Storek, Architect
		Max Blanchet, PG&E
		Bob Heaton, Solar Consultant
		Rick Nelson, Accurex Corp.
		Tom Simonson, Engineer
		Zulfikar Cumali, Consultants Computation Bureau
		Tom Brumleve, Sandia Livermore Lab.
		James Lerner, State Energy Commission
		Mike Wahlig, LBL
		Don Grether, LBL
		Marlo Martin, LBL
		Paul Berdahl, LBL
19 May	U. C. Davis	William Rains, Agronomy Department (U.C.D.)
		Robert Loomis, Agronomy Department (U.C.D.)
		Jerry Hatfield, Land, Air, Water Resources Department (U.C.D.)
		Paul Berdahl, LBL
		Marlo Martin, LBL
24 May	Aerospace Corporation, El Segundo	Howard Webb, Aerospace Corporation
		Stan Leonard, Aerospace Corporation
		Mason Watson, Aerospace Corporation
		Keith Cretcher, Aerospace Corporation
		Walt Melton, Aerospace Corporation
		Jim Rogan, McDonnell-Douglass

Table A-1. Continued.

Date	Location	Attendees/Affiliation
24 May	Aerospace Corporation, El Segundo	Bob French, Jet Propulsion Laboratory MacGregor Reid, Jet Propulson Laboratory Martin Berdahl, Jet Propulson Laboratory Nick Patapoff, Souther California Edison James Lerner, State Energy Commission Marlo Martin, LBL Paul Berdahl, LBL
25 May	California Polytechnic State University, San Luis Obispo	Thomas Lukes, Food Industries Ed Carnegie, Argicultural Engr. Dept. (C.P.S.U.) Paul Berdahl, LBL Marlo Martin, LBL
25 May	General Atomic Co., San Diego	John Russell, General Atomic John Schuster, General Atomic Paul Berdahl, LBL Marlo Martin, LBL
26 May	San Diego Gas & Electric Company	Alan Stewart, SDG&E Robert Resley, SDGE&E Paul Berdahl, LBL Marlo Martin, LBL
26 May	Naval Undersea Center, San Diego	Howard Wilcox, Naval Undersea Center Paul Berdahl, LBL Marlo Martin, LBL

4. Sky "temperature."
5. Probability of freezing.

Remarks

The data manual should contain explanations of how the data presented are derived from raw data. Serious users should have access to the raw data so they can develop their own statistical distributions. All the data, including that contained in the data manual, should be available on computer tape or punched cards, in a standard format. (M. Wahlig pointed out that the state has not decided whether or not this should be done.)

There was some discussion about using models to estimate the amount of direct radiation. T. Brumleve pointed out that Sandia is funding Aerospace Corp. to develop models for estimating the direct component.

The question of preparing contour maps of microclimates was discussed. Professor Merriam pointed out that if the uncertainty in the values plotted becomes greater than the contour interval, the maps would be nearly meaningless.

The group agreed that distribution of the manual by a commercial publisher would be very helpful in obtaining wide readership. Further discussion touched on the number and type of manuals to be produced and their size and price. No definite conclusions were reached, except that these issues should be raised in the data format questionnaires. B. Wilcox made the interesting point that some of the present methods for using data to size systems are used simply because there is not much data. As better data become available, different methods may be developed.

MEETING #2, 19 MAY 1976, UNIVERSITY OF CALIFORNIA, DAVIS

Suggested Solar Data

1. Direct and diffuse radiation data for use with Liu and Jordan's estimation technique for radiation received on inclined surfaces. Surfaces facing north are not unimportant.

2. Incoming and outgoing infrared radiation. These data would be useful since the water loss of plants is sensitive to infrared radiation. An alternative would be data on the net radiation exchange with a standard surface (e.g., moist grass, dense foliage, etc.).
3. Ultraviolet radiation data. This would be useful because of the biological effects of uv radiation.

Suggested Nonsolar Data

1. Detailed information on temperature, such as standard daily profiles.

Remarks

In general, the participants at this meeting were interested in solar and other weather data as input for their research related to plant growth. As a consequence of the research nature of their work, extremely detailed information was desired.

For weather data which were tabulated, it was felt that 30-year means and standard deviations should be presented. Statistical distributions could supplement the data on averages.

From a strictly practical point of view, solar data are of marginal value to agronomists. However, for research purposes--e.g., models of plant growth--these data are of considerable interest.

MEETING #3, 24 MAY 1976, THE AEROSPACE CORPORATION, EL SEGUNDO

In this meeting, the types of solar and weather data which might be displayed in a manual were regarded as self-evident by a majority of the participants. For this reason, after examination of the draft solar data manual formats, attention was concentrated on how the data should be processed, displayed, and marketed.

Even relatively sophisticated data users, who generally require hourly data on computer tapes, have a need for general purpose information such as might appear in a solar data manual.

Methods for determining and ensuring data quality were discussed. LBL's proposed visits to sites where data are being taken were regarded as a useful check. The number of years of the data record is regarded as a measure of the quality of the long-term averages obtained from the data. It was pointed out that, in general, the data errors are not of the random type, but are systematic--too high or low all year long.

The display of contour maps and the related problem of interpolation were discussed. One concern was that contour maps could not be detailed enough to display the various microclimate effects present in California, even if the necessary data were known. Another concern was that the user of the contour maps might attempt to interpolate across mountain ranges or near bodies of water where interpolation is unwarranted. The idea of dividing California into climatic zones--within which it might be possible to interpolate--was suggested and discussed. the use of climatic zones appeared to be of considerable potential value, particularly if it would be possible to exclude some mountaneous regions of low population density.

The problem of presenting suitable data in a useful format for future users who may not be technically sophisticated was addressed. In this case if may not be possible to determine data needs by querying users. It was suggested that individuals in research and development may have to make the relevant decisions. It was pointed out that for some future applications, which are presently known, there is no one who can make appropriate recommendations.

Several participants expressed the opinion that it would be inappropriate to publish specialized data manuals aimed at exotic applications. Handbooks or manuals are thus considered a good idea only if the potential user group numbers in the hundred or thousands.

MEETING #4, 25 MAY 1976, CALIFORNIA POLYTECHNIC STATE UNIVERSITY, SAN LUIS OBISPO

Suggested Data

1. Solar radiation received on a horizontal surface.
2. Wet- and dry-bulb temperatures for solar drying of fruits and vegetables. Measurements of the dew point (yielding the absolute

humidity) are potentially more useful than measurements of the wet-bulb temperature (yielding relative humidity); absolute humidity shows a smaller variation during the course of the day.

3. In general it is desirable to have measured values of solar and other meteorological variables more frequently than daily, but hourly data are not required. Distributions or typical daily profiles should suffice.

Remarks

The participants emphasized that meaningful data regarding wind speed and direction can be very difficult to obtain if the wind fluctuates strongly. Does one tabulate average values, peak values, or something else?

The participants stated that they had a preference for climate zones as a means to summarize climatic differences, rather than having the data presented on contour maps.

Professor Carnegie discussed the economics of solar fruit and vegetable drying in California, pointing out that the long drying season offers a favorable chance to amortize the necessarily large capital investment. Most of the large drying organizations presently operating in the state face restrictions on the amount of natural gas (the present fuel) they can obtain. Solar heating appears economically competitive to the alternatives to natural gas.

MEETING #5, 25 MAY 1976, GENERAL ATOMIC COMPANY, SAN DIEGO

Suggested Data

1. Detailed information on clear-day solar radiation, especially the direct-beam component. The actual solar data, expressed as a fraction of the various clear-day values, should also be presented. This approach is particularly advantageous for climates with many clear days.
2. String statistics for successive days with low insolation.

Remarks

It would be useful to have one page in the solar data manual(s) that contained important constants, such as the solar constant and conversion factors, and order-of-magnitude numbers, such as mean yearly totals of solar radiation.

A conceptual design was described for General Atomic's fixed-mirror movable-focus solar conversion system.

MEETING #6, 26 MAY 1976, SAN DIEGO GAS AND ELECTRIC COMPANY, SAN DIEGO

In general the participants preferred data displayed in a format similar to that used in the climatological atlases. Climatic summaries, with suitable emphasis on microclimates, were also requested.

The opinion was expressed that wind speed data was of marginal value.

It is the opinion of the San Diego Gas and Electric engineers that the coastal areas of San Diego receive about 20% less sun than the interior areas. Measurements that are presently under way should allow a more quantitative statement to be made.

MEETING #7, 26 MAY 1976, NAVAL UNDERSEA LABORATORY, SAN DIEGO

Dr. Wilcox is the originator and proponent of the concept of large-scale ocean farming of kelp, using floating platforms in the open ocean. He expressed the opinion that development of this concept has not yet progressed to the point where solar data are needed. Only extremely rough estimates are required.

Appendix B
SOLAR DATA USER QUESTIONNAIRE AND SAMPLE FORMATS

Name of Repondent ____

Company or Institution ____

Address ____

____

Telephone ____

==

(1) My interest in solar radiation data stems from my activities as a(n)...

(CHECK MORE THAN ONE IF APPROPRIATE)

[ ] agricultural engineer
[ ] agronomist
[ ] architect
[ ] banker
[ ] builder
[ ] consultant
[ ] developer
[ ] employee of a government regulatory agency
[ ] engineer
[ ] equipment manufacturer
[ ] owner of a solar building
[ ] planner
[ ] research worker
[ ] other (please specify) ______________________________________

(2) I would use solar radiation data primarily for...

(CHECK MORE THAN ONE IF APPROPRIATE)

[ ] designing residential space-heating systems
[ ] designing industrial or commercial space-heating systems
[ ] designing domestic water heating systems
[ ] designing industrial or commercial process heat systems
[ ] designing solar air conditioning systems
[ ] designing passive solar heating and cooling systems
[ ] designing agricultural drying or dehydrating systems
[ ] predicting crop growth and/or maturity
[ ] siting solar electric power plants
[ ] designing solar electric power plants
[ ] predicting impact of solar technology on utility companies
[ ] investigating photovoltaic conversion processes
[ ] developing biomass conversion techniques
[ ] other uses (research projects, etc...please specify)

____

____

____

PLEASE RESPOND TO QUESTIONS 3 and 4 ONLY IF YOU REQUIRE SOME OF THE FOLLOWING TYPES OF DATA AT SHORTER INTERVALS THAN MONTHLY. IF MONTHLY AVERAGE DATA IS SUFFICIENT FOR YOUR PURPOSES LEAVE THE BOXES BLANK AND CONTINUE WITH QUESTION (5).

(3) I require the following types of insolation data more frequently than on a monthly average basis:

	Hourly	Daily	Other (please specify)
- Total insolation on a horizontal surface	[ ]	[ ]	________
- Total insolation on a vertical surface facing south	[ ]	[ ]	________
- Total insolation on inclined surfaces (please specify angles:________)	[ ]	[ ]	________
- Direct beam component of insolation	[ ]	[ ]	________
- Diffuse component of insolation	[ ]	[ ]	________
- Spectral composition of insolation	[ ]	[ ]	________
- Turbidity	[ ]	[ ]	________
- Sunshine hours (or minutes)	[ ]	[ ]	________
- Other insolation data (specify type and frequency)			

____
____
____

(4) I require the following types of weather data more frequently than on a monthly average basis:

	Hourly	Daytime Average	Nighttime Average	24 hour Average
- Temperature (dry bulb)	[ ]	[ ]	[ ]	[ ]
- Temperature (wet bulb)	[ ]	[ ]	[ ]	[ ]
- Dew point (absolute humidity)	[ ]	[ ]	[ ]	[ ]
- Relative humidity	[ ]	[ ]	[ ]	[ ]
- Wind speed	[ ]	[ ]	[ ]	[ ]
- Wind direction	[ ]	[ ]	[ ]	[ ]
- Cloud cover	[ ]	[ ]	[ ]	[ ]
- Other weather data (specify type and frequency)	[ ]	[ ]	[ ]	[ ]

____
____
____
____

(5) Please check the appropriate boxes to indicate the desirability of including the following types of averaged monthly insolation data in a Solar Data Manual.

	Necessary	Useful	Unnecessary	No opinion
- Total insolation on a horizontal surface	[ ]	[ ]	[ ]	[ ]
- Total insolation on a vertical surface facing south	[ ]	[ ]	[ ]	[ ]
- Direct beam component of insolation	[ ]	[ ]	[ ]	[ ]
- Diffuse component of insolation	[ ]	[ ]	[ ]	[ ]
- Spectral composition of insolation	[ ]	[ ]	[ ]	[ ]
- Turbidity	[ ]	[ ]	[ ]	[ ]
- Hours of sunshine	[ ]	[ ]	[ ]	[ ]
- Sun charts showing elevations and azimuths of the sun each month	[ ]	[ ]	[ ]	[ ]

(6) Techniques are available for approximately converting measured monthly horizontal insolation data to the amount of total radiation received by a sloped surface. Please indicate the nature of this type of data that you require in your work.

A) Slopes facing SOUTH only:

	Necessary	Useful	Unnecessary	No opinon
- 15°, 30°, 45°,60°, 75°, 90° slopes	[ ]	[ ]	[ ]	[ ]
- 30°, 60°, 90° slopes	[ ]	[ ]	[ ]	[ ]
- slope = latitude angle	[ ]	[ ]	[ ]	[ ]
- slope = latitude + 15°	[ ]	[ ]	[ ]	[ ]
- slope = latitude - 10°	[ ]	[ ]	[ ]	[ ]
- other required south facing slope angles (please specify)	[ ]	[ ]	[ ]	[ ]

____

____

____

B) Slopes facing in other compass directions:

	Necessary	Useful	Unnecessary	No opinion
-Which directions are most important?				
North	[ ]	[ ]	[ ]	[ ]
East	[ ]	[ ]	[ ]	[ ]
West	[ ]	[ ]	[ ]	[ ]
Other (please specify)	[ ]	[ ]	[ ]	[ ]
-The following slopes should be included for the compass directions of major importance.				
- 15°, 30°, 45°, 60°, 75°, 90° slopes	[ ]	[ ]	[ ]	[ ]
- 30°, 60°, 90°, slopes	[ ]	[ ]	[ ]	[ ]
- Other required slope angles for surfaces not facing SOUTH	[ ]	[ ]	[ ]	[ ]

____

____

____

____

(7) Selected <u>average</u> <u>monthly</u> weather data may be included along with solar radiation data. Please check the appropriate boxes to indicate the desirability of including each type of weather data in the Solar Data Manuals.

	Necessary	Useful	Unnecessary	No opinion
- Dry bulb temperature				
- 24 hour	[ ]	[ ]	[ ]	[ ]
- daytime	[ ]	[ ]	[ ]	[ ]
- nighttime	[ ]	[ ]	[ ]	[ ]
- min/max temperatures	[ ]	[ ]	[ ]	[ ]
- Wet bulb temperature				
- 24 hour	[ ]	[ ]	[ ]	[ ]
- daytime	[ ]	[ ]	[ ]	[ ]
- nighttime	[ ]	[ ]	[ ]	[ ]
- Typical daily temperature profiles	[ ]	[ ]	[ ]	[ ]
- Absolute humidity profiles	[ ]	[ ]	[ ]	[ ]
- Relative humidity profiles	[ ]	[ ]	[ ]	[ ]
- Dew point				
- daytime	[ ]	[ ]	[ ]	[ ]
- nighttime	[ ]	[ ]	[ ]	[ ]
- Probability of freezing temperature	[ ]	[ ]	[ ]	[ ]
- Heating degree days (65°F base)	[ ]	[ ]	[ ]	[ ]
- Cooling degree days (75°F base)	[ ]	[ ]	[ ]	[ ]
- Sky temperature				
- daytime	[ ]	[ ]	[ ]	[ ]
- nighttime	[ ]	[ ]	[ ]	[ ]
- Ground temperature	[ ]	[ ]	[ ]	[ ]
- Cloud cover information				
- daytime	[ ]	[ ]	[ ]	[ ]
- nighttime	[ ]	[ ]	[ ]	[ ]
- Rainfall	[ ]	[ ]	[ ]	[ ]
- Wind speed				
- daytime	[ ]	[ ]	[ ]	[ ]
- nighttime	[ ]	[ ]	[ ]	[ ]
- Wind Direction distribution	[ ]	[ ]	[ ]	[ ]
- Other weather data required (please specify)	[ ]	[ ]	[ ]	[ ]

____

____

____

____

(8) Which units should be used in presenting solar insolation data?

	Necessary	Useful	Unnecessary	No opinion
-Btu/sqft	[ ]	[ ]	[ ]	[ ]
-Langleys = cal/cm^2	[ ]	[ ]	[ ]	[ ]
-Kilowatt-hours/m^2	[ ]	[ ]	[ ]	[ ]
-Joules/m^2	[ ]	[ ]	[ ]	[ ]
-Other: (please specify) ____________________.	[ ]	[ ]	[ ]	[ ]

(9) Two types of monthly graphical representations are presented for solar insolation data in format C. Please indicate the desirability of presenting such data in these formats.

	Necessary	Useful	Unnecessary	No opinion
-Bar graph (graph I, format C)	[ ]	[ ]	[ ]	[ ]
-Line graph (graph II, format C)	[ ]	[ ]	[ ]	[ ]
-Should high/low limits be included on the graphs?	[ ]	[ ]	[ ]	[ ]

(10) Different types of statistical information can be provided as illustrated by graphs III to V of format C. If you have need for a specific type of statistical distribution (i.e., daily insolation frequency, wind speed, wind direction, etc.) please specify:

____

____

____

(11) There are a limited number (about 40) of solar insolation measuring stations in California for which records are available. Would you prefer to have a data manual showing:

	Necessary	Useful	Unnecessary	No opinion
-The actual monthly values measured at these stations on a year-by-year basis	[ ]	[ ]	[ ]	[ ]
-The average monthly values (averaged over as many years as data is available)	[ ]	[ ]	[ ]	[ ]
-Average monthly values for all major cities and population areas (interpolated by us)	[ ]	[ ]	[ ]	[ ]
-Average monthly values interpolated by us and plotted continously (i.e., as contour maps)	[ ]	[ ]	[ ]	[ ]
-If average monthly values are to be presented should minimum and maximum values be furnished in order to illustrate deviations in the data?	[ ]	[ ]	[ ]	[ ]

(12) Please indicate the desirability of representing solar radiation data by means of the following formats:

	Necessary	Useful	Unnecessary	No opinion
- Tabular format A	[ ]	[ ]	[ ]	[ ]
- Tabular format B	[ ]	[ ]	[ ]	[ ]
- Contour map format D	[ ]	[ ]	[ ]	[ ]

(13) What size should an adequate Solar Data Manual be?

[ ] 50 pages or less
[ ] 100 pages
[ ] 250 pages
[ ] 500 pages
[ ] 1000 pages or more
[ ] No preference

(14) What should be the price range for a Solar Data Manual of this type?

[ ] Free
[ ] $1 - $5
[ ] $5 - $20
[ ] $20 - $50
[ ] More than $50
[ ] No preference

(15) Do you wish to be contacted again for your comments when we are prepared to send out the next modifications of the Data Manual Formats? YES [ ], NO [ ]

(16) Please list the names of any acquaintances who you feel have an active interest in applications of solar energy and to whom we should send copies of this sample data format and questionaire.

NAME	ADDRESS

DESCRIPTION OF THE ATTACHED FORMATS

Two basic tabular formats are presented on the following pages:

FORMAT A- Selected insolation and weather data are combined and presented on a monthly basis for each of a number of California cities.

FORMAT B- A list of California cities is presented with a single type of insolation or weather data. Any number of such pages can be included so that the same amount of data can be tabulated as with FORMAT A.

A graphical format is also presented in which insolation and/or weather data are shown on a monthly basis.

FORMAT C- Each page of the data manual would be devoted to a selected California city. A number of graphs of the type indicated (this is intended only as a possible sampling) could be included on each page.

A contour map format is presented.

FORMAT D- A number of contour maps would be prepared. Each such map would show the contours for selected insolation and/or weather data throughout the state. In some cases it will be necessary to present twelve contour maps (one for each month of the year) for given types of data.

TABULAR FORMAT A

COMBINED INSOLATION AND WEATHER DATA

Location: ANTIOCH Lat 38° 04′ Long 121° 49′ Elev. 25′

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Mean daily total insolation on a horizontal surface [langleys/day]	180	260										
min/max total insolation values [langleys/day]	155/240	205/320										
Mean daily direct beam insolation [kWh/m² · day]	2.3	3.1										
min/max direct beam insolation values [kWh/m² · day]	1.6/2.9	2.6/3.8										
Mean daily total insolation on sloped surfaces facing south [langleys/day]												
20° slope	205											
40° slope	246											
60° slope	252											
90° slope (verticle surface)	165											
Mean daytime temperature °F	48	50										
[°C]	[8.9]	[10.1]										
min/max daytime temperatures												
°F/°F	29/58	30/62										
[°C/°C]	[1.7/14.4]	[-1.1/16.7]										
Mean nighttime temperatures												
°F	36	40										
[°C]	[3.2]	[4.4]										
min/max nighttime temperatures												
°F/°F	20/51	25/66										
[°C/°C]	[− 6.7/10.6]	[−3.9]/18.9]										
Mean daytime wind speed												
miles/hour	8	6										
[meters/sec]	[3.8]	[2.9]										
Mean nighttime wind speed												
miles/hour	3	4.5										
[meters/sec]	[1.4]	[2.1]										

TABULAR FORMAT B

MEAN DAILY INSOLATION ON A HORIZONTAL SURFACE

(Direct + diffuse radiation)

Mean daily integrated intensities are tabulated for each month of the year in units of langleys = 1 cal/cm^2.

City	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Antioch												
Arcata												
Auburn												
* Bakersfield												
Barstow												
.												
.												
.												
** Davis												
Yosemite												
Yreka												
Yuba City												

** More than 5 years of insolation data recorded at this location.

* Fewer than 5 years of insolation data recorded at this location.

[no asterisk] interpolated values. No insolation data recorded.

TABULAR FORMAT B

MEAN DAILY INSOLATION ON A TILTED SURFACE

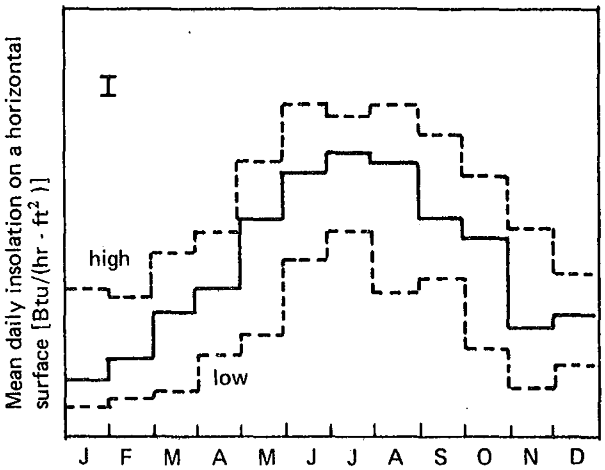
[Angle of tilt = Latitude + 10°]

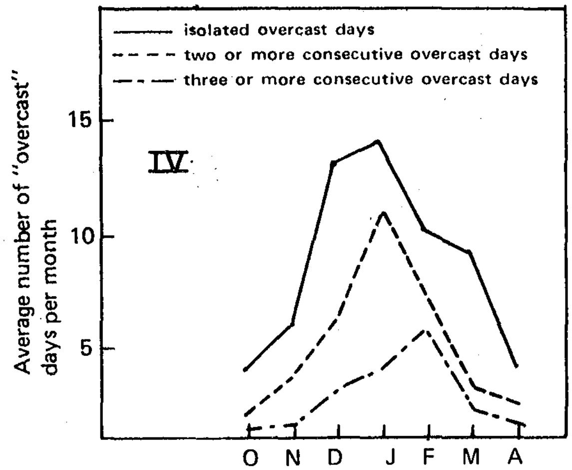
Mean daily integrated intensities are tabulated for each month of the year in units of Btu/(hr-sqft).

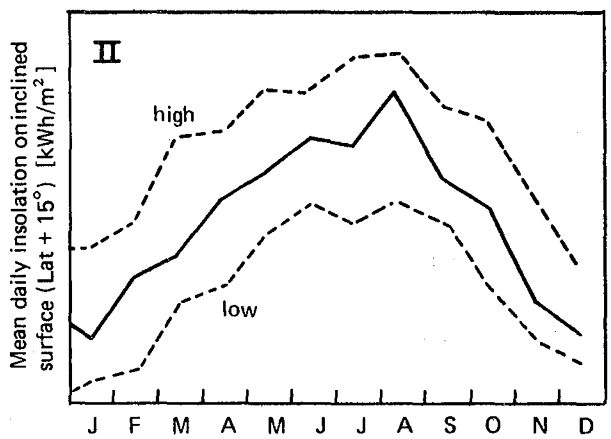
City	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Antioch												
Arcata												
Auburn												
Bakersfield												
Barstow												
.												
.												
.												
Yosemite												
Yreka												
Yuba City												

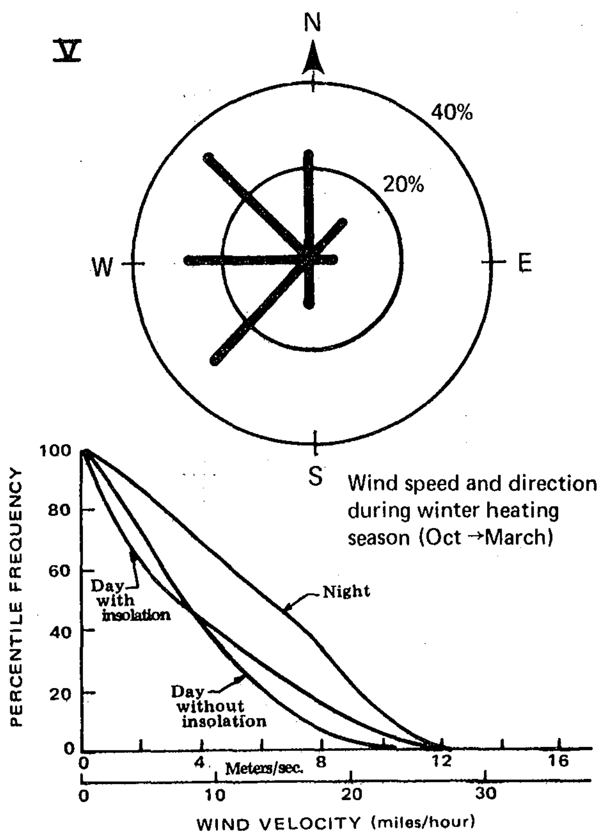
City: ANTIOCH
Lat: 38° 04′
Long: 121° 49′

FORMAT C

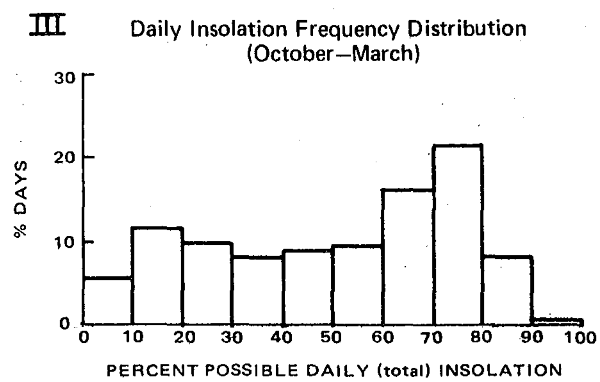






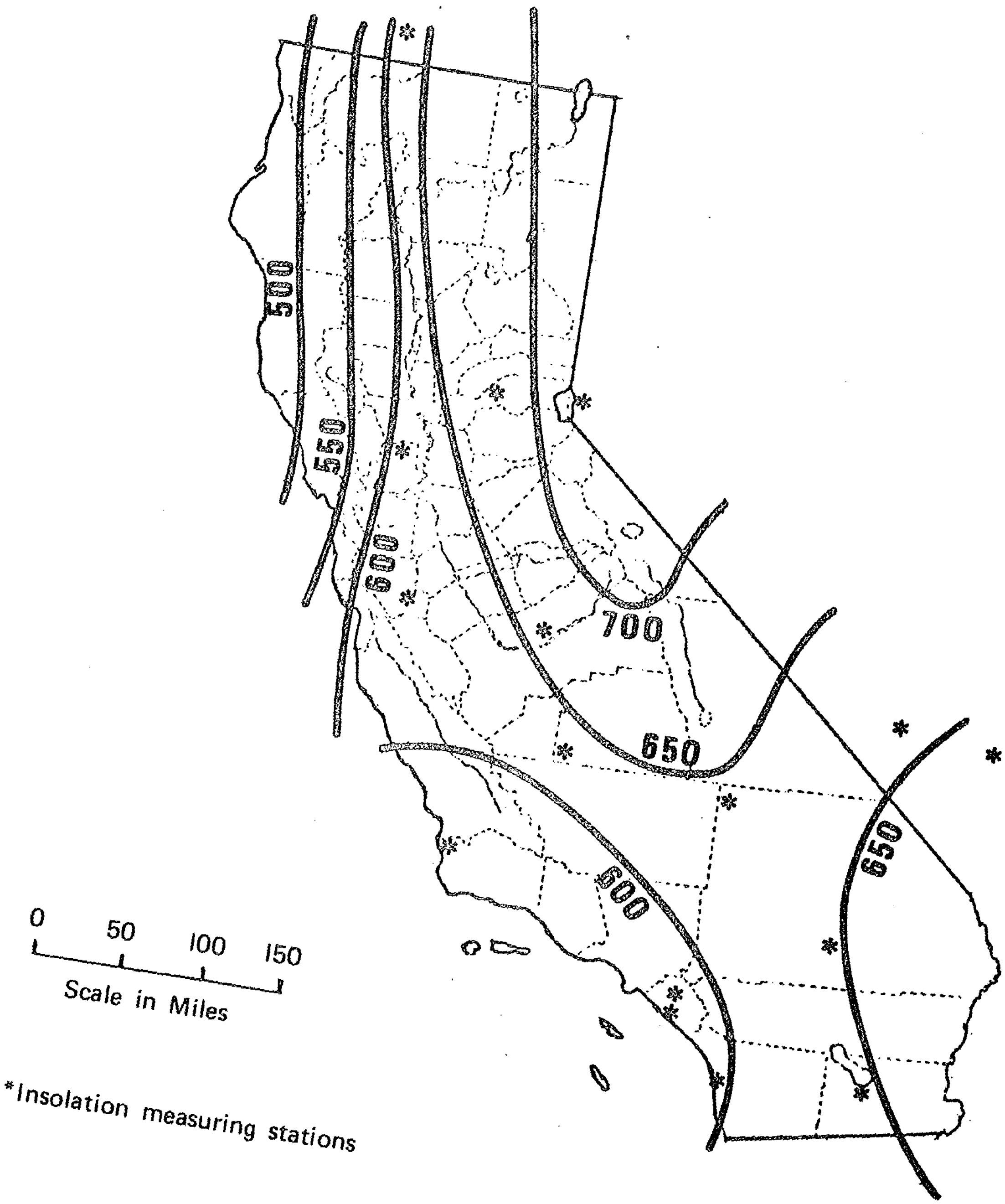


Wind speed and direction during winter heating season (Oct → March)



XBL 766-3069

FORMAT D



*Insolation measuring stations

Appendix C
EVALUATION OF THE SOLAR DATA USER QUESTIONNAIRE

INTRODUCTION

The solar data user questionnaire, which is reproduced in Appendix B, was sent to 300 potential solar data users throughout California. Fifteen detailed questions were posed regarding the desired content and format of data to be presented in the solar data manuals. Completed questionnaires were received from 152 individuals, which is a remarkably good response considering the detailed nature of the questions asked.

PURPOSE OF THE QUESTIONNAIRE

Questionnaire responses have been analyzed and used as an aid in determining: (a) the number of different solar data manuals to be prepared; (b) the content of each; (c) the formats most suitable for presenting various types of data; and (d) the user's view of data needs, to be used in a broader sense as one of the inputs in defining a future solar resource program for the state. The questionnaire is only one of several types of input to be weighed in making these decisions. Other inputs are: (a) direct user contacts; (b) inherent limitations on the available data; (c) analysis of accuracy required for different applications; and (d) our own experience with solar energy data requirements.

GENERAL SUMMARY OF QUESTIONNAIRE RESULTS

The immediate importance of the questionnaire results is related to the number, content, and formats of the solar data manuals. In the longer term, the results must be interpreted in terms of data needs for formulating a future solar data resource program for the state. With these considerations in mind, the responses to each question are interpreted below.

Questions 1 and 2. These are information items used to identify the occupation of each respondent and the applications for which the data would be used.

Questions 3 and 4. These were only to be answered by users who needed data at shorter than monthly time intervals: hourly, daily, daytime, or nighttime. Of all users responding to question 3, 21% requested daily horizontal insolation data, 10% requested daily direct-beam data, and 13% requested daily measurements of sunshine hours. None of the remaining choices for solar data was requested by more than 9% of the respondents. Requests for hourly solar data were made as follows: 27% wanted horizontal insolation data, 26% wanted direct beam data, 18% wanted diffuse insolation data, 13% requested insolation data on inclined surfaces, and 10% requested data on sunshine hours. None of the remaining choices for hourly solar data was requested by more than 9% of the respondents.

Question 4 polled users on their need for weather data on an hourly or daily basis. Daily values were requested by few respondents (none of the items was chosen by more than 7% of the sampling). On the other hand, daytime and nighttime values for dry-bulb temperature were requested by 13% of the respondents, and 12% requested daytime cloud cover data. None of the remaining data selections presented as daytime and nighttime values was requested by more than 9% of the respondents.

Hourly weather data were requested by a greater fraction of the respondents than were daily data. Hourly dry-bulb temperature readings were requested by 33% of the sampling, wet-bulb temperature by 23%, wind speed by 21%, hourly cloud cover by 16%, and wind direction, relative humidity, and dew point data were requested by slightly more than 10%. In short, all the hourly weather data choices were requested by a significant fraction of the polled sample.

Questions 5 and 7. These are the critical two questions that treat the contents of the solar data manuals. The responses to these questions have been studied in the greatest detail and are evaluated separately in the following sections in terms of user occupation and application categories.

Question 6. This question included 13 detailed items querying the desirability of solar radiation data at various tilt angles and facing different azimuthal directions. Although many individuals responded to this question, the responses were so spread out among the various angle choices offered that no obvious conclusions could be reached on specific items. However, the overall response was sufficient to indicate that some types of tilted data should be included, even if the relative desirability of the alternatives could not be distinguished from this questionnaire.

Question 8. The responses to this question demonstrated an overwhelming desire for the use of English units (Btu/sq ft). However, the issue of units involves policy decisions by DOE and the California Energy Commission; both English and metric units will be included in the data manuals.

Question 9. The responses here clearly indicated that line graphs are preferred over bar graphs, and that high/low limits should be included.

Question 10. This question asked if any specific types of statistical distributions were desired. Most requests were for data on frequency distribution of daily total insolation on a horizontal surface and frequency distributions for strings of consecutive cloudy days. One or two requests were made for each of the following items: statistical distribution of instantaneous insolation; cloud frequency and duration statistics; dew-point temperature statistics; detailed wind-speed and velocity statistics; and probability of high winds, dust storms, and rain/hail storms.

Question 11. There was almost uniform agreement that the data published should be the average monthly insolation values, with minimum/maximum limits rather than the actual year-by-year data. Much interest was expressed in some type of interpolation method for providing solar data at locations other than those at which the data are taken. Respondents preferred that specific values be given for these locations rather than just contour plots. This is consistent with the decision to present the data by climate zone.

Question 12. There was almost unanimous preference for the presentation of the data in tabular format A, which corresponds to listing all the various solar and meteorological parameters together for a single location. This is very similar to the climate-zone type of presentation and provides support for the adoption of that approach.

Question 13. Approximately 42% of the respondents expressed no preference for the size of a solar data manual; 14% felt a manual should be less than 50 pages in length; 23% favored a manual between 50 and 100 pages; and 16% favored 100 to 250 pages.

Question 14. The preferred pricing of a solar data manual was expressed as follows: 11% felt such a manual should be free; 34% favored a price between $1 and $5; and 34% preferred a cost between $5 and $20. Two percent even favored having the manual cost more than $50!

Question 15. This question asked if the respondent was interested in being consulted again for further input to the solar data manual formats. More than 85% of the respondents were agreeable to this, which is another indication of the high level of interest in obtaining reliable solar data.

CONCLUSIONS

The conclusions arrived at from the evaluation of the questionnaire are as follows:

1. There is a significant need for virtually every type of data that was included in the questionnaire. Therefore, an attempt should be made to provide all the data types listed in Table C-4.
2. Only a single solar data manual can be justified at this time. It should contain all of the data types in Table C-4 for which data are presently available.
3. If possible, the data manual should include calculated solar radiation data for tilted surfaces. Since no specific angles were preferred, the tabulation should be complete enough that any user-selected angle would be bounded by tabulated ones, allowing a linear interpolation by eye without appreciable error.
4. There is a need for hourly solar radiation data and weather data, which should be taken into account in future data planning for California.

5. English units (Btu/sq ft) are preferred, overwhelmingly.
6. The preferred formats for average monthly data presentation are consistent with the climate-zone approach.

DETAILED ANALYSIS OF THE QUESTIONNAIRE

Methodology

The simplest form of analysis is a listing of the total number of responses given by each question. It is felt that this is inadequate in the present case since no attempt was made to obtain responses from a proportional sampling of the various user occupations. It would have been very difficult to decide on a meaningful set of factors for proportionally weighting the responses from builders, consultants, agronomists, and others. Therefore, it was decided to correlate the responses to specific questions with the occupation of the user and the range of applications of interest.

User/Application Matrices

A user/application matrix is constructed in which each element, N_{ij}, represents the total number of respondents classified under the i^{th} user occupation and the j^{th} application type. Figure C-1 is the user/application matrix constructed for the 152 responses to the Solar Data User Questionnaire. Such a matrix is not "orthogonal" since respondents were encouraged to check more than one category of activity where applicable. (Therefore, the sum over a row or a column of the matrix thus does not equal the number of respondents.) This matrix merely furnishes a "profile" correlating the types of user occupations with the types of applications. A weighted user/application matrix is constructed for each question, as will be described below.

Question Matrices

Each question having qualitative responses is analyzed using a similar user/application matrix format. Weight factors are assigned to each of the four response choices provided. Two different sets of weight factors

	residential space heat	industrial space heat	domestic hot water	process heat	air conditioning	passive systems	agricultural drying/dehydration	crop growth	siting solar electric plants	designing solar electric plants	utility impact	photovoltaics	biomass conversion	other
Agricultural Engineer	6	6	5	6	4	5	6	3	2	3	3	3	4	4
Agronomist	0	0	0	0	0	0	0	6	1	0	0	0	2	4
Architect	18	18	17	9	12	19	3	0	2	2	3	2	3	3
Banker	1	1	1	0	2	1	0	0	0	0	0	0	0	1
Builder	11	6	10	1	9	8	1	1	1	1	2	2	2	2
Consultant	43	43	40	35	31	36	20	3	13	12	15	5	6	12
Developer	5	4	5	1	6	4	0	1	2	1	1	1	1	2
Government Agency	4	2	4	0	3	2	0	0	1	0	0	1	0	5
Engineer	51	48	51	41	43	35	23	4	17	19	17	11	7	17
Equipment Mfgr.	20	19	20	17	19	10	10	2	5	7	6	2	3	8
Owner	17	11	13	7	12	11	4	1	2	3	4	2	1	8
Planner	5	5	5	3	5	4	2	3	7	6	5	3	4	5
Research	36	34	32	34	25	27	21	12	13	16	14	12	9	26
Other	27	20	25	15	18	23	9	5	9	9	7	8	2	6

Figure C-1. Number of responses to questions 1 and 2 of the Solar Data User Questionnaire, by user occupation and application. Screened areas indicate $N_{ij} \geqq 5$.

are used to determine if the conclusions reflect the respondents' views. The following two sets of weight factors have been selected for analyzing these questions in order to determine the desirability of including specific types of data.

Response	Weight Factors Set 1	Weight Factors Set 2
necessary	3	5
useful	1	2
unnecessary	-3	-2
no opinion	0	0

In the questionnaire, only questions 5, 6, 7, 8, 9, 11, and 12 are answered using these four response choices. These are the main questions concerned with user requests relevant to the data manuals. Each response to one of these questions is thus represented by an integer, s, where $s \epsilon \{A,B,C,D\}$. A user/application matrix is formed in which each element is initially set to $M_{ij} = 0$. The appropriate integer, s, is added to each element, M_{ij}, of the matrix for which i is one of the user occupation categories and j is one of the application categories selected by the respondent. The summation process is represented for each response to the question. Each matrix element is then normalized by dividing M_{ij} by the value for N_{ij} obtained earlier. This number is multiplied by the factor (10/A) where A is the largest of the weight factors; that is, A = 3 in the example of Set 1. The resulting number is truncated to an integer equal to or less than 9. This integer represents the weighted response to the question under consideration and the matrix format permits correlation with user occupation and application.

This weighted response should be evaluated with the total number of user/application respondents, N_{ij}, for each user/application pair. In this way both the weighted response and the absolute number of responses are taken into consideration. Five or more respondents within one user/application category (N_{ij}) are considered to constitute a meaningful sampling. Only the elements M_{ij} of the question matrices for which the associated

$N_{ij} \geqq 5$ are included in the summations described below. The screened areas of the user/application matrix shown in Figure C-1 indicate user/application pairs for which meaningful samplings were obtained according to this criterion.

Application Categories

The questionnaire identifies 14 user occupations and 14 applications of solar radiation data. The 14 applications can be further grouped under five general categories:

A) Heating and Cooling Applications
   a) residential space-heating systems
   b) industrial or commercial space-heating systems
   c) domestic water-heating systems
   d) industrial process heat systems
   e) solar air-conditioning systems
   f) passive solar heating and cooling systems
B) Agricultural Applications
   g) agricultural drying and dehydrating systems
   h) prediction of crop growth and/or maturity
C) Solar Electric Applications
   i) siting of solar electric power plants
   j) design of solar electric power plants
   k) predicting solar impact on utility companies
D) Photovoltaic Conversion
E) Biomass Conversion

The user/application matrix in Figure C-1 can be presented in terms of these five application categories as shown in Figure C-2. Here the rows corresponding to user occupations have been transposed to better illustrate the correlations between user occupations and their application interests. The numerical values shown in Figure C-1 have been replaced by shading where $N_{ij} \geqq 5$.

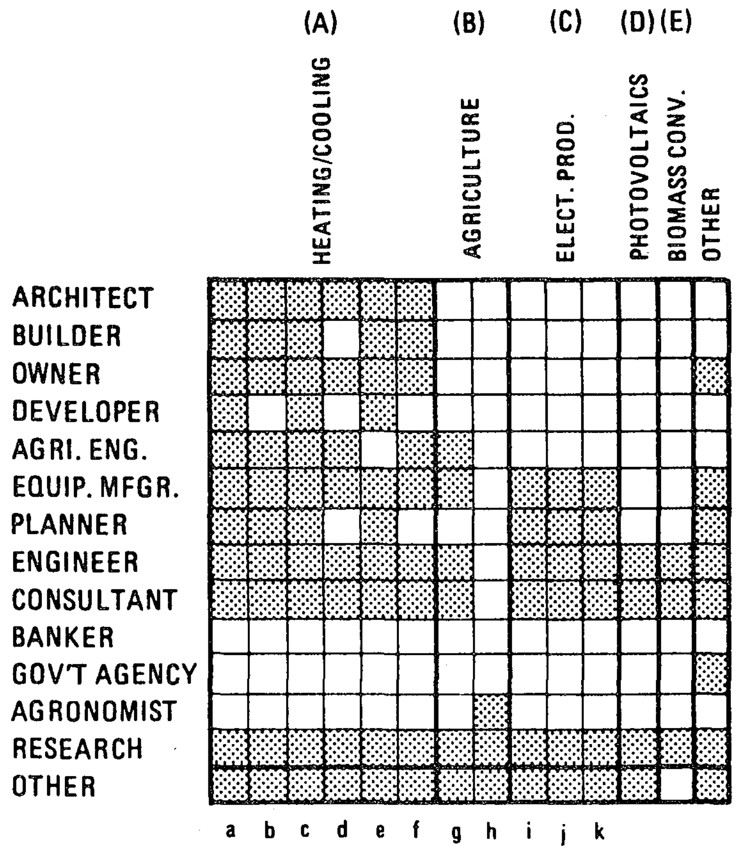


Figure C-2. User/application matrix. Shading indicates $N_{ij} \geqq 5$.

Several points should be noted with regard to this matrix:

1. The "research" category of users includes individuals interested in all types of solar applications.
2. The users identified as "banker" and "employee of a government regulatory agency" did not respond in sufficient numbers to be included in the subsequent analysis.
3. "Agronomists" are interested almost exclusively in predicting crop growth and maturity.
4. The remainder of the users separate into rather distinct groups with regard to application categories (A) through (E). Accordingly, these five generalized categories were used for the subsequent analysis of the questionnaire results.

Response Analysis by Application Category

Each question that can be answered in terms of "necessary, useful, unnecessary, or no opinion" is analyzed by forming the weighted sum of responses in each user/application category. The sum for each category (A) through (E) is then divided by the number of significant responses, which is determined by the number of user/application groups for which $N_{ij} \geqq 5$. The numbers of these responses are: A, 53; B, 7; C, 15; D, 3; and E, 3.

The resulting normalized index value gives an indication of the relative desirability of including various types of data in the solar data manuals for each application category. Each question is analyzed in this manner and the index values are presented in Table C-1. This table can be used to determine the types of data needed by the respondents in each application category. The weighting factors used here are Set 1.

One possible objection to such a criterion is that a certain type of data might be requested by a small number of respondents from each application category, but the total number of such requests might be significant. Data of this type probably ought to be included in the data manuals for each application category. The following section describes a second type of analysis designed to overcome this shortcoming.

Table C-1. Normalized index values of the desirability of data types from the Solar Data User Questionnaire, by application.*

Data Type (Question & Part)		Application† (A)	(B)	(C)	(D)	(E)
5	1	6.8	6.7	6.1	9.0	6.0
	2	0.5	-	-	1.7	-
	3	1.2	3.0	5.1	5.7	-
	4	1.2	0.9	1.1	-	-
	5	-	-	-	-	-
	6	-	-	-	-	-
	7	1.6	0.7	1.7	2.3	7.0
	8	1.3	-	-	2.3	2.0
6	X	All the responses to question 6 are so low that they are not included in this table.				
7	1	2.2	2.7	5.1	1.7	7.0
	2	0.9	-	0.3	-	-
	3	0.4	-	-	-	-
	4	4.5	5.3	4.1	3.3	6.3
	5	0.2	0.7	0.7	-	-
	6	0.4	-	1.4	-	-
	7	0.2	-	1.1	-	-
	8	3.4	4.3	4.3	2.0	6.7
	9	0.1	0.7	-	-	-
	10	0.1	-	0.3	-	-
	11	0.1	-	-	-	-
	12	0.1	-	-	-	-
	13	2.9	0.7	-	-	3.3
	14	5.8	1.7	2.9	5.3	6.3
	15	5.0	1.7	2.9	5.3	6.3
	16	0.7	-	-	-	-
	17	1.3	1.4	0.3	-	1.7
	18	1.0	2.1	-	1.7	3.7
	19	4.0	4.1	5.2	2.0	6.3
	20	0.7	-	0.3	-	1.7
	21	1.1	1.6	-	-	4.7
	22	7.1	6.6	5.2	4.3	7.7
	23	4.0	3.1	5.5	1.7	6.0
	24	1.1	1.4	0.5	-	-
	25	-	-	-	-	-

continued

Table C-1 cont.

Data Type (Question & Part)		Application† (A)	(B)	(C)	(D)	(E)
8	1	6.6	4.1	2.5	5.7	-
	2	-	0.9	-	-	-
	3	-	-	1.0	1.7	-
	4	-	-	-	-	-
	5	-	-	-	-	-
9	1	-	-	-	-	-
	2	0.3	1.6	-	-	6.0
	3	1.5	1.4	1.1	3.7	1.7
11	1	-	-	-	-	-
	2	6.5	6.1	6.7	4.7	6.0
	3	4.2	2.6	0.3	-	-
	4	0.5	3.1	-	-	3.3
	5	2.6	2.9	1.7	5.3	1.7
12	1	5.1	3.4	3.6	4.3	-
	2	0.6	0.7	-	-	-
	3	0.5	1.6	-	-	-

*Weighting factors used are Set 1.

†Application categories are:

A, heating and cooling;

B, agricultural;

C, solar electric;

D, photovoltaic conversion; and

E, biomass conversion.

Weighted Total Response Analysis

The total number of responses to each question is tabulated by computer for each possible choice presented. These values are then multiplied by the two sets of weight factors used for evaluating the question matrices. The results of this procedure are presented graphically in Figure C-3. It should be noted that the scale factor is different for each set of weights, but that once this scale factor has been chosen no further adjustments are made.

The advantages of this procedure are as follows.

1. It permits visual inspection of the range of results obtained for each question in order to determine if significant qualitative changes result from changing the set of weight factors.

2. It permits the total response to be evaluated for each question in order to complement the response by application category, as described above.

Response Analysis by User Occupation

A normalized index, indicating the relative desirability of including various types of data in the solar data manuals, was computed from the responses to each question by each user occupation category. The number of significant responses (for which $N_{ij} \geqq 5$) used to normalize the index for each user occupation category follows.

(a) agricultural engineer, 6
(b) architect, 6
(c) builder, 5
(d) consultant, 12
(e) developer, 3
(f) engineer, 12
(g) equipment manufacturer, 10

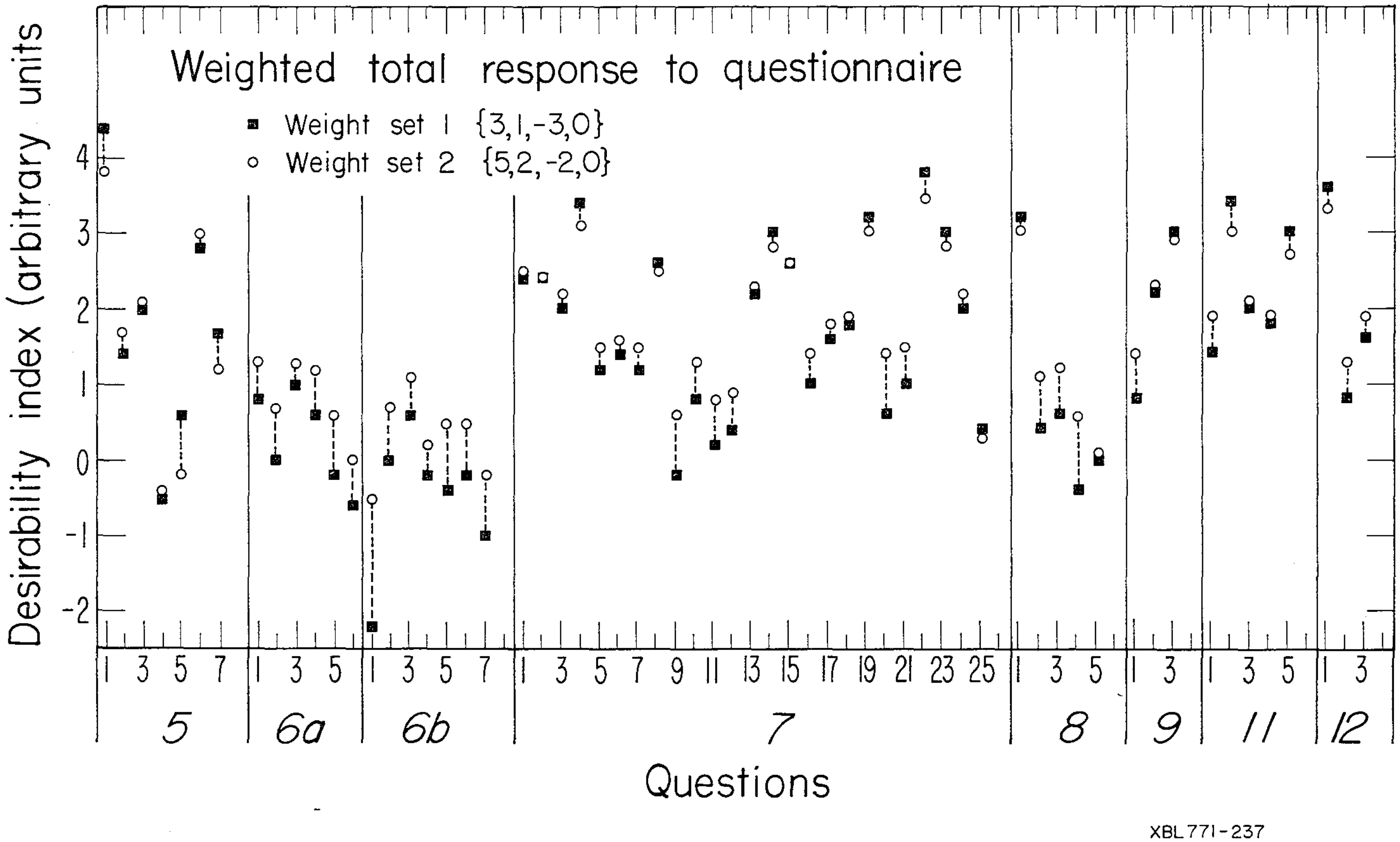


Figure C-3. Weighted total response to Solar Data User Questionnaire.

(h) owner, 6

(i) planner, 7

Each question is analyzed in this manner and the indices calculated are presented in Table C-2. This table, together with Table C-1, which performs a similar analysis by application categories, enables data groupings of common interest to be ascertained on the basis of user occupation categories. Set 1 weighting factors are used in constructing both Tables 1 and 2. Tables generated using the Set 2 weighting factors result in slightly different numerical entries, but the trends and conclusions are the same.

ANALYSIS OF QUESTIONS 5 AND 7

A detailed breakdown of the desirability of including specific types of solar and weather data (questions 5 and 7) in one or more solar data manuals is presented in the following two sections, first by application and then by user occupation. One of the main purposes for such a breakdown is to determine whether a need exists for more than one type of data manual, and if so, how many and to which user/application groups they should be directed.

Data Requested by Application

The indices appearing in Table C-1 for the five application categories (A) through (E) are presented in a more tractable form by specifying a minimum cutoff level for the index values. All index values that are equal to or greater than this cutoff value (selected to be 1.0) are interpreted as a positive request to include the type of data addressed by the question. A new table (Table C-3) is then constructed in which a plus sign denotes such a positive request. The entries are tabulated in a sequence starting with data that are requested for only a single application.

Table C-3 shows that the first five data items are requested for all five application categories, and should be included in any data manuals assembled. The next four items are each requested for four out of the five applications. Categories (A), (C), and (E) require all of these items, and categories (B) and (D) require only two of these items each. It may

Table C-2. Normalized index values of the desirability of data types from the Solar Data User Questionaire, by user occupation.*

Data Type		Occupation†								
(Question & Part)		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
5	1	6.2	8.3	4.4	8.3	6.3	7.1	6.5	6.0	6.0
	2		-	1.0	0.4	7.0	-	-	-	-
	3	2.7	-	-	1.8	1.7	2.8	4.6	-	3.7
	4	3.7	-	-	0.9	-	-	3.7	1.7	-
	5	-	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-	-
	7	4.2	-	6.8	1.0	3.7	2.9	0.6	-	0.7
	8	-	0.8	5.0	1.1	5.0	-	-	-	2.6
6	X	All the responses to question 6 are so low that they are not included in this table.								
7	1	7.7	5.0	1.0	2.3	-	2.3	1.2	1.7	4.1
	2	-	3.7	2.0	-	-	0.4	1.5	-	-
	3	-	3.7	-	-	-	-	-	-	-
	4	7.7	7.0	6.2	5.4	5.7	4.0	1.6	3.7	8.0
	5	-	-	-	-	-	-	-	-	3.1
	6	-	-	2.0	-	-	0.8	-	-	3.3
	7	-	-	-	-	-	0.4	-	-	3.3
	8	6.0	5.5	4.4	0.9	5.7	3.1	3.5	6.8	6.4
	9	1.7	-	-	-	-	-	-	-	-
	10	1.0	-	-	-	-	-	-	-	0.7
	11	-	-	-	-	-	-	-	0.8	-
	12	-	-	-	-	-	-	-	0.8	-
	13	1.7	1.7	6.6	-	7.7	1.3	0.5	5.7	3.9
	14	7.0	5.0	7.4	5.3	5.7	4.3	4.6	3.7	5.7
	15	5.5	4.7	6.6	4.7	5.7	4.0	4.6	1.7	5.7
	16	1.7	-	-	-	-	-	-	-	3.7
	17	4.7	-	-	-	-	0.8	0.6	0.8	4.6
	18	4.0	1.7	-	0.8	-	0.5	-	4.3	-
	19	0.8	3.5	6.6	2.3	3.3	6.3	6.4	6.8	6.4
	20	-	-	2.4	-	-	-	1.2	2.8	-
	21	6.3	-	5.4	-	-	0.5	-	-	-
	22	8.2	7.0	7.4	5.5	6.7	6.9	8.1	7.3	7.4
	23	5.7	6.0	7.4	4.3	3.3	3.1	5.6	7.3	6.4
	24	2.7	-	3.6	-	-	-	1.2	4.5	-
	25	-	-	-	-	-	-	-	-	-

continued

Table C-2 cont.

Data Type (Question & Part)		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
		Occupation†								
8	1	7.5	6.8	7.2	5.8	6.7	4.4	3.9	6.7	5.0
	2	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	0.4	-	-	0.7
	4	-	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-	-
9	1	-	-	-	-	-	-	-	-	-
	2	-	-	-	0.6	5.0	0.4	-	-	-
	3	-	0.8	7.6	0.5	3.7	1.7	0.5	1.7	1.7
10	1	-	-	-	-	-	-	-	-	-
	2	8.8	5.5	4.8	6.5	1.7	6.9	6.4	8.5	7.3
	3	6.8	4.5	6.2	0.8	6.0	1.7	4.9	5.3	2.0
	4	5.0	-	-	-	-	0.8	0.7	-	-
	5	2.7	3.3	5.2	0.9	6.3	2.1	1.0	5.8	2.4
12	1	3.0	7.0	6.2	5.3	8.0	4.9	3.9	3.0	0.7
	2	6.0	-	-	-	-	-	-	-	-
	3	1.8	-	-	-	5.0	-	0.5	-	-

*Weighting factors used are Set 1.

†Occupation categories are:

a, agricultural engineer;

b, architect,

c, builder;

d, consultant;

e, developer,

f, engineer;

g, equipment manufacturer;

h, owner; and

i, planner.

Table C-3. Data requested by application type.

Question No.	Data Item*	Application Type† (A)	(B)	(C)	(D)	(E)
(5-1)	to horizontal insolation	+	+	+	+	+
(7-4)	min/max temperature	+	+	+	+	+
(7-8)	daily temperature profiles	+	+	+	+	+
(7-19)	daytime cloud cover	+	+	+	+	+
(7-22)	daytime wind speed	+	+	+	+	+
(7-1)	dry bulb temp. (24 hr. avg.)	+	+	+	0	+
(7-14)	heating degree days	+	0	+	+	+
(7-15)	cooling degree days	+	0	+	+	+
(7-23)	nighttime wind speed	+	+	+	0	+
(5-3)	direct beam insolation	0	+	+	+	0
(7-17)	nighttime sky temperature	+	+	0	0	+
(5-8)	sun charts	0	0	0	+	+
(7-13)	freeze probability	+	0	0	0	+
(7-18)	ground temperature	0	+	0	0	+
(5-7)	sunshine hours	0	0	0	+	+
(7-24	wind direction distribution	+	+	0	0	0
(5-4)	diffuse insolation	+	0	+	0	0
(7-21)	rainfall	0	0	0	0	+
(5-2)	total insolation, vertical surface	0	0	0	+	0
(7-20)	nighttime cloud cover	0	0	0	0	+
(7-6)	daytime wet bulb temp.	0	0	+	0	0
(7-7)	nighttime wet bulb temp.	0	0	+	0	0

*Items in this table are arranged in order of decreasing desirability based on the demand by different numbers of application types.

†Application categories are defined in Table C-1. A plus sign signifies that the corresponding index value from Table C-1 is in excess of the cutoff value 1.0.

then be argued that the basic information to be included in all versions of the data manuals should consist of the first nine data items listed in Table C-3.

The remaining six data types are requested for one to three of the applications. Since the first nine items would presumably be reprinted in each of the versions of the data manual, the responses to these last six questions will be helpful in determining the number of separate manuals to be prepared for different types of solar applications. Direct-beam insolation data are requested for applications (B), (C), and (D), whereas all the remaining types of data are requested for only one or two applications. On the other hand, for category (E), biomass conversion, all the listed data are requested except direct-beam radiation. This is significant since it means that it would be necessary to produce at least one data manual containing all the data specified in Table C-3, with the exception of direct-beam radiation. Individuals in the other application categories could thus satisfy almost all their data requirements by referring to this one manual.

Justification for producing more than one solar data manual thus depends on the expense and difficulty of incorporating one additional type of data (direct-beam radiation) in a manual designed to otherwise satisfy the requirements of application (E). Inclusion of direct-beam radiation would amount to the addition of only one or two rows of data for each location in addition to all the other data listed in Table C-3.

Thus it seems sensible to add this one data type to the manual for category (E), producing one data manual that will satisfy all the application categories.

In the following section this question is considered with respect to desirability of multiple manuals broken down by the type of user.

Data Requested by User Occupation

A procedure similar to the one described above for application categories has been followed for the analysis by user occupation. In this case an index value in Table C-2 above the cutoff value is interpreted as a positive request (again taking the cutoff index value to be 1.0) to include that type of data in the manuals. The results of this procedure are presented in Table C-4, which is the analog of Table C-3.

Table C-4 shows that the first 4 of the 26 data items are requested by all nine types of users, and should thus be included in all data manuals. The next four times are requested by eight types of users, and can thus reasonably be included in the basic data to be published in each of the possible user-oriented solar data manuals. The 18 remaining data items form the basis for deciding whether to publish one or more solar data manuals based on user occupation categories.

A study was made to see if the user occupation categories could be grouped in a sensible way leading to two or three solar data manuals with different contents. Three types of users (a, c, and i in Table C-4) requested 8 or 9 of the remaining 18 types of data. Since there was little overlap among these requirements, three separate solar data manuals would be required. However, none of these three manuals would satisfy the needs of user categories (b), (e), or (h).

It was felt that a difference of one or two data items among groups of requested items would not be sufficient to justify separate manuals. Also, it was realized at the time of the questionnaire evaluation that certain types of data would simply not be available for inclusion in the first data manuals--such as ground temperature, daytime sky temperature, nighttime sky temperature, diffuse radiation, and nighttime cloud cover.

Accordingly, each of user categories (b), (e), and (h) could be satisfied by adding only one or two types of data to the data manual that satisfies category (c). At this point, the modified data manual for (c) would only differ by three types of data from the manual for (a), and only one of these types of data would be available for the manuals. Therefore, category (a) is satisfied by adding the one available type of data to the manual for (c). Likewise, this modified manual for (c) then satisfies the requirements for user category (i) except for three types of data, only one of which is available. Therefore, this one available data type should also be added to the manual for (c). The result is that a single data manual of reasonable size should satisfy the requirements of all the user categories in Table C-4.

Table C-4. Data requested by user category.

Question No.	Data Item*	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
		User Occupation Category†								
(5-1)	total horizontal insolation	+	+	+	+	+	+	+	+	+
(7-14)	heating degree days	+	+	+	+	+	+	+	+	+
(7-22)	daytime wind speed	+	+	+	+	+	+	+	+	+
(7-23)	nighttime wind speed	+	+	+	+	+	+	+	+	+
(7-4)	min/max temperature	+	+	+	+	+	+	0	+	+
(7-8)	daily temperature profiles	+	+	+	0	+	+	+	+	+
(7-15)	cooling degree days	+	+	+	+	+	+	+	0	+
(7-19)	daytime cloud cover	0	+	+	+	+	+	+	+	+
(7-1)	dry bulb temp (24 hr. avg.)	+	+	0	+	0	+	0	0	+
(5-3)	direct beam insolation	+	0	0	0	0	+	+	0	+
(5-7)	sunshine hours	+	0	+	0	+	+	0	0	0
(7-13)	freeze probability	0	0	+	0	+	0	0	+	+
(5-8)	sun charts	0	0	+	0	+	0	0	0	+
(7-24)	wind direction	+	0	+	0	0	0	0	+	0
(5-4)	diffuse radiation	+	0	0	0	0	0	+	0	0
(7-2)	dry bulb temp (daytime)	0	+	+	0	0	0	0	0	0
(7-6)	wet bulb temp (daytime)	0	0	+	0	0	0	0	0	+
(7-17)	nighttime sky temperature	+	0	0	0	0	0	0	0	+
(7-18)	ground temperature	+	0	0	0	0	0	0	+	0
(7-20)	nighttime cloud cover	0	0	+	0	0	0	0	+	0
(7-21)	rainfall	+	0	+	0	0	0	0	0	0
(5-2)	total vertical insolation	0	0	0	0	+	0	0	0	0
(7-3)	dry bulb temp (nighttime)	0	+	0	0	0	0	0	0	0
(7-5)	wet bulb temp (24 hr. avg.)	0	0	0	0	0	0	0	0	+
(7-7)	wet bulb temp (nighttime)	0	0	0	0	0	0	0	0	+
(7-16)	daytime sky temperature	0	0	0	0	0	0	0	0	+
(7-9)	absolute humidity profiles	+	0	0	0	0	0	0	0	0
(7-10)	relative humidity profiles	+	0	0	0	0	0	0	0	0

*Items in this table are arranged in order of decreasing desirability based on the demand by different numbers of user categories.

†Occupation categories are defined in Table C-2. A plus sign signifies that the corresponding index value from Table C-1 is in excess of the cutoff value 1.0.

Appendix D
REMARKS STIMULATED BY THE SOLAR DATA USER QUESTIONNAIRE

In addition to the formal, tabulated responses to the data questionnaire, many notes, letters, and telephone calls were received. Suggestions and remarks that were particularly thoughtful or often repeated are recorded here.

Several items of data were requested by from 3 to 20 people. A list of these requests follows.

1. Solar data for inclined surfaces facing southwest and southeast are requested, as well as for south-facing surfaces.
2. Often requested was hourly solar and weather data for "typical" days or typical-day profiles. (Although it is certainly generally understood what a typical day is, none of the respondents defined this term precisely.)
3. Many respondents requested frequency distributions of daily total radiation on a horizontal surface.
4. "String statistics" for sequences of cloudy (low-isolation) days were requested.
5. Respondents emphasized the need to show high/low limits for the data, number of years upon which averages were based, estimates of systematic data errors, and so forth. Thus, a substantial minority is concerned that they be given sufficient information to estimate the reliability of the data.
6. Even though sky temperature was listed on the questionnaire (question 7), several people emphasized that they needed this information to estimate radiative cooling effects.
7. Individuals who indicated that they needed hourly data (on questions 3 and 4) sometimes stated explicitly that the data were required only on a typical day.

Some of the ideas listed by only on or two people were as follows.

1. Suggestions regarding solar data.
   - Statistical distribution of instantaneous insolation values would be useful.
   - For high/low limits on graphs, a confidence level of 2-1/2% is typical.

- If a method is used for estimating insolation on an inclined surface, it would be useful to give formulas and a sample calculation in the data handbook.
- Cloud frequency and duration data were requested.
- Data should be exhibited to show the effects of smog.
- Clear-day values should be tabulated, with the insolation then expressed as a percentage of the clear-day values.
- Monthly insolation totals for each of 10 consecutive years would give an idea of the year-to-year fluctuations.
- Rather than sun charts, the formulae from which they are derived could be given.
- Sky brightness data are desired for daylighting applications.
- Mean hourly insolation data for the winter months are particularly useful in areas with extreme ground fog conditions.
- It would be useful to develop a graph or nomograph that permits the designer to vary both tilt and azimuth angles of an inclined surface and read off the daily average insolation.

2. Suggestions regarding nonsolar weather data.
   - Tabulate heating degree-days relative to a base of 55°F rather than the usual 65°F. This is relevant if the occupants are willing to wear sweaters. This procedure is also relevant for very well insulated houses for which the incidental heat is a larger fraction of the total heating load than for a poorly insolated house.
   - Statistical data regarding dew-point temperatures is desired.
   - Probability statistics for high winds, dust storms, and rain and hail storms are desired.
   - Low-temperature collectors, without glazing, have an efficiency which is highly dependent on wind speed. Detailed statistical data could be useful. Typical wind-speed profile might be sufficient.
   - Evaporation rates might be useful.

3. Suggestions for the solar data manuals not directly related to solar or other weather data.
   - In addition to a printed manual, computer tapes should be available with hourly data.
   - The price of the manual should be approximately the cost of printing it.
   - F. T. C. Bartels of Spectrolab commented, "It is my impression from my work in this field (photovoltaic production of electricity at remote sites) that the more experience a person has, the less detailed information he feels is required. I think this results primarily from the fact that experience develops an appreciation of the limited accuracy of the primary data available."
   - It would be useful to publish a guide to all the known solar data, describing sources and formats.
   - Metric units should be preferred to English units because the solar energy industry is in its infancy and we have a chance to avoid a changeover in the future.

Appendix E
EFFECTS OF SOLAR DATA ACCURACY ON THE PERFORMANCE AND ECONOMICS OF SOLAR ENERGY SYSTEMS

EFFECTS OF SOLAR DATA ACCURACY ON THE PERFORMANCE AND ECONOMICS OF SOLAR ENERGY SYSTEMS*

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ABSTRACT

The effects of designing solar systems using inaccurate solar radiation data have been examined. The primary effect is that the energy output of the solar system, and the corresponding cost of energy, will be proportionally greater or less than expected. The constant of proportionality between the fractional solar data error and the fractional output error ranges from 0.2 to 1.0 for the examples studied. A secondary effect is that the system cannot be optimized correctly with inaccurate values of solar input data. This effect leads to net increases in the cost of energy produced which amount to 2% in the worst case examined. Domestic space and water heating and solar thermal electric conversion are used as examples to illustrate the effects.

INTRODUCTION

The accuracy required for solar radiation data should be determined, at least partially, by the consequences resulting from the use of inaccurate data. In general, one strives to obtain data which are as accurate as possible. However, stringent data requirements lead to excessive costs for large numbers of sophisticated data stations. The goal of this paper is to delineate and quantify the effects of using inaccurate data; such analyses will assist in the formulation of goals for solar data accuracy.

The primary effect of inaccurate solar radiation data is that the net amount of energy to be produced over the lifetime of a system cannot be accurately predicted. One might think that uncertainties in net energy production would be identical percentage-wise to the uncertainties in the solar data, but this is not the case. For example, it will be shown that, for domestic heating systems of conventional solar design, the uncertainty in energy produced is only half the uncertainty in input solar radiation; i.e., $\pm$ 20% errors in input lead to $\pm$ 10% errors in output. This effect is a result of various non-linearities in the system, the most important of which is due to energy overflow from storage.

A secondary effect of using inaccurate solar data is more subtle than the primary effect, but leads directly to increased energy costs. This is in contrast with the primary effect which leads only to cost uncertainties. The secondary effect is a result of designing a solar system for optimal operation (minimum cost) using incorrect values of the solar radiation data. As a consequence of this "incorrect" design, net energy costs are increased by an amount proportional to the square of the error in the solar data.

In this paper dimensionless parameters α and β will be introduced to quantify primary and secondary effects, respectively. Specific values of these parameters will then be derived for domestic solar heating systems and for solar thermal power plants.

DERIVATION OF THE SENSITIVITY PARAMETER

1. General Considerations

From a systems point of view a solar system is an energy conditioning device which accepts input energy in the form of solar radiation and produces output energy in the form of useful heat, electricity, or some other form. From this point of view it is desirable to describe the sensitivity of output to input on purely general grounds, without reference to the specific details of each system.

Let E_s represent the annual average usable energy produced by a solar energy system, and let I be the annual average input insolation. The insolation I can be the radiation received by a horizontal surface, the direct normal radiation, or other relevant solar input. We want to examine the response of the system when the input is increased or decreased. We can denote the fractional change in the input by the symbol δ:

$$\delta = \Delta I/I. \tag{1}$$

This increment of the annual input should be understood to consist of a fixed fractional increase or decrease, independent of time of the day or year.

Next, the sensitivity parameter, α, which relates the change in output energy to the change in input insolation level, can be expressed as:

$$\alpha \equiv \frac{\Delta E_s/E_s}{\Delta I/I} \quad . \tag{2}$$

Or, equivalently, combining eqns (1) and (2), one obtains:

$$\frac{\Delta E_s}{E_s} = \alpha\delta \quad .$$

The annual output E_s, compared to the nominal output $E_{s,o}$ for $\delta = 0$ may be deduced from eqns (1) and (2):

$$E_s = E_{s,o}\ (1 + \alpha\delta). \qquad (3)$$

Equation (3) is just a series expansion for E_s in powers of δ, terminated after the first two terms.

For the purposes of this article, δ will represent the error in the incident solar radiation, and multiplication by the sensitivity parameter α will convert this to an error in the calculated value of the system output energy. For example, if $\alpha = 0.5$, and the original solar data used in the system design was 20% too high, the situation may be described by a change of -20% in the input ($\delta = -0.2$). In this case, eqn (3) shows that 10% less energy than anticipated will be produced or, equivalently, that the unit cost of solar energy (in this example) will be increased by 10% (assuming that the annual operating cost is independent of the amount of energy produced).

Before presenting values of α for different solar systems it is worthwhile to make some statements regarding the values which α can assume. The efficiency η of the solar system is given by the relation

$$E_s = \eta I, \qquad (4)$$

and hence with eqn (2) the sensitivity α can be written in the form

$$\alpha = 1 + \frac{\Delta\eta/\eta}{\Delta I/I} \quad . \tag{5}$$

Thus, to the extent that the efficiency is independent of the input power level I, α is equal to unity. If the efficiency decreases with I, α will be less than unity. This line of reasoning can be pursued a little further by writing the overall efficiency as the product of subsystem efficiencies,

$$\eta = \eta_1 \, \eta_2 \cdot \cdot \cdot \eta_N \tag{6}$$

and substituting in eqn (5):

$$\alpha = 1 + \sum_{i=1}^{N} \frac{\Delta\eta_i/\eta_i}{\Delta I/I} \quad . \tag{7}$$

This equation permits one, in principle, to compute α as a sum of of terms each of which refers primarily to a component subsystem. It will prove useful for the analysis of solar thermal electric conversion.

Another general observation regarding α is the following. Consider, for simplicity, a domestic heating system. If f_s, the fraction of the load provided by solar energy, is very large ($f_s \simeq 1$), much of the collected energy must be discarded. This is particularly true of the <u>incremental</u> heat available, if the insolation I is increased. Thus, from eqn (2), α is small because ΔE_s is small. More generally, one has

$$\alpha \rightarrow 0 \text{ as } f_s \rightarrow 1 \; . \tag{8}$$

This limit applies to systems in which unlimited amounts of "surplus" energy cannot be stored indefinitely.

2. Application to Domestic Space and Water Heating (DSWH)

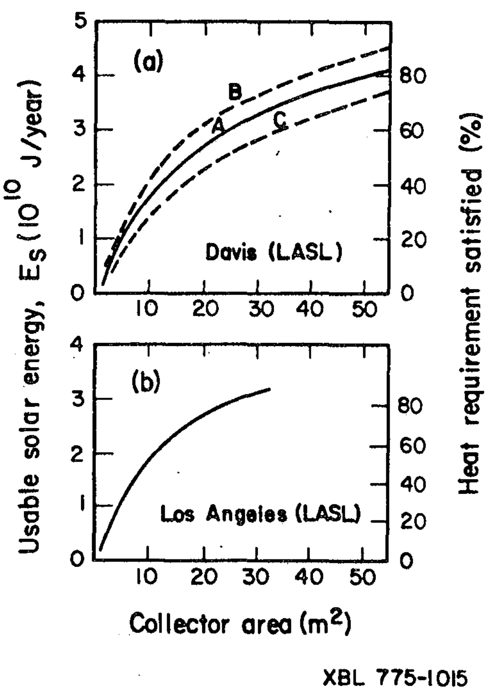
The method employed to estimate α for DSWH systems was to carry through standard design procedures to estimate the solar heat produced by systems of conventional solar design. Two California climates were considered (Davis and Los Angeles), and two design methods were employed. With each method and for each climate, the solar input was varied parametrically from its nominal value and α was computed from eqn (2).

The specific design techniques employed were those developed by J. D. Balcomb et al. at Los Alamos (the LASL simplified method [1]), and by C. Barnaby of the Berkeley Solar Group(BSG). The BSG method is based upon the "utilizability curve" approach originally discussed by Hottel and Whillier [2] and extended by Liu and Jordan [3].

Both procedures were used to analyze the performance of solar heating systems for a house of 138 m^2 (1500 ft^2) floor area and a heating load factor of 7.9 kWh per degree-day (Celsius)(15 kBtu per degree-day (Fahrenheit)). In the LASL method the collectors are tilted from the horizontal at an angle equal to the latitude +10°, whereas in the BSG program a fixed tilt angle of 45° was employed. For the present purposes, these differences are insignificant.

Figure 1 shows curves of usable solar energy E_s versus collector area as determined from the LASL method. The dashed curves in Fig. 1a display the values which are obtained when the solar data are varied from nominal values by $\pm$ 20%. Figure 2 gives more detail; it shows the differences ΔE_s. From

Figure 1. Plot of usable solar energy E_s as a function of collector area, using the LASL simplified design method. Curve A represents the actual (nominal) long-term system behavior. Curve B shows the output that would be obtained if the solar input were larger than nominal by 20% (δ = +0.2). Thus curve B also represents the output that would be predicted if the solar data were 20% too high. Curve C shows the output values for δ = -0.2.



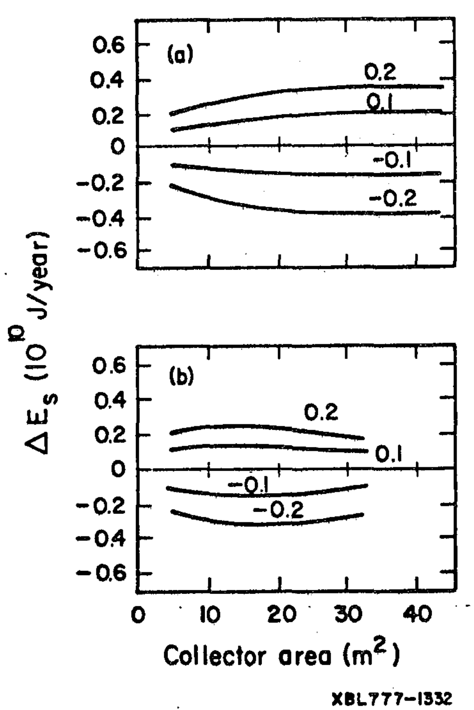


Figure 2. The difference in annual output ΔE_s as a function of collector area. The curves are labeled with corresponding values of δ, the error in the incident solar radiation.

these results it is possible to compute α using eqn (2). The results for α are plotted versus the solar heating fraction f_s in Fig. 3. This plot shows the results for two climates and for both the LASL and BSG computational methods. The simplified design methods are based on entirely different approaches so it is not surprising that there is considerable scatter in the values for α. Also, the methods cannot be expected to be accurate for values of f_s much outside of the range of 0.4 to 0.8. Nevertheless, the behavior $\alpha \to 0$ as $f_s \to 1$ is observed as anticipated by eqn (8).

Based on the results shown in Figure 3, it is concluded that, for domestic space and water heating in the climates studied, the sensitivity parameter is given by

$$\alpha = 0.5 \pm 0.2,$$

for values of f_s in the range of 0.4 to 0.8.

3. Application to Solar Thermal Electric Conversion (STEC)

Many of the important losses in a solar thermal electric conversion power plant are of a particularly simple type: they lead to component efficiences which are independent of the operating power level. Examples are losses due to tracking and aiming errors, shading of mirrors, shading of the receiver(s), and imperfect reflectivities. Each of these losses corresponds to an efficiency which is independent of input power and thus cannot contribute to α in eqn (7).

One type of loss which leads to a component efficiency depending on the operating power level is turbine efficiency. This efficiency is a function of the pressure and temperature of the working fluid, and hence could,

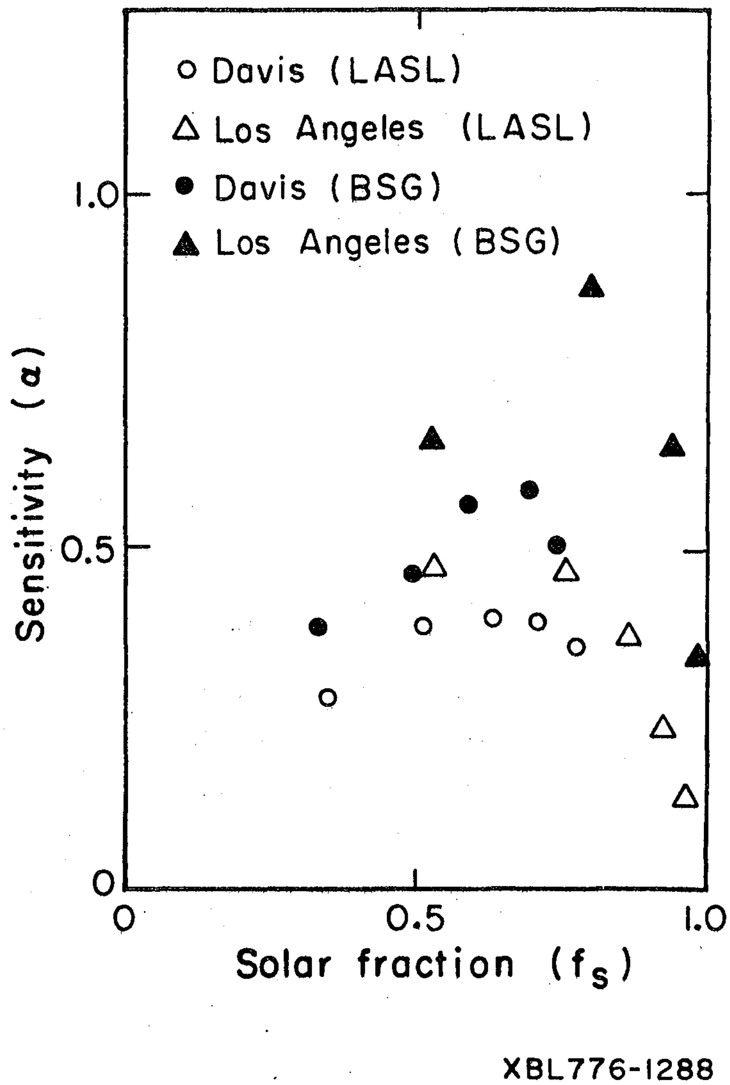


Figure 3: The sensitivity parameter α, plotted as a function of the solar heating fraction f_s, for the Davis and Los Angeles climate regions, using both the Los Alamos (LASL) and Berkeley Solar Group (BSG) design methods.

depending upon the details of power plant operation, vary with the input solar radiation level. On the other hand, the operating strategy of the power plant will likely include efforts to keep the turbine efficiency high (and therefore fairly constant), and those efforts would mitigate efficiency variations.

Other losses which depend on the input operating level are the heat wasted due to storage overflow (which will be small for a well-designed plant) and the receiver thermal losses. The corresponding efficiencies will vary only slowly with input power level and will not contribute significantly to eqn (7).

The conclusion of the foregoing discussion is that, for STEC power plants of "conventional" design, the sensitivity parameter is

$$\alpha \simeq 1.$$

One major proviso should be attached to this result. Since the marginal cost of producing power (from thermal energy already collected) is very small, it has been assumed that all electricity that the power plant can produce is effectively used. In the case of a utility operating an intermediate load solar power plant, the <u>effective</u> value of α can be much smaller because (economic) credit may not be given for energy produced in the absence of intermediate load demand. If this "unwanted" energy is not counted in the output, values of α can fall to the range of $\alpha \simeq 0.2$. Figure 4 shows a plot of change in effective power produced versus change in input solar radiation for a 100 MW_e intermediate load power plant of the central receiver type, with 6 hours of thermal storage. The Figure is adapted from results obtained by the Aerospace Corporation [4], and is constructed from those results by using the fact that, for the Aerospace model, fractional changes in the total heliostat area A cause the same changes in output

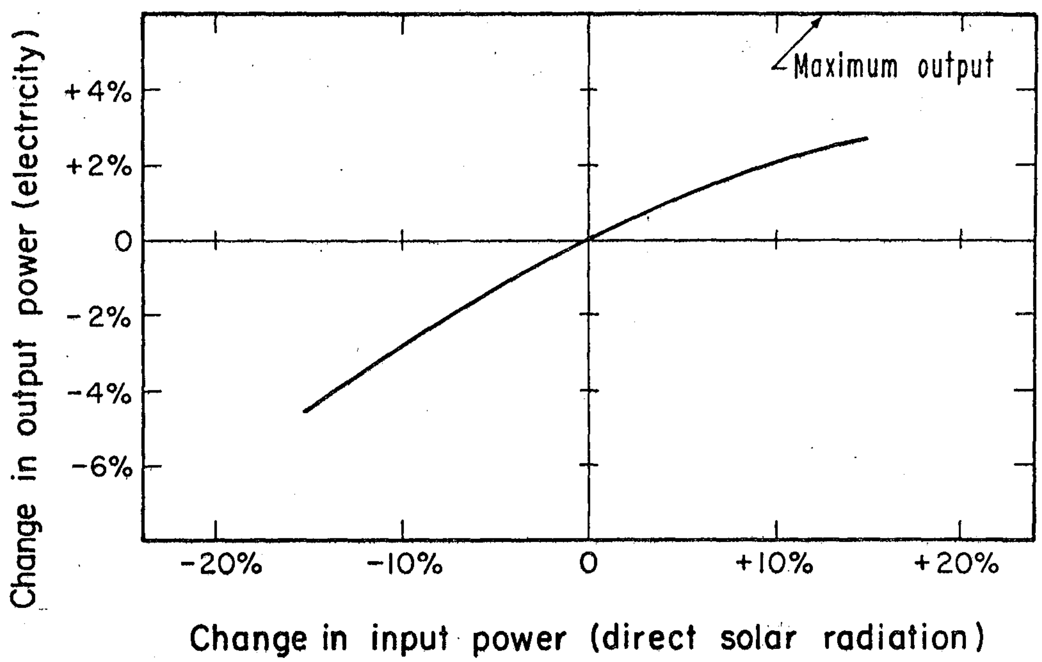


Figure 4: Percent change in effective power produced versus percent change in input radiation, for a particular power plant with $\alpha = 0.24$. The upper bound of 106% of nominal output power corresponds to the limit at which 100% of the demand for electricity is met.

as fractional changes in solar input energy. The slope of this graph gives:

$$\alpha_{eff} \simeq 0.24$$

for this power plant which meets 94% of its load ($f_s = 0.94$). The small value of α can be regarded as a consequence of the closeness of f_s to unity (cf. eqn (8)).

CONSEQUENCES OF THE USE OF INACCURATE DATA

The primary consequence of using inaccurate solar radiation data is the actual realization of an output energy level from the solar system that is different from that predicted (using inaccurate data) during the system design. The values of the sensitivity parameter α described above indicate the measure of the difference between expected and actual system output.

Economically, α can be interpreted as the fractional error in cost of energy produced by the solar system, as a result of the use of inaccurate solar radiation data. Thus for the DSWH system, the value of $\alpha \simeq 0.5$ indicates that a 20% error in solar data results in a 10% error in the unit cost of the heating energy produced by the solar system. For the STEC system, the range of values of α between 0.2 and 1.0 indicates that a 20% error in solar data would result in an error between 4% and 20% in the unit cost of the solar-generated electricity.

It should be noted that this effect is only an "apparent" cost penalty (or gain) associated with the solar-produced heat or electricity; i.e., this effect results in a difference between the expected and the actually achieved system output. This actual achieved system output will be essentially the same (see next section) as if the correct solar data had been used to design the system. However, this should not be interpreted as meaning the effect is unimportant. The perception of the expected system output is what is used in the decision-making process, when deciding whether to make the economic investment in the solar system. Use of inaccurate solar data might therefore produce an incorrect decision resulting in a substantial economic penalty from misapplication of capital.

There is a secondary consequence of using incorrect solar data. It is associated with systems that have been optimized using erroneous input solar data, thereby arriving at a non-optimum system design point. Although this effect is smaller in magnitude than the primary consequence discussed previously, this secondary effect results in a real cost penalty. It will be described separately for solar heating systems and solar electric systems in the following subsections.

1. Secondary Effect for Domestic Space and Water Heating (DSWH)

When a solar heating system is optimized using inaccurate solar data, the resulting cost of heating is always equal to or greater than the cost obtained if correct solar data had been used. This can be seen by referring to Figure 5. The Figure displays curves of annual heating cost vs. solar collector area near the minimum in the cost curve. By optimization of the solar system is meant selection of the system parameters so as to operate at this point of minimum cost. The solar collector area is a usual parameter used in the optimization calculation.

Suppose that a solar system were to be optimized using an erroneously high value of solar input data. Then the system would be optimized to

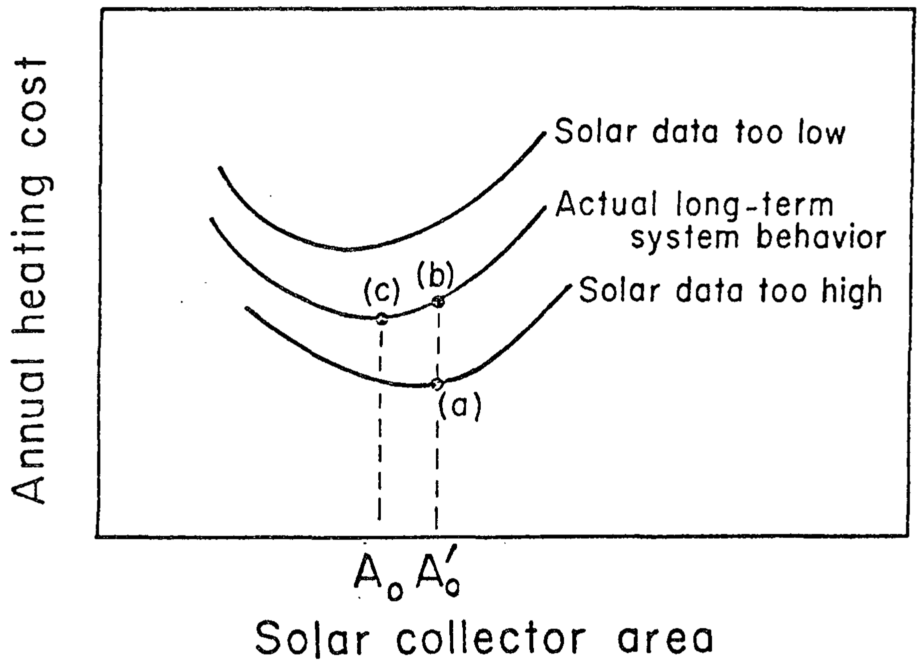


Figure 5: Illustration showing the "primary" and "secondary" effects discussed in the text. Solar data that is too high leads to a low prediction for the annual heating cost shown by (a) at a collector area A_o'. The actual performance of the system is at point (b), and the cost shift between these points is the primary effect. If the correct solar data had been available, the system would have been designed to operate at (c) with collector area A_o. The annual cost difference between (b) and (c) is the secondary effect.

point (a) in Figure 5, and a collector area A_o' would be selected. However, after the system were built, it would be observed to operate over a long period of time at point (b) instead of (a). If the system had been designed with knowledge of the correct solar data, it would have operated at point (c), the minimum for the true-data curve. The economic penalty associated with this effect is the annual difference in heating cost between points (b) and (c).

Two properties of this effect can be seen from Figure 5. First, the real cost using erroneous data is always equal to or higher than the real cost using correct solar data; i.e., the cost penalty is always positive (or zero). If the minima of the curves in Figure 5 were all in a vertical line, then the cost penalty would be zero. For all other cases, the cost penalty is positive. The second property is that the shape of the curves in Figure 5 near the optimum operating points is quadratic in nature. Thus the cost penalty for the use of inaccurate data is proportional to $(A_o' - A_o)^2$. Since the error in collector area $(A_o' - A_o)$ is caused by the solar data error ΔI, these errors can be shown to be proportional to one another. Consequently, the design cost penalty is proportional to $(\Delta I)^2$, and the annual cost of energy C is related to the cost C_o relevant to "perfect" solar data by the relation

$$C = C_o\ (1 + \beta\ \delta^2), \tag{9}$$

where $\delta = \Delta I/I$ and $\beta = \geq 0$ is a dimensionless number.

The methods used previously to estimate α for DSHW have also been used to estimate β. Figure 6 shows some of the optimization curves obtained for DSHW systems for the Davis and Los Angeles locations. Assumptions used to obtain the annual heating cost were: (i) Solar system cost, \$1,000 plus \$100 per square meter

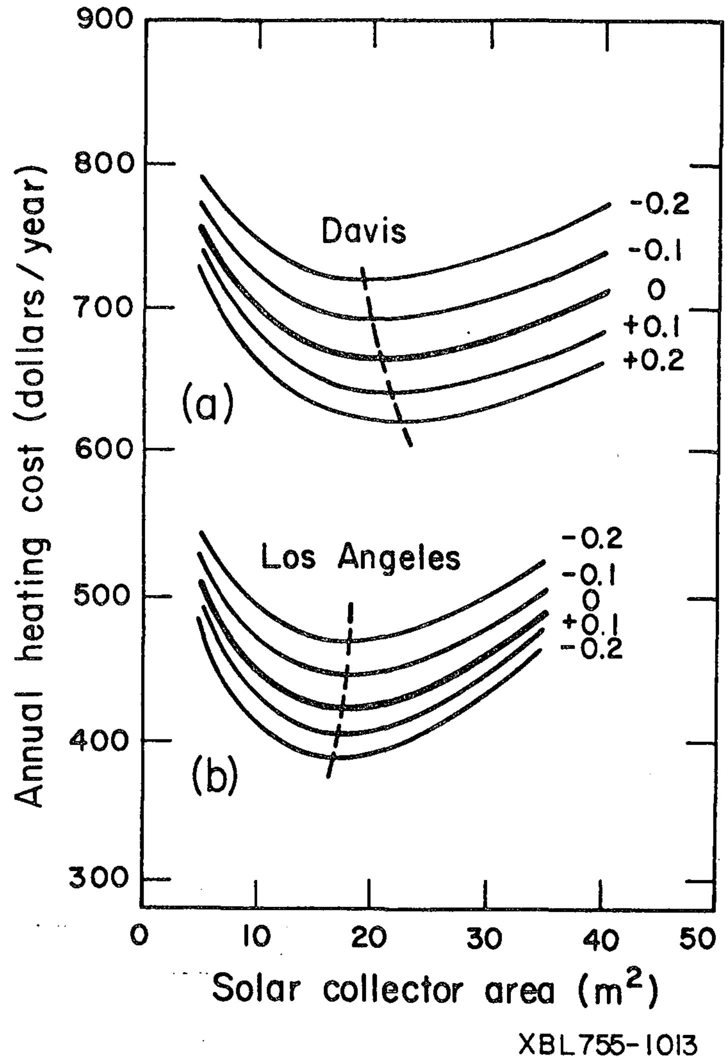


Figure 6: The annual cost of owning and operating a solar heating and hot water system plotted as a function of collector area for Davis and Los Angeles. Curves are labeled with the appropriate values of δ, corresponding to differing values of input solar radiation, Assumptions regarding cost parameters are given in the text. These results were obtained using the LASL design method.

of collector area; (ii) Auxiliary fuel cost, \$1.50 per 10^8 J (\$1.50 per therm; and (iii) Payback period of 30 years at 9% interest. Values for β for the systems and climates under consideration lead to estimates in the range of 0.1 to 0.5. Using the large values $\beta = 0.5$ and $\delta = 0.2$ (20% data error), one finds from eqn (9) that even in this case the cost penalty is only 2%. Thus the solar data need not be known to high precision in order to produce an economically reasonable design.

2. Secondary Effect for Solar Thermal Electric Conversion (STEC)

The situation for solar thermal electric conversion is slightly different because the auxiliary (back-up) system is not part of the plant, but rather is part of a network. Furthermore, the demand for energy is not fixed at some total annual energy produced. That is, the market share of the power plant(s) depends on the unit cost of power, so that this is the quantity that should be minimized.

It should be further noted that the cost of the auxiliary energy is not known, so that a procedure directly analogous to that used for DSWH cannot be used. Denoting the unit cost of energy by R, one designs for minimum R and consequently obtains

$$R = R_o \ (1 + \beta \ \delta^2), \tag{10}$$

for the same fundamental reasons that eqn (9) was obtained. Use of the same symbol β as appears in eqn (9) should not lead to confusion since they refer to different systems. Furthermore, in both cases β has the same interpretation as a measure of the cost of design error caused by errors in solar data.

An estimate of β has been made using the graph in Figure 4. Since, for the Aerospace model, changes in A are equivalent to changes in I, one can write for the effective solar electricity produced,

$$E_s = E_{s,o}[1 + a(\frac{A}{A_o} - 1) - b(\frac{A}{A_o} - 1)^2], \tag{11}$$

where $E_{s,o}$ and A_o are nominal values, and the constants a and b are evaluated graphically as $a \simeq 0.24$, $b \simeq 0.45$. The expression for the annual cost of power has the form

$$C_s = C_{s,o}[1 + c(\frac{A}{A_o} - 1)], \tag{12}$$

assumed linear as a function of heliostat area A. The constant c can be determined by using the fact that the minimum in

$$R = C_s/E_s \tag{13}$$

occurs at $A = A_o$. This requires that $c = a = 0.24$.

Consider now the form that eqns (11) and (12) would have if the solar input were changed from its nominal value I_o to $I = I_o(1 + \delta)$. Equation (11) can be rewritten with $A(1 + \delta)$ replacing A, since a change in area is equivalent to a change in I. Equation (12) is unchanged. The resulting equations for R display a minimum at a new value of A, corresponding to the appropriate change in design. From these results the cost penalty for use of solar data in error by the fraction δ can be obtained, after some lengthy but straightforward algebra. Equation (10) is reproduced, with $R_o = C_{s,o}/E_{s,o}$, and

$$\beta = b\,[1 - \frac{a(1-a)}{2b}]^2 . \tag{14}$$

Substitution of the values of a and b listed after eqn (11) yields

$$\beta \simeq 0.3.$$

As in the case of DSWH, the obtained value for β indicates that the design penalty for inaccurate data is not very large: only about a 1% cost penalty for a 20% data error. In different power plant designs or different climates β will of course vary. But it would be surprising if it were to become much larger than unity.

SUMMARY

The secondary effect--the cost penalty incurred by non-optimum design resulting from the use of erroneous solar radiation data--is found to be relatively small for both domestic solar heating systems and solar thermal power plants. The maximum penalty consistent with the foregoing calculations is of the order of 2% of the cost of power produced.

The primary effect has a larger magnitude. For domestic space and water heating systems in temperate climates α is approximately 0.5, which means that a 20% data error leads to a 10% error in the amount of usable energy produced. For solar thermal electric conversion α varies from 0.2 to 1.0, depending upon the ability of the electric network grid to make effective use of all the power producible by the solar plant. Thus a 20% data error leads to an error in energy output that varies from 4% to 20%, depending upon the specific power plant operational circumstances.

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* This appendix has appeared separately as a Lawrence Berkeley Laboratory Report, LBL-6354.

NOMENCLATURE

a - constant equal to 0.24

A - total collector or heliostat area

A_o - nominal or optimum collector or heliostat area

A'_o - modified optimum collector area

b - constant equal to 0.45

c - constant equal to 0.24

C - total annual cost

C_s - annual cost of solar system

E_s - annual solar energy utilized

f_s - fraction of the load supplied by a solar system

I - annual solar input energy (insolation)

R - unit cost of energy; e.g., C_s/E_s

α - sensitivity of output to input

α_{eff} - effective sensitivity when part of the output energy is not utilized

β - cost penalty coefficient

δ - fractional change in I

Subscripts

o - nominal or optimum value

i - part i of whole system

s - solar

REFERENCES

[1] Balcomb, J. D., and Hedstrom, J. C., in Proc. of the International Solar Energy Society Joint Conference, Winnipeg, Canada, Vol. 4, p. 281 (1976).

[2] Hottel and Whillier, Trans. of the Conf. on the Use of Solar Energy, Vol. 2, Part 1, p. 74, Univ. of Arizona Press (1958).

[3] Liu, B. Y., and R. C. Jordan, Solar Energy, Vol. 7, p. 53 (1963).

[4] Aerospace Corporation Report # ATR-74 (7414-16)-1, Vol IV, "Solar Thermal Conversion Mission Analysis," (1974).

Appendix F
SUMMARY OF SOLAR DATA MEASUREMENTS

INTRODUCTION

There have been many solar data stations either in California or near its borders. Unfortunately, only a small fraction of the data currently available from these stations is useful for resource analysis.

Most of the existing solar data originate with pyranometers, which measure the total shortwave solar radiation received on a horizontal surface. Some pyrheliometers, which measure the direct component of the radiation, have been installed since 1976 and others will certainly be installed in the future. However, in this report, discussion of the existing sets of solar data must necessarily be limited to the data originating with pyranometers.

MOST USEFUL STATIONS

Twenty-two stations that have collected data with thermopile pyranometers for five years or more are shown in Figure F-1. Five years is an estimated minimum useful period of data recording, considering that many records contain gaps and sequences of poor data. Although these 22 stations have generally useful records, they are not without problems. Some records are known to be too high, and others contain major discrepancies. More specific information about such problems can be found in Appendix H (Data Correction Factors).

A group of stations with data potentially suitable for resource analysis is listed in Table F-1, along with some details about station operation. Many of these stations have records shorter than five years. The locations of these stations are shown in Figures F-2 to F-8. Only stations using thermopile pyranometers have been included. Instruments that depend on the photoelectric effect (silicon solar cells) have been excluded because their spectrally selective sensitivity can lead to unknown errors. Bimetallic strip instruments, which depend on differential thermal expansion, have also been excluded, as they tend to display a temperature-dependent sensitivity. Of greater significance than the systematic errors of approximately 20% in the records from such instruments is that the operating characteristics of the instruments are not well known. The properties of thermopile-type pyranometers, although not always favorable, are at least reasonably well determined.

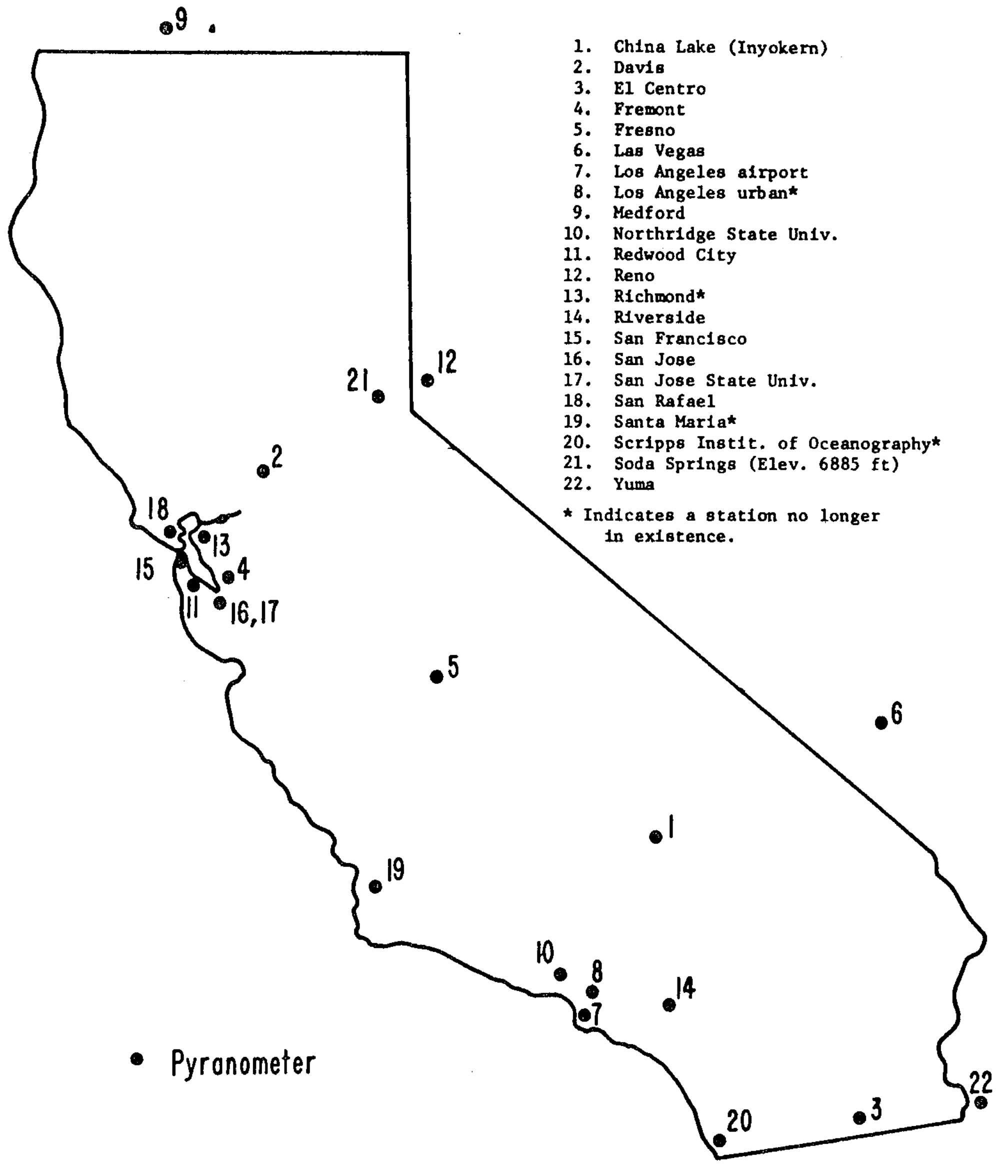

Figure F-1. Thermopile-type pyranometer sites yielding more than five years of data.

DATA STATIONS WITH SIGNIFICANT RECORDS

All significant data stations that have been identified in California are listed in Table F-2. The listing for each station includes the type of instrument used and the reported period during which data have been recorded. Stations using all types of instruments are included--not just those using pyranometers as was the case in Table F-1. Some of these stations no longer exist and the quality of data is often unreliable, especially in cases where only a year or two of data have been taken. The recently established WEST Associates stations are not included in Table F-2; they are listed in Table F-1.

Table F-1. Solar data stations potentially useful for resource analysis.*

Station	Lat.	Long.	Elev.[1]	Solar measuring instrument[2]	Recording technique	Period of record	Data availability	Period(s) for which daily totals are stored at LBL	Period(s) useful for data manuals	Remarks[3]
NATIONAL WEATHER SERVICE										
China Lake (Inyokern)	35° 41'	117° 37[4]	2160	Model 8-48	strip chart	1948-present	For all NWS stations, daily totals are available from Nat'l Climatic Center, Asheville, N.C.[5] Some hourly data is available at Asheville for China Lake, Los Angeles airport, Medford, Riverside, and Santa Maria. (Much of this data is presently being reprocessed by NCC to upgrade its quality.)	7/52-9/71	5/54-2/60, 5/60-5/61, 1/62-2/63, 10/67-9/71	Weather: W,T Station moved about 1958.
Davis	38° 32'	121° 45'	60	Model 50	strip chart	1942-present		7/52-12/74	12/56-12/74 except for several short periods of 5 months or less.	Weather: T,W
El Centro	32° 49'	115° 40'	30			1963-present		1/63-12/75	1/68-1/69, 10/71-12/75	
Fresno	36° 46'	119° 43'	328	Model 2 since 1974 or 1975	Honeywell Electronik strip chart	1928-present		7/52-12/75	1/59-5/68, 10/68-12/75	To be included in new network.[6] Weather:C,S,T,W,H
Las Vegas, Nev.	36° 05'	115° 10'	2160	Model 2	Brown Electronik circular chart	1960-present		7/52-12/75	7/54-9/56, 7/58-1/62 5/62-2/68, 8/69-10/71, 7/72-9/73, 7/74-6/75	Present instrument is temporary. To be included in new network.[6] Weather:C,S,T,W,H
Los Angeles (airport)	33° 56'	118° 23'	105	Model 50	Brown circular chart	1951-present		12/51-12/73	1/51-8/58, 11/58-5/72, 8/72-3/73, 5/73-12/73	To be included in new network.[6,7] Weather:C,T,W,H
Los Angeles (urban)	34° 03'	118° 14'	280			1951-1974		7/52-6/74	7/52-4/62, 8/68-12/69, 6/70-2/71, 9/71-12/72	Weather:C,S,T,W,H
Medford, Ore.	42° 17'	122° 52'	1560			1950-1975		12/51-12/74	12/51-6/55, 6/56-9/64, 5/65-1/70, 3/73-12/74	Weather:C,T,W,H Plan to reopen in 1977 as part of new network.[6]
Reno, Nev.	39° 30'	119° 47'	5290	Model 10	Electronik Model 18	1966-present		12/65-12/75	12/65-11/69, 1/73-2/74	Weather:C,S,T,W,H
Riverside	33° 58'	117° 20'	840E	Model 10	Leeds and Northrup Model Speedomax	1930-present		1/52-12/75	1/54-4/61, 3/62-12/63, 10/68-5/72	
Santa Maria	34° 54'	120° 27'	236			1950-1975		7/52-1/75	9/53-6/55, 3/56-6/57, 2/59-11/59, 5/60-12/62, 11/63-1/75	Weather:C,T,W,H

*All footnotes appear at the end of this table.

Table F-1. Solar data stations potentially useful for resource analysis (cont).*

Station	Lat.	Long.	Elev.[1]	Solar measuring instrument[2]	Recording technique	Period of record	Data Availability	Period(s) for which daily totals are stored at LBL	Period(s) useful for data manuals	Remarks[3]
BAY AREA AIR POLLUTION CONTROL DISTRICT[8]										
Burlingame	Coordinates for all stations[9]		NSL	Model 8-48	All stations use Esterline-Angus strip chart recorders	1973-1976	Daily totals for all BAAPCD stations are stored at the District headquarters in San Francisco. Strip charts are retained in storage.	11/73-5/76 plus a few months in 1971-1973	none	May be recommissioned
Fremont			NSL	Model 50 until 1972 Model 8-48 thereafter		1970-present		1/71-8/72, 11/73-3/74, 7/74-8/76	8/70-8/76	
Livermore			500E	Model 50		1971-1973		3/71-11/73	none	
Napa			NSL	Model 50		1972-1974		3/72-8/74 with 2 small gaps	none	
Pittsburg			NSL	Model 50		1970-1974		2/70-11/70, 8/71-12/74	2/70-10/70, 1/72-3/74	
Redwood City			NSL	Model 50		1964-present		2/70-8/76	2/70-3/74, 10/75-8/76	
Richmond			NSL	Model 50		1970-1975		2/70-3/74	2/70-11/70, 2/71-3/74	
San Francisco			NSL	Model 50 until 1972 Model 8-48 thereafter		1970-present		2/70-8/76	1/70-3/72	
San Jose			NSL	Model 50		1969-present		2/70-8/76	1/70-3/74, 8/75-8/76	
San Rafael			NSL	Model 50		1970-present		2/70-8/76	2/70-3/74	2 instrument changes
Vallejo			NSL	Model 50		1972-1975		3/72-1/75	3/72-3/74	

*All footnotes appear at the end of this table.

Table F-1. Solar data stations potentially useful for resource analysis (cont).*

Station	Lat.	Long.	Elev.[1]	Solar measuring instrument[2]	Recording technique	Period of record	Data availability	Period(s) for which daily totals are stored at LBL	Period(s) useful for data manuals	Remarks[3]
UNITED STATES GEOLOGICAL SURVEY										
Barrett Reservoir	32° 41'	116° 40'	615E	Model 10		1959-1961	Daily totals, USGS Professional Paper 272-F	11/59-10/61	11/59-10/61	Weather:T,H
Cottonwood	33.8°	117.0°	1500E	Model PSP			Same as Lake Skinner	8/73-7/74	8/73, 10/73-7/74	near San Jacinto
Lake Mead, Ariz-Nev.	35° 59'	114° 51'		Model 10		1952-1953	Daily totals, USGS Professional Paper 272-F (1964)	3/52-9/53		Weather:T,H
Lake Mojave, Ariz-Nev.	35° 12'	114° 34'	500E	Model 10		1959-1961		9/59-2/61		Weather:T,H
Lake Skinner	33.5°	117.1°	500E	Model PSP			Daily totals to be published 1976 in USGS Water Supply Paper (Jobson et al.)[10]	8/73-7/74	8/73-7/74	near Winchester
Salton Sea	33° 30'	116° 03'	-200E	Model 10		1967-1968	To be published late 1976	8/67-12/68		
San Vicente Reservoir	32° 55'	116° 55'	650E	Model 10		1957-1959	Daily totals, USGS Professional Paper 272-F	10/57-10/59	10/57-10/59	Weather:T,H
UNITED STATES BUREAU OF RECLAMATION										
Five Points (Westside Field Sta.)	36° 22'	120° 06'	180E	Weather Measure R413 Star pyranometer	Model 279 Disc Integrator, Weather Measure ET-1200 recorder (strip chart)	1972-present	Daily totals[11]	7/73-11/73, 1/74-2/75, 1/76-6/76	none	These records may contain intervals of data from other USBR stations.
Tranquility			220E	Model 8-48	Model 279 Disc Integrator, Weather Measure ET-1200 recorder (strip chart)	1976-present	Daily totals[11]	5/76-10/76		

*All footnotes appear at the end of this table.

Table F-1. Solar data stations potentially useful for resource analysis (cont).*

Station	Lat.	Long.	Elev.[1]	Solar measuring instrument[2]	Recording technique	Period of record	Data Availability	Period(s) for which daily totals are stored at LBL	Period(s) useful for data manuals	Remarks[3]
MISCELLANEOUS[12]										
Brawley (ARS)	32° 57'	115° 33'	140E	Eppley Model?		1967-1969(?)	Not readily available			Station may be reestablished. Located 10 miles from El Centro NWS station.
China Lake	35° 39'	117° 40'	2700	Model PSP plus Willson pyrheliometer	magnetic tape	1976-present				In early 1977 will be moved to Barstow for indefinite period. Operated by Lawrence Berkeley Lab.
Chico (CSU)			200E	Model 8-48	strip charts	1975-present	Unreduced charts[13]			
Fresno (CSU)	36° 49'	119° 44'	335	Model 8-48	Bristol Dynamaster strip chart	1972-present	Unreduced charts[14]			Weather:T,W
Goldstone Tracking Center			3500E	2 SR-75's 1 Eppley pyranom. 2 pyrheliometers	magnetic tape	1974-present	2-min. intervals on magnetic tape; not readily available[15]			Operated by Jet Propulsion Lab. Weather data taken.
Livermore (Lawrence Lab)			500E	Model 8-48	Leeds Northrup strip chart	1974-present	Hourly totals[16]	1/75-9/76		Weather:W,T Presently installing a pyrheliometer
Livermore (Sandia Lab)			500E	Eppley Model NIP pyrheliometer Spectrolab Model SR75 pyranometer	magnetic tape	1974-present	Hourly(?)totals[17]	8/74-10/74; 1/75-10/75		Weather:T Some gaps in data exist.
Long Beach (CSU)	33° 46'	118° 11'	35	Kahl Sci. Instrum. Corp. Star pyranometer since about 1974. (Eppley Model R411 previously)	Weather Measure strip chart	1971-present	Daily totals[18]	4/72-9/76 daily means		Weather:T,H,W, some C and S. Data quality uncertain
Monterey (U.S. Navy)	36° 36'	121° 52'	NSL	Model 50	strip charts	1971-present	Unreduced charts[19]			Weather:T,W, some S Instrument poorly mounted.
Northridge (CSU)			1000E	1960's: Eppley Model 50 1970's: Moll-Gorczynski		1963-1969; 1971 or 1972-present	Presently records instantaneous values hourly[20]			Weather: some S
Point Mugu (U.S. Navy)			NSL	Model 50 until 1972; Model 8-48 thereafter	strip charts	1966-1972; 1975-present	Some data reduced[21]			Epply data taken irregularly

*All footnotes appear at the end of this table.

Table F-1. Solar data stations potentially useful for resource analysis (cont).*

Station	Lat.	Long.	Elev.[1]	Solar measuring instrument[2]	Recording technique	Period of record	Data availability	Period(s) for which daily totals are stored at LBL	Period(s) useful for data manuals	Remarks[3]
Richmond Field Sta. (Univ. Calif., Berkeley)			NSL							
Sacramento (CSU)			50E	Model 8-48 and Model PSP	magnetic tape	1976-present	Physics Dept.[22]			Some weather data
San Jose (CSU)	37°21'	121°54'	100E	Eppley Model 50; Model 8-48 since 9/76	strip chart	1963-present	Hourly and daily totals[23]	12/63-10/64; 2/66-12/67; 9/68-8/76, some short gaps	10/69-2/73, 11/73-7/75	
Scripps Instit. Oceanography, LaJolla	32°50'	117°15'	NSL	Eppley pyranometer	strip charts	1928-1950	Only available for 1929-1942. Some hourly, some daily.	6/29-12/42	8/33-12/35, 7/36-12/42	
Shafter (USDA)	35°32'	119°17'	400E			1975-present		1/75-7/76		
Soda Springs Snow Lab. (USFS)	39°20'	120°22'	6885	2 Eppley Model 50	presently magnetic tape	1946-present	daily totals[24]	10/46-7/52 last 2 years intermittent	10/46-12/48, 5/49-9/50	Take data only in winter, when snow is usually on the ground.
Yuma (Ariz.) Proving Grounds (U.S. Army)	32°15'	114°24'	200E	Several Eppleys	1952-present			1/52-12/76 monthly averages		

*All footnotes appear at the end of this table.

Table F-1. Solar data stations potentially useful for resource analysis (cont).*

Station	Lat.	Long.	Elev.[1]	Solar measuring instrument[2]	Recording technique	Period of record	Data Availability	Period(s) for which daily totals are stored at LBL	Period(s) useful for data manuals	Remarks[3]
WEST ASSOCIATES[25]										
SOUTHERN CALIFORNIA EDISON										
Barre	23.8°	118.0°	NSL	All stations have Eppley Model 8-48 pryanometers. Those followed by + also have an Eppley Model NIP pyrheliometer.	All stations have Westinghouse magnetic tape cartridges.	All stations installed 1975 or 1976.				
Barstow +	34.9°	117.0°	2000E							
Blythe +	33.6°	114.6°	270E							
El Dorado, Nevada	35.9°	115.0°								
El Segundo	33.8°	118.4°	NSL							
Huntington Beach	33.7°	118.0°	NSL							
Irvine	33.7°	117.8°	NSL							
LaFresa	33.8°	118.3°	NSL							
Laguna Bell	34.0°	118.2°	250E							
Lancaster +	34.7°	118.2°	2400E							
Mandalay	34.1°	119.2°	NSL							
Mira Loma	34.0°	117.5°	700E							
Moorpark	34.3°	118.9°	500E							
Palm Springs +	33.9°	116.5°	500E							
Pardee	34.5°	118.6°	1000E							
Ridgecrest +	35.6°	117.7°	2300E							

*All footnotes appear at the end of this table.

Table F-1. Solar data stations potentially useful for resource analysis (cont).*

Station	Lat.	Long.	Elev.[1]	Solar measuring instrument[2]	Recording technique	Period of record	Data availability	Period(s) for which daily totals are stored at LBL	Period(s) useful for data manuals	Remarks[3]
Rio Hondo	34.1°	118.0°	500E							
Vestal	35.8°	119.1°	300E							
Victorville +	34.5°	117.3°	2700E							
Walnut	34.0°	117.9°	500E							
Yucca Valley +	34.1°	116.5°	3200E							
SAN DIEGO GAS AND ELECTRIC										
Alpine	32.8°	116.7°	2500E	All stations have a Model 8-48 pyranometer. Escondido also has a pyrheliometer.	All stations are being switched from strip charts to Westinghouse magnetic tape cartridges.	All stations were installed in 1975 or 1976				
Chula Vista	32.6°	117.0°	NSL							
Del Mar	33.0°	117.2°	NSL							
El Cajon	32.8°	116.9°	300E							
Escondido	33.1°	117.1°	650E							
San Diego	32.7°	117.1°	NSL							
San Diego State Univ.[26]	32.8°	117.0°	NSL							
Spring Valley	32.7°	116.9°	500E							

*All footnotes appear at the end of this table.

Footnotes

1. Elevations given in feet above sea level. Values followed by the letter E were estimated from contour maps. NSL = near sea level (within about 250 ft.)
2. Eppley Laboratories thermopile instruments:
   Model 10 and Model 50 are "lightbulb" type pyranometers; 10 and 50 refer to the (approximate) number of thermopile junctions.
   Model 8-48 is the "black-and-white" single-dome pyranometer.
   Model 2 and Model PSP are double-dome precision spectral pyranometers.
   Spectrolab:
   SR-75 is a double-dome thermopile pyranometer.
3. Other weather variables measured:
   C cloud cover
   S sunshine hours
   T temperature
   W wind
   H humidity.
   Information in the table concerning weather variables is not necessarily complete for all stations.
4. The station was moved 4 miles to this location in 1958.
5. U.S. Dept. of Commerce
   National Oceanic and Atmospheric Admin.
   Environmental Data Service
   National Climatic Center
   Federal Bldg.
   Asheville, N.C. 28801
6. New NWS network will have pyrheliometers and new pyranometers and recording instruments.
7. A reflecting aluminum dome was installed near the pyranometer in Aug. 1975.
8. Weather variables for all stations: hourly wind direction and average velocity; daily temperature max. and min.; hourly cloud conditions for all or most stations. Some data in 1974-1975 was not analyzed for some stations.
9. UTM(Universal Transverse Mercator) coordinates for all stations are recorded at the San Francisco Office.
10. 10-minute intervals on magnetic tape available from Automatic Data Processing Unit, Water Resources Div., USGS, Reston, Virginia 22092.
11. Contact John Williford or Charles McNiesh, U.S. Bureau of Reclamation, Mid Pacific Region, Federal Bldg. Room 2215, 1130 O Street, Fresno, CA 93721.
12. ARS - Agricultural Research Service, U. S. Dept. Agriculture (USDA)
    USFS - U. S. Forest Service
    USCE - U. S. Army Corps of Engineers
    CSU - California State Univ.
13. Contact Loren Weakly, Physics Dept., Chico State Univ., Chico, CA.
14. Contact Don Morgon, Dept. Geography, Fresno State Univ., Fresno, CA.
15. Contact MacGregor Reid, Jet Propulsion Lab., Calif. Institute of Technology, Pasadena, CA 91103.
16. Contact Arnold Clark, Lawrence Livermore Lab., Livermore, CA.
17. Contact Steve Grey, Division 8342, Sandia Laboratories, Livermore, CA 94550.
18. Contact John Kimura, Dept. of Geography Climatology Lab., Bldg. LA4, Long Beach State Univ., Long Beach, CA. 90840.
19. Contact Mike McDermott, U.S. Navy Post Graduate School, Code 63, Montery, CA 93940.
20. Contact Arnold Court, Geography Dept., Northridge State Univ., Northridge, CA. 91130.
21. Contact Robert deViolini, Geophysics Div., Pacific Missle Test Center, Pt. Mugu, CA. 93042
22. Contact Mike Shea, Physics Dept., Sacramento State Univ., Sacramento, CA.
23. Contact Albert Miller, Dept. Meteorology, San Jose State Univ., San Jose, CA.
24. Contact James Smith, U. S. Forest Service, Pacific Southwest Forest and Range Experiment Station, 1960 Addision St., Berkeley, CA.
25. Latitude and longitude read to nearest 0.1° from maps provided by the utilities.
26. Data from this independent station is processed by SDG and E.

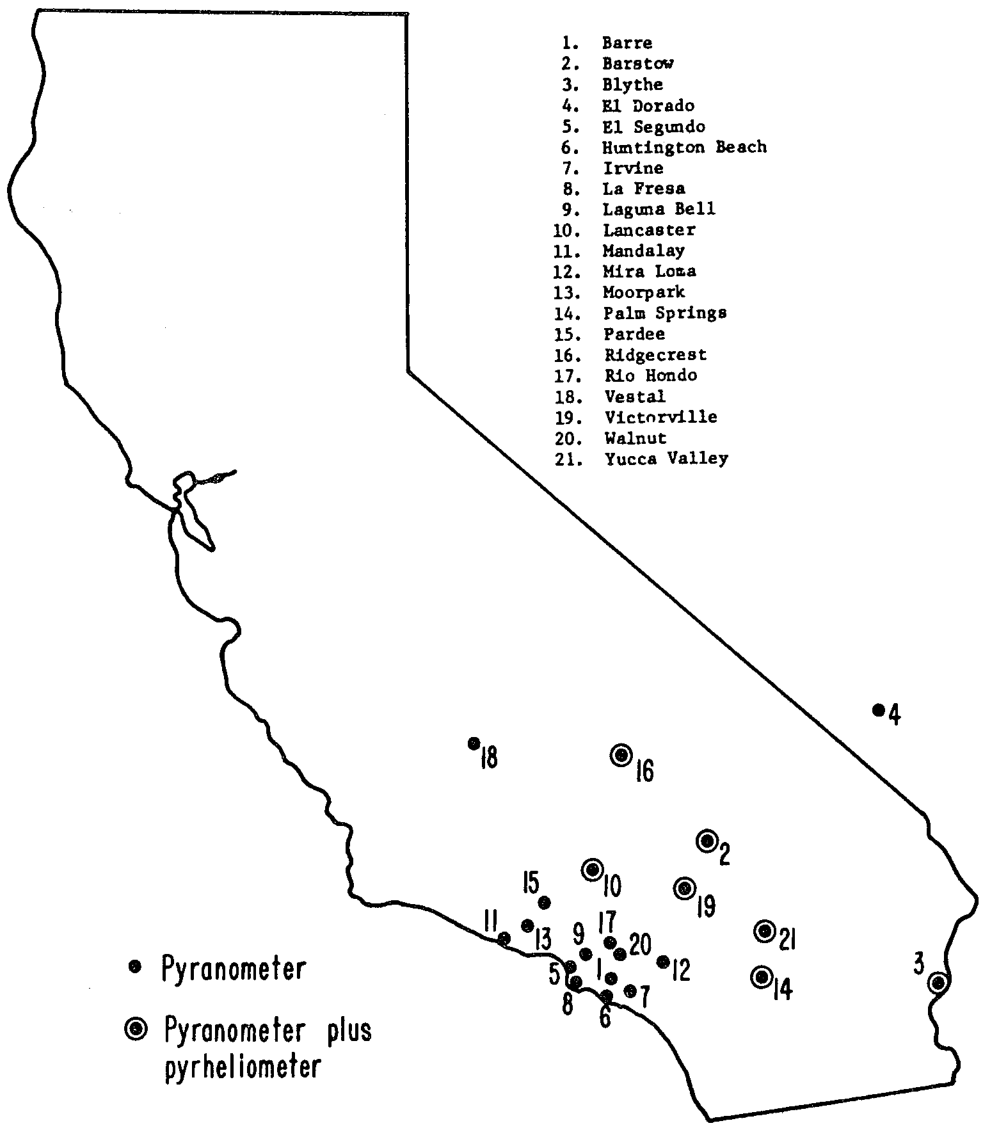

Figure F-2. Southern California Edison solar data stations.

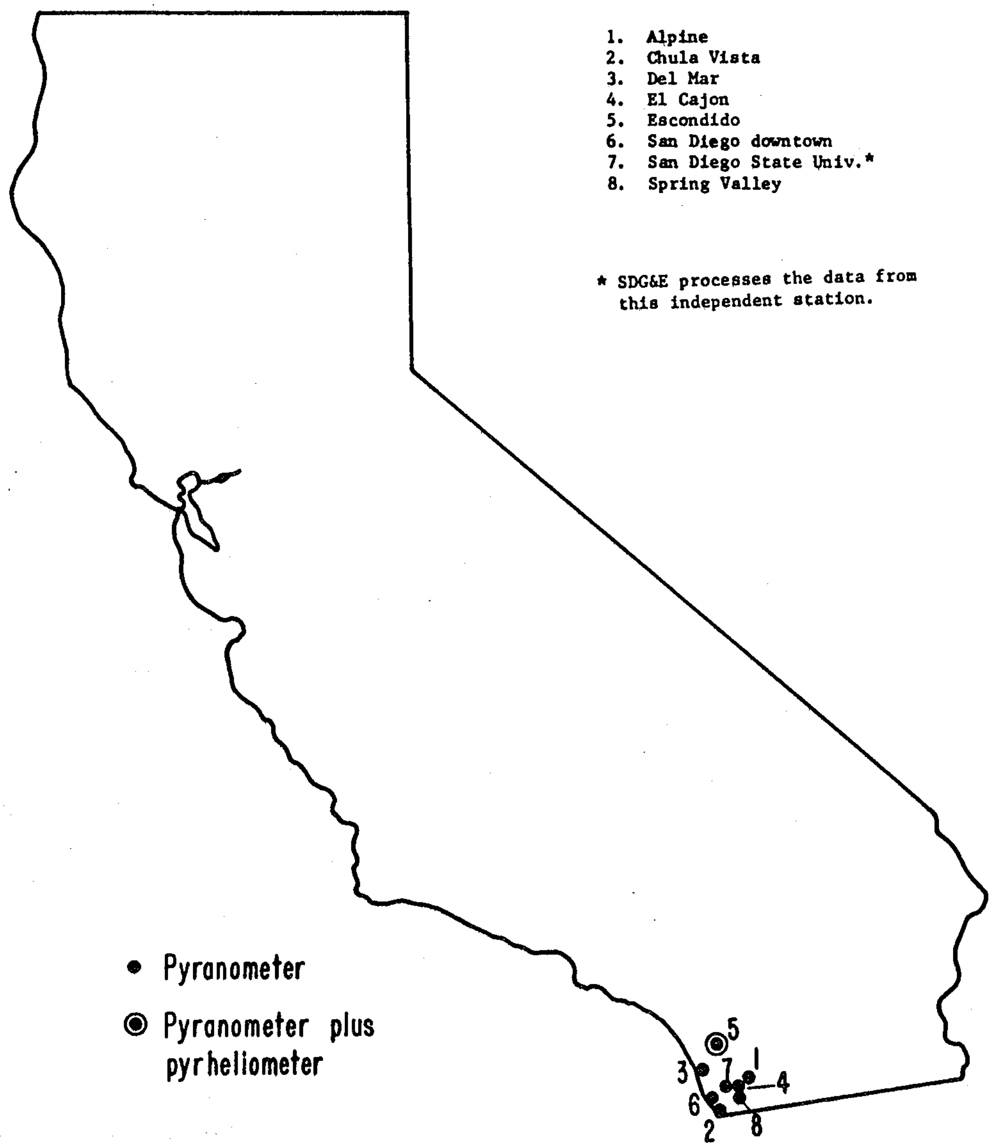

Figure F-3. San Diego Gas and Electric solar data stations.

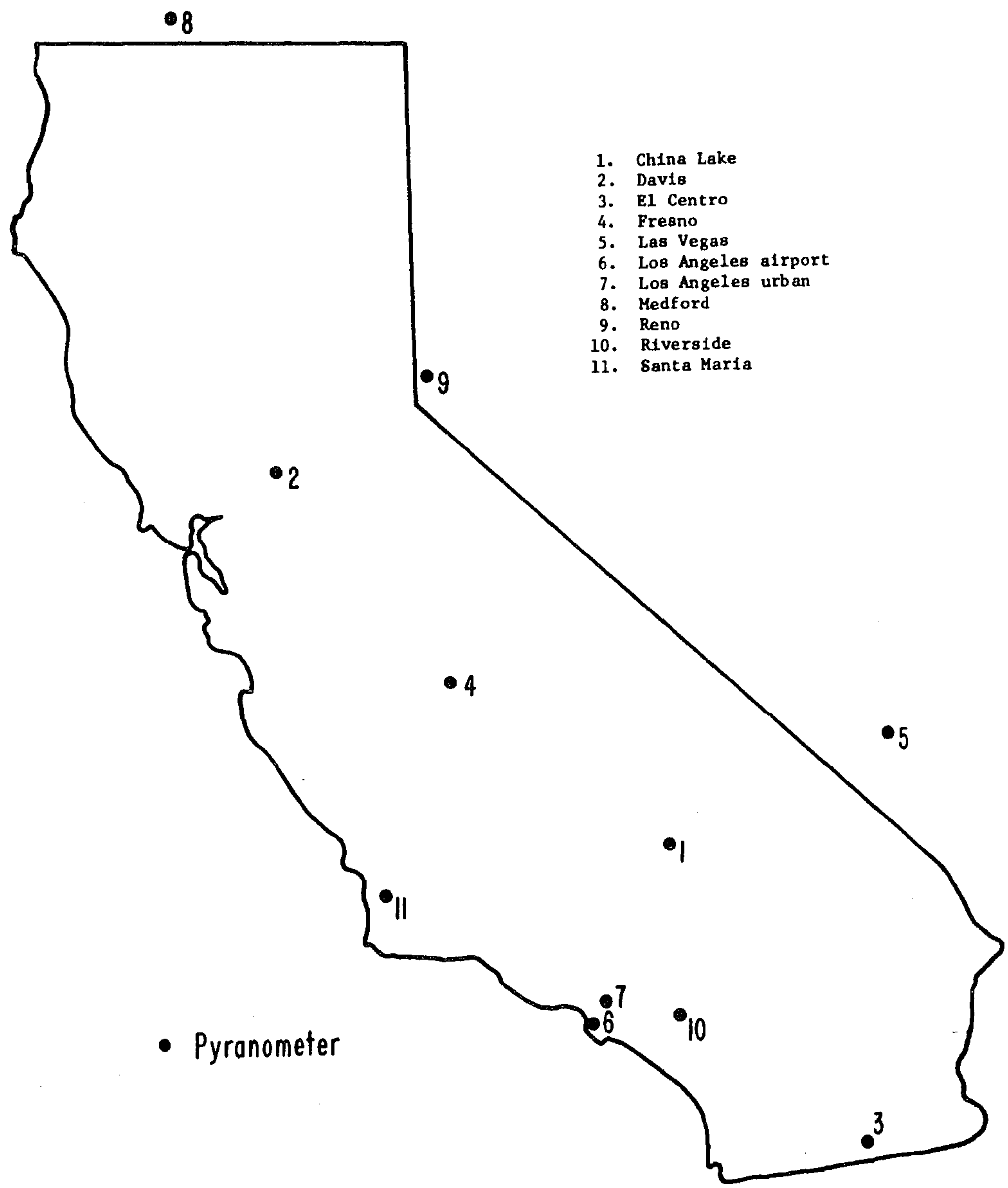

Figure F-4. National Weather Service old network pyranometer sites.

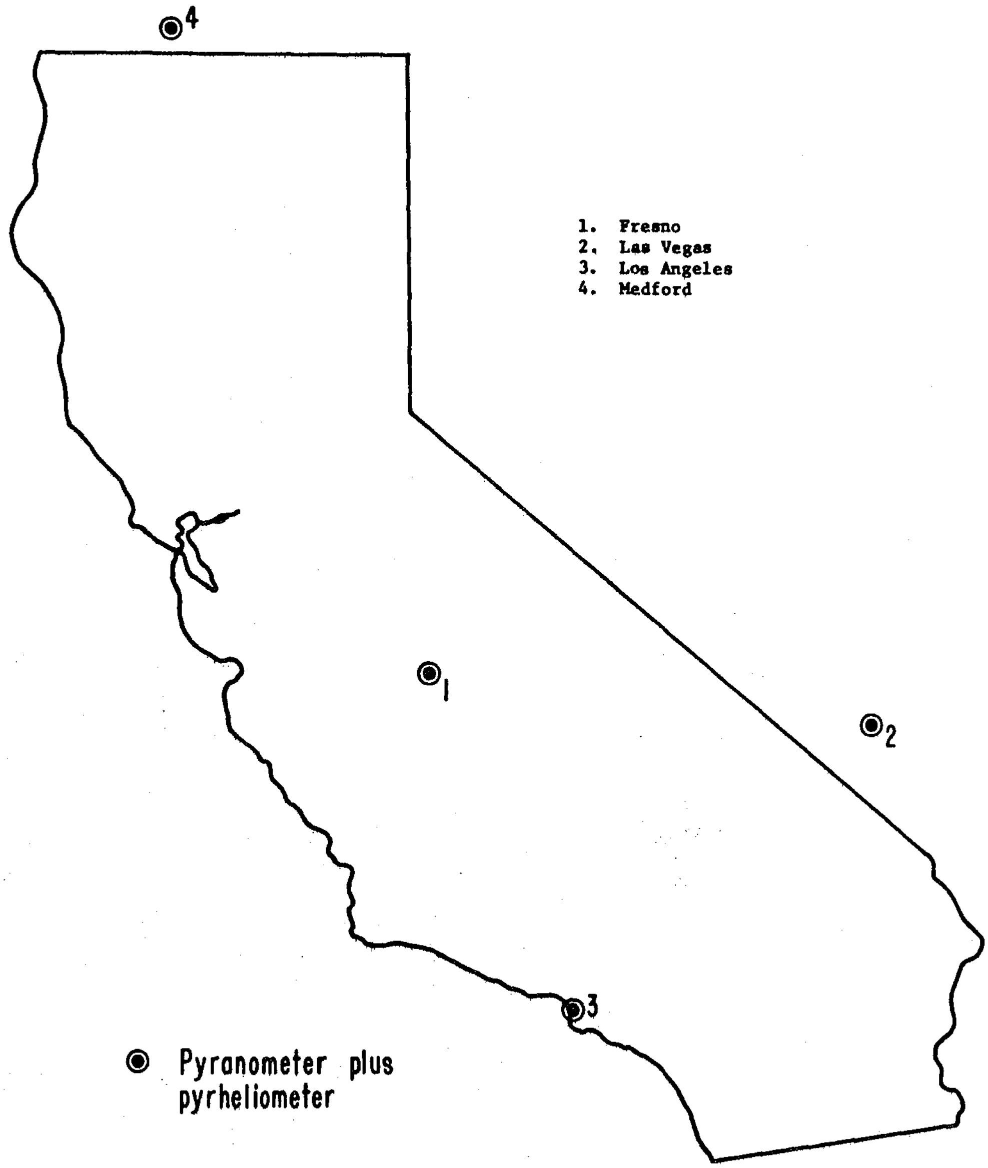

Figure F-5. National Weather Service new network solar data stations.

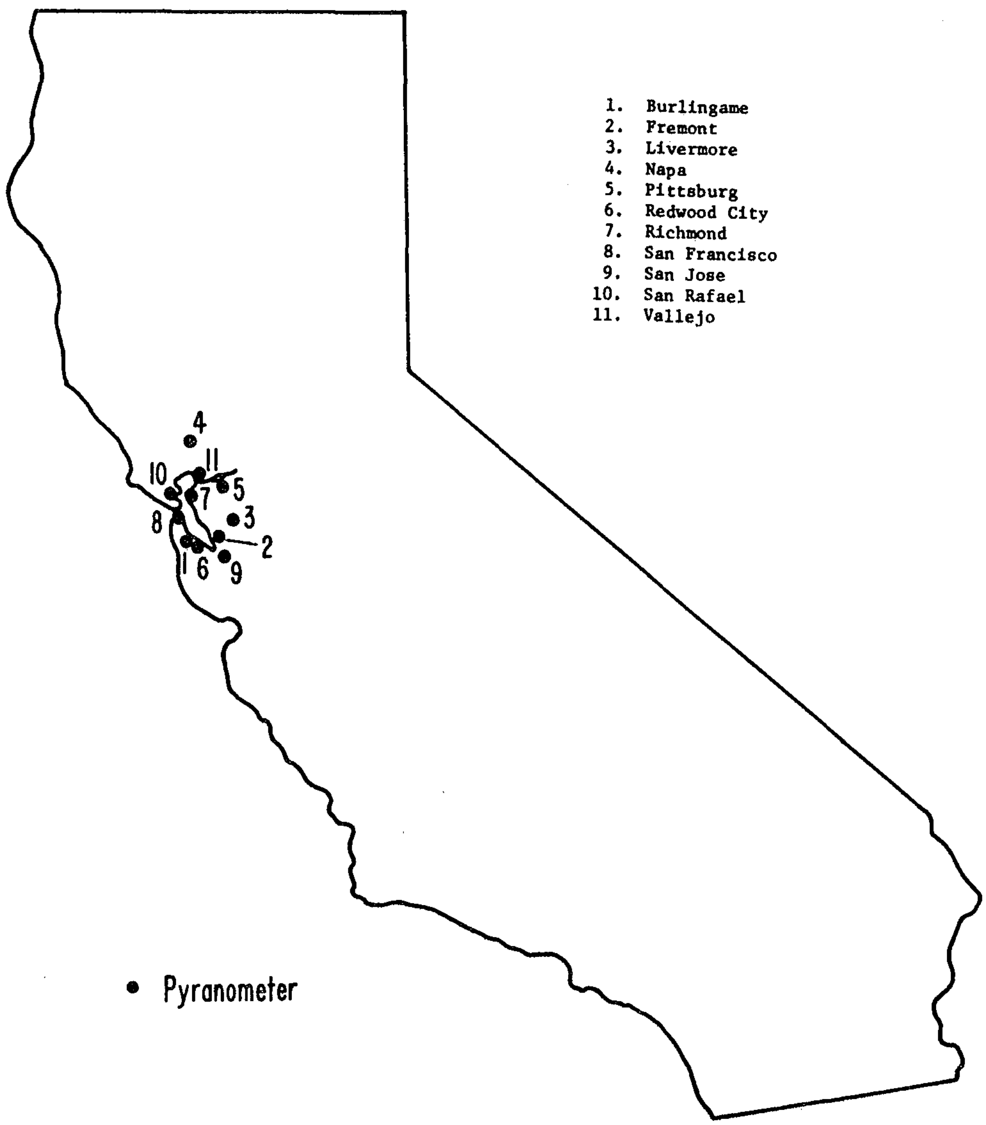

Figure F-6. Bay Area Pollution Control District pyranometer sites.

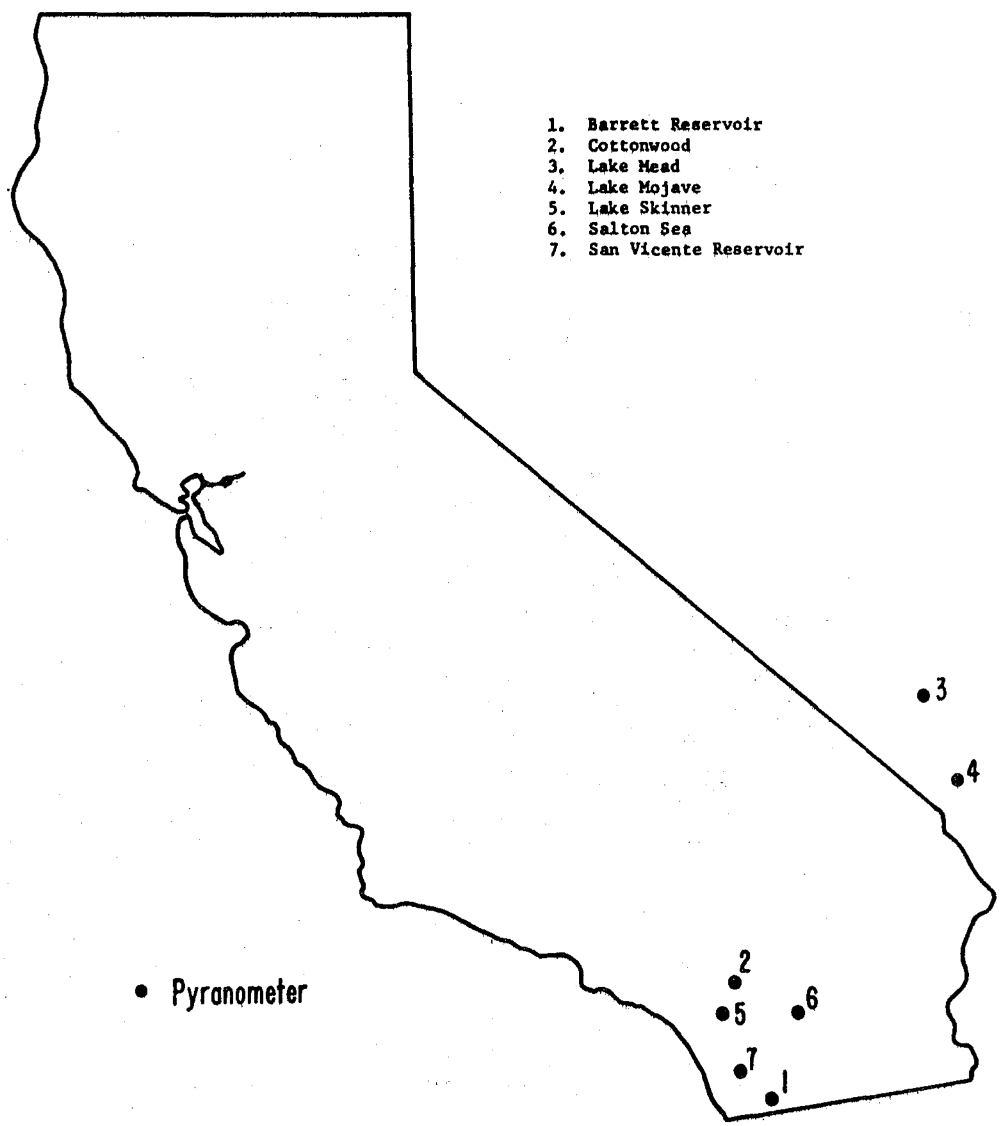

Figure F-7. U. S. Geological Survey pyranometer sites.

Table F-2. Listing of California's solar data stations (continued).

Station	Instruments*	Period of Record (Dates)	Duration (No. of Years)
U.S. BUREAU OF RECLAMATION			
Blythe	B	1973-1977	5
Coachella	B	1972-1976	5
Dixon	B	1976-1977	2
Five Points	T	1972-1977	6
Folsom Dam	B	1974-1977	4
Institute of Forest Genetics (Placerville)	B	1976-1977	2
Schramm's Ranch (see Harza Ag. Services)			
Tranquility	T	1976-1977	2
Vacaville	B	1976-1977	2
Welton, Arizona	B	1973-1977	5
HARZA AGRICULTURAL SERVICES			
Allen Ranch (Coalinga)	B	1975-1977	3
Coit Range (near Fresno)	B	1974-1977	4
Metzler Ranch (near Fresno)	B	1976-1977	2
Schramm Ranch (near Fresno)	B	1975-1977	3
U.S. GEOLOGICAL SURVEY			
Barrett Reservoir	T	1959-1961	3
Cottonwood	T	1973-1974	2
El Capitan	T	1957-1959	3
Lake Hodges	T	1957-1959	3
Lake Mead	T	1952-1953	2

* Key to instruments appears on last page of table.

Table F-2. Listing of California's solar data stations (continued).

Station	Instruments*	Period of Record (Dates)	Duration (No. of Years)
U.S. GEOLOGICAL SURVEY (cont.)			
Lake Mojave	T	1959-1961	3
Lake Skinner	T	1973-1974	1
Lake Wohlford	T	1962-1963	2
Loveland	T	1959-1961	3
Marina	T	1959-1961	3
Salton Sea	T	1968-1969	2
San Diego Aqueduct	T	1973-1974	2
Sandy Beach	T	1961-1962	2
San Vicente Reservour	T	1957-1959	3
CALIFORNIA DEPARTMENT OF WATER RESOURCES			
Alturas	B	1958-1969	12
Arvin-Frick	B	1959-1965	7
Bakersfield	B	1969-1970	2
Bakersfield College	B	1976-1977	2
Brenda	B	1962-1963	2
Buttonwillow	B	1965-1966	2
Covelo	B	1966-1969	4
Cummings Valley	B	1965-1971	7
Finley	B	1972	1
Gerber	B	1973-1977	5
Glenburn	B	1963-1966	4
Guadalupe	B	1961-1964	4
Kerman	B	1964	1
Los Banos	B	1959-1962	4
Maze Bridge	B	1962-1965	4

* Key to instruments appears on last page of table.

Table F-2. Listing of California's solar data stations (continued).

Station	Instruments*	Period of Record (Dates)	Duration (No. of Years)
CALIFORNIA DEPARTMENT OF WATER RESOURCES (cont.)			
McArthur	B	1959	1
Newville	B	1966-1970	5
Old River	B	1965-1967	3
Oroville (Butte College)	B	1976-1977	2
Red Bluff	B	1967-1969	3
Redding	B	1958	1
Redding (Shasta College)	B	1969-1977	9
Ruth Reservoir	B	1967	1
Salinas	B	1974-1977	4
San Luis Dam	B	1966-1977	12
San Luis Obispo	B	1969-1972	4
Soledad	B	1963-1971	9
Stockton	B	1960-1961	2
Thornton	B	1963-1968	6
Upper Lake	B	1970-1972	3
Wasco	B	1975-1977	3
OTHER			
Brawley	T	1967-1969	3
Butler Valley Ranch	B	1970-1975	6
Challenge	B	?-1966	?
Chico State University	T	1975-1977	3
Coon Creek	B	1961-1966	6
Coyote Dam	B	1975-1977	3
Fresno (PG&E)	T_2	1976	1
Fresno State University	T	1972-1977	6
Goldstone	T_1	1974-1977	4

* Key to instruments appears on last page of table.

Table F-2. Listing of California's solar data stations (continued).

Station	Instruments*	Period of Record (Dates)	Duration (No. of Years)
OTHER (cont.)			
Highpoint (U. S. Army)	R	1972-1977	6
Jolon (U. S. Army)	R	1969-1977	9
Livermore (Lawrence Lab.)	T	1974-1977	4
Livermore (Sandia Lab.)	T_1	1974-1977	4
Lompoc	B, some T	1958-1969	12
Long Beach State Univ.	T	1971-1977	7
Monterey	T	1971-1977	7
Northridge State Univ.	T	1963-1977	15
Oakdale (PG&E)	T_2	1976	1
Optical Coating Labs, Inc. (Santa Rosa)	T (tilted)	1975-1977	3
Pacific Grove (Hopkins Marine Station)	B	1970-1977	8
Point Mugu	T	1966-1977	12
Richmond Field Station (Univ. Calif., Berkeley)	T	1955-1967	13
Sacramento State University	T	1976-1977	2
San Jose State University	T	1963-1977	15
San Luis Obispo (California Polytechnical University)	B	1975-1977	3
Santa Clara (City of)	T (tilted)	1975-1977	3
Scripps Institute of Oceanography (La Jolla)	T	1928-1950	23
Shafter		1975-1977	3
Soda Springs Snow Lab.	T	1946-1977	32
Superior Farming Co. (near Shafter)	P	1976-1977	2

* Key to instruments appears on the last page of table.

Table F-2. Listing of California's solar data stations (continued).

Station	Instruments*	Period of Record (Dates)	Duration (No. of Years)
OTHER (cont.)			
Warm Springs dam site	B	1973-1977	5
Yuma Proving Ground, Arizona	T	1952-1977	26

* Key to instruments:

T = thermopile pyranometer

B = bimetallic strip pyranometer (pyranograph)

R = "flat plate" radiometer (sensitive to all wavelengths)

T_1 = thermopile pyranometer with pyrheliometer

T_2 = two thermopile pyranometers, one with shadowband

P = photovoltaic detector

Appendix G
REPORTS OF SITE VISITS TO SOLAR DATA MEASUREMENT STATIONS

INTRODUCTION

During the fall of 1976, LBL personnel visited 24 solar data stations in California. At each site, detailed information about the condition of the instruments, maintenance, and data reduction procedures was obtained. This information is summarized in Table G-1. The detailed site visit report forms are reproduced after the table.

The following criteria were applied in the selection of data stations for site visits:

1. Preference was given to stations for which five or more years of data had been recorded and for which continued operation is planned.
2. Stations using different types of radiation detectors were selected, e.g., thermopile pyranometers, pyranographs, and photovoltaic detectors.
3. Stations were considered on the basis of diverse geographical location.
4. Stations were considered in order to sample the installations of a variety of sponsoring agencies, e.g., National Weather Service, state and local agencies.

Table G-1. Summary of site visits to solar measurement stations.

STATION(AGENCY)[1]	APPLICATION	TYPE INSTRUMENT	SENSOR	LEVEL	DESSICANT blue = dry pink = wet	POSSIBILITY OF MOVEMENT	TEMPERATURE COMPENSATION	OBSTRUCTION REFLECTION	DEVIATION IN % FROM LBL PSP	LBL B&W	WEATHER CONDITIONS DURING MEASUREMENTS
1. China Lake (NWC)	Air Quality	Model 8-48	ok	yes	blue/pink	no	yes	none	-3.7	0.0	---
2. Chula Vista(SDG&E)	Solar	Model 8-48	ok	yes	blue/pink	yes	no	none	----	----	---
3. Davis (NWS)	Weather	Model 50	greenish/ white	yes	n/a	no	no	none	0.0	+5.7	cloudy
4. Dixon (USBR)	Agriculture	Sol-A-Meter	-----	---	-----	no	no	yes	----	----	---
5. El Cajon(SDG&E)	Solar	Model 8-48	ok	no	pink	yes	no	none	+1.6	+2.6	clear
6. Folsom Dam (USBR)	Agriculture	Sol-A-Meter	ok	yes	white	no	no	yes	----	----	---
7. Fresno (CSU)	Weather	Model 2	ok	no	blue/pink	no	yes	possible	+5.7	+6.3	cloudy
8. Fresno (NWS)	Weather	Model 2	ok	yes	pink	no	yes	yes	+8.9	+3.6	cloudy
9. Gerber (DWR)	Agriculture	Bimetallic	flaking	no	n/a	no	no	no	----	----	---
10. Las Vegas (NWS)	Weather	Model 2	ok	---	-----	yes	--	---	----	----	---
11. Livermore (LLL)	Solar	Model 8-48	ok	yes	pink/blue	no	no	possible	-3.9	-0.5	clear
12. Long Beach (CSU)	Weather	Star; Kahl	white streaks	yes	not visible	no	no	no	-15.4	-11.8	cloudy
13. Los Angeles (NWS)	Weather	Model 50	-----	---	n/a	no	---	yes	+16.9	+16.7	---
14. Monterey (USNPGS)	Weather	Model 50	ok	no	n/a	no	no	yes!	----	----	—
15. Pt. Mugu (USN)	Weather	Model 8-48	ok	---	-----	no	--	---	----	----	---
16. Redding (DWR)	Weather	Bimetallic	ok	no	n/a	no	no	no	+24.8	+24.6	clear
17. Redwood City (BAAPCD)	Air Quality	Model 50	greenish/ white	no	n/a	yes	no	no	-7.5	-4.1	part.cloudy
18. Reno (NWS)	Weather	Model 10	ok	no	n/a	no	no	no	----	----	—
19. Riverside (NWS)	Weather	Model 10	greenish/ white	no	n/a	no	no	yes	+6.3	+3.1	clear
20. San Francisco (BAAPCD)	Air Quality	Model 8-48	greenish/ white	no	pink	yes	yes	no	-3.6	0.0	clear
21. San Jose (BAAPCD)	Air Quality	Model 50	-----	---	n/a	yes	yes	possible	----	----	----
22. San Jose (CSU)	Weather	Model 50	greenish/ white	no	n/a	no	no	possible	-11.1	-9.2	clear
23. Vacaville (USBR)	Agriculture	Sol-A-Meter	ok	yes	pink	no	no	yes	+5.3	+7.0	clear
24. Walnut/LA (SCE)	Solar	Model 8-48	ok	no	dark blue	no	no	no	-1.1	+1.2	clear

[1]BAAPCD = Bay Area Air Pollution Control District; CSU = California State University; DWR = Department of Water Resources; LLL = Lawrence Livermore Laboratory; NWS = National Weather Service; SCE = Southern California Edison; SDG&D = San Diego Gas and Electric; USBR = U. S. Bureau of Reclamation; USN = U. S. Navy; USNPGS = U. S. Navy Post Graduate School.

Station Name China Lake (NWC) Date October 8, 1976

Organization U.S. Navy-Nat'l. Naval Weapons Center Time of Visit 12:45-13:45 PDST

Visited By Anson

Latitude 35° 44'N Longitude 117° 39'W Elevation 2160'

Directions for finding station Obtain pass at main gate! Enter NWC and travel 270° around traffic circle. Proceed through two stop signs along Power Line Road until "T" intersection (~ 3 miles). Take a left (ignore "keep out" signs) and travel 1 mile to blue and white trailer.

Contact person: Name Ray Kelso

Address NWC, Code 3203
China Lake, Calif. 93555

Phone (714) 939-6300 or x 6420 (trailer phone)
also: Paul Owens 939-6211

Insolation data: (measured)

	hourly	daily	monthly	Frequency (recorded)
Total (global)	X			
Direct				
Sunshine Hours				
Cloud Cover				
Other				

Weather Data:

	Yes	No	Frequency
Temperature (dry bulb)	X		
(wet bulb)	X		
Wind Speed (Ht. ~20')	X		
Wind Direction	X		
Other Air quality	X		

Description of Solar Radiation Measuring Instruments

Manufacturer Eppley

Model 8-48

Serial No. 13861

Date of Installation ~July-August 1975

Calibration Constant 11.24×10^{-6} V/Wm^2

Last Calibration Date April 7, 1975

Condition of: Dome clean, few pits

Dessicant blue/pink

Sensor o.k.

Leads Connect. from B&W to terminal strip exposed to weather & shows it. Lamp cord to complete connection from term. strip to recorder.

Level Gimbal mounted! Ship-type installation, stainless steel, not attached to trailer roof.

Contact for Station History:

Name ~~Paul Owen~~

Address ~~NWC China Lake, CA 93555~~

Phone ~~(714) 939-6211~~

Instrument Location On roof of trailer, ~10' high.

Description of Recording Instrument

Manufacturer Philips (strip chart)

Model PM 8235

Serial No. n/a

Scale Units 0-2 ly

Description 12 channels (difficult to read chart due to need for converting chart units to those measured). Chart & readout on dial disagreed by ~5%.

Type of Record

Strip Chart	
Magnetic Tape	
Circular Chart	
Hand Recorded	

Other Metrodata (mag cartridge recorder) Model 620, units mV. Data taken at 10-min. intervals. Temp. Comp. Range: -20 to +40C calibration temperature; 25C corrected calibration as of 7/18/75 (Eppley) due to change in white point. Values were 3% high.

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes ☐ No ☐

Describe Process

Maintenance & Calibration Procedure

	Frequency
Solar Radiometer /Recorder No Calibration performed since instrument received ~ 1 year ago.	
Zero adjust on recorder is routinely performed each day, and data is adjusted accordingly.	

Results of Cross-Calibration with LBL Instruments Test 1) Station B&W and LBL B&W both averaged 3.6% too low in values relative to LBL PSP. Station instrument on station recording equip. Test 2) Average deviation of station B&W from PSP on LBL DVM averaged .5% too high.

Period(s) of Data Collection Best data is for ~ January 1976 to present (~ 6 months).

Solar Data Stored at: Contact ~~Ray Kelso~~

Address ~~NWC, Code 3203~~
~~China Lake, Calif. 93555~~

Phone ~~(714) 939-6300~~

Miscellaneous Comments: Future of this station is dependent on funding--which is somewhat unclear at this point. Data recorded in 3 places since 1946. First in Inyokern Airport, then moved to NWC ranges in 1950's. Instrument (?) broken and recalibrated several times. Steve Lee (NWC) has all of this old data on tape. Also Dave Wirtz has 2-3 years of data, not reduced, and Rick Davis (NWC) has analyzed solar data in some detail.--Paul Owens

Station Name Chula Vista
Date September 30, 1976
Organization San Diego Gas & Electric
Time of Visit 11:45 a.m.
Visited By Anson

Latitude 32.6^{o} Longitude 117^{o} Elevation <100'

Directions for finding station Make arrangements with Rob Taylor. Instrument is located on roof of one story service office.

Contact person: Name ~~Robin Taylor~~
Address ~~P.O. Box 1831 (101 Ash St.)~~
~~San Diego, Calif. 92112~~
Phone ~~(714) 232-4252 x1861~~
or Chuck Lischer

Insolation data: (measured)	hourly	daily	monthly	Frequency (recorded)
Total (global)	☐	☒	☐	
Direct	☐	☐	☐	
Sunshine Hours	☐	☐	☐	
Cloud Cover	☐	☐	☐	
Other				

Weather Data:	Yes	No	Frequency
Temperature (dry bulb)		X	
(wet bulb)		X	
Wind Speed (Ht.)		X	
Wind Direction		X	
Other		X	

Description of Solar Radiation Measuring Instruments

Manufacturer Eppley
Model 8-48
Serial No. 13925
Date of Installation October 1975
Calibration Constant 10.69×10^{-6} v/Wm^2
Last Calibration Date n/a
Condition of: Dome o.k.
Dessicant o.k.
Sensor o.k.
Leads o.k.
Level o.k.

Contact for Station History:
Name ~~Robin Taylor, SDG&E~~
Address ~~101 Ash St.~~
~~San Diego, Calif. 92112~~
Phone ~~(714) 232-4252~~
Instrument Location On roof of one story district office building-on 4'-4"x4" post.

Description of Recording Instrument

Manufacturer Bristol
Model 71A - 1PH 760-51
Serial No. -
Scale Units 0-2.0 ly
Description strip chart plus integrator

Type of Record
Strip Chart ☒
Magnetic Tape ☐
Circular Chart ☐
Hand Recorded ☐

Other Same recorder is used at all SDG&E stations.

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes ☒ No ☐
Describe Process Daily totals are taken by reading the number of peaks on integrator chart for the day. Hourly values could be obtained in a similar way.

Maintenance & Calibration Procedure

Frequency

Solar Radiometer /Recorder No calibration since receipt of instrument from factory--to be checked against traveling reference pyranometer from WEST Associates.

Results of Cross-Calibration with LBL Instruments
None performed.

Period(s) of Data Collection Data collected since October 1975 when instrument was installed. Most reliable data is since January 1976. Data recording system for all SDG&E stations is soon to be converted to magnetic cartridge and processed by So. California Edison (WEST Assoc.)

Solar Data Stored at: Contact ~~Robin Taylor, SDG&E~~
Address ~~101 Ash Street (PO Box 1831)~~
~~San Diego, California 92112~~
Phone ~~(714) 232-4252 x1861~~

Miscellaneous Comments: Instrument is mounted on a free standing post; subject to movement by wind; leveling is performed by placing gravel under one leg of base.

Station Name Davis

Organization National Weather Service

Date September 28, 1976

Time of Visit 9:15 to 10:30 PDST

Visited By Anson

Latitude 38° 32'N Longitude 121° 46' W Elevation ∿ 56'

Directions for finding station Take Hutchinson Drive west across Highway 113. Take a sharp left @ s-shaped turn in road, marked by group of signs. Turn right after first building and continue ∿ 100' to fenced-in area.

Contact person: Name Dick Miller

Address Agricultural Engineering, Room 1303
University of California
Davis, California 95616

Phone (916) 752-1432

or, Prof. Jerry Hatfield, Atmos. Sci. Sec: LAWR, 752-3243

Insolation data: (measured)

	hourly	daily	monthly	Frequency (recorded)
Total (global)		X		strip chart
Direct				
Sunshine Hours				
Cloud Cover				
Other				

Weather Data:

	Yes	No	Frequency
Temperature (dry bulb)	X		
(wet bulb)	X		
Wind Speed (Ht. ∿ 15')	X		
Wind Direction	X		
Other evaporation	X		

Description of Solar Radiation Measuring Instruments

Manufacturer Eppley

Model Light Bulb

Serial No. 2818

Date of Installation n/a

Calibration Constant 2.04 mv/ly min^{-1}

Last Calibration Date n/a

Condition of: Dome some dust

Dessicant n/a

Sensor greenish tinge, pitted, w/white ridges

Leads o.k.

Level o.k.

Contact for Station History:

Name Jerry Hatfield

Address Dept: LAWR
U.C. Davis, California 95616

Phone (916) 752-3243

Instrument Location on ∿ 6' mast in enclosed area in agricultural area

On well supported 3" pipe mast. Also wind vane and anemometer attached to same mast.

Description of Recording Instrument

Manufacturer Minneapolis Honeywell/Brown Electronic

Model n/a

Serial No. n/a

Scale Units 0-4 mv or 0-2 ly

Description

Other

Type of Record

- Strip Chart [X]
- Magnetic Tape [ ]
- Circular Chart [ ]
- Hand Recorded [ ]

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [X] No [ ]

Describe Process Daily total taken off chart, read into computer tapes, cards, etc.

Maintenance & Calibration Procedure — Frequency

RECORDER: Calibrated twice yearly by NWS electronics technician from Sacramento, calibrated to NWS standards. Recorder is referenced to standard cell every 4-6 minutes.

Results of Cross-Calibration with LBL Instruments

Average insolation values were in complete agreement with LBL PSP, while LBL B&W was an average of 5% low. Rapidly changing conditions.

Period(s) of Data Collection Solar data goes back to 1940's

Solar Data Stored at: Contact Dick Miller - raw data

Address Jerry Hatfield - computer tape

Phone

Miscellaneous Comments: *Data correction made for April-May-June 1976

*Some solar data questioned by NWS-dropped for 4 years.

*Started up again with new calibration policy.

*Davis is a benchmark (NOAA) station, e.g., a "standard" by which other stations are compared and changed to agree with this one.

*104 years (1872) rainfall data in Davis, began by Southern Pacific

70 years (1906) continuous temperature data.

Station Name Dixon

Date October 14, 1976

Organization Solano Irrigation District
U.S. Bureau of Reclamation

Time of Visit 9:15 a.m.

Visited By Anson

Latitude 38° 30'N Longitude 121° 50'W Elevation 60'

Directions for finding station Take Midway or Redrock Road off of I-80 near Dixon. Site is ∿ 1/4 mile off Redrock Road and ∿ 1/2 mile south of Midway Road behind isolated unit of farm labor housing project.

Contact person: Name ~~Vince LaNovara~~

Address ~~508 Elmira Road~~

~~Vacaville, Calif. 95688~~

Phone ~~(707) 448-6847~~

(916) 678-4414 (Dixon Office)

Insolation data: (measured)		hourly	daily	monthly	Frequency (recorded)
	Total (global)	[ ]	[x]	[ ]	
	Direct	[ ]	[ ]	[ ]	
	Sunshine Hours	[ ]	[ ]	[ ]	
	Cloud Cover	[ ]	[ ]	[ ]	
	Other				

Weather Data:		Yes	No	Frequency
	Temperature (dry bulb)	X		
	(wet bulb)	X		
	Wind Speed (Ht. ∿8')	X		
	Wind Direction		X	
	Other evaporation	X		

Description of Solar Radiation Measuring Instruments

Manufacturer Matrix, Inc. Phoenix, Arizona

Model Mark XIV (Sol-A-Meter)

Serial No. not available

Date of Installation approx. May 1976

Calibration Constant n/a

Last Calibration Date June 1975

Condition of: Dome n/a

Dessicant n/a

Sensor n/a

Leads n/a

Level n/a

Contact for Station History:

Name ~~Gordon Lyford, U.S.B.R.~~

Address ~~Room W2212, 2800 Cottage~~ Wy.

~~Sacramento, California~~

Phone ~~(916) 484-4656~~

Instrument Location Inside 10'x10' chain link fence enclosure on top of 4'4" x4" post on north side of weather shelter.

Description of Recording Instrument

Manufacturer Matrix, Inc. Phoenix, Arizona

Model Mark XIV

Serial No. (same unit as sensor)

Scale Units 0-2 ly meter; digital integrator readout

Type of Record

Strip Chart [ ]

Magnetic Tape [ ]

Circular Chart [ ]

Hand Recorded [x]

Other Recorder gives both instantaneous values and daily totals.

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [x] No [ ]

Describe Process Raw data reported to USBR office in Sacramento. Calibration constant is used with computer program to tabulate data and for use in evaporation/irrigation studies.

Maintenance & Calibration Procedure

Frequency

Solar Radiometer/Recorder Calibrated at factory. Batteries checked periodically.

Results of Cross-Calibration with LBL Instruments Not performed.

Period(s) of Data Collection May 1976 to present, intermittant record due to frequent problems with recorder. *Data is also available from Vince LaNovara at Solano Irrigation District, Vacaville in both raw and reduced form.

Solar Data Stored at: Contact ~~Gordon Lyford, U.S.B.R.~~

Address ~~Room W2212, 2800 Cottage~~ Wy.

~~Sacramento, CA~~

Phone ~~(916) 484-4656~~

Miscellaneous Comments: Station has experienced several instrument failures in its short existence (as was the case during this station visit).

Station Name El Cajon | Date September 30, 1976

Organization San Diego Gas & Electric | Time of Visit 2:30 pm

Visited By Anson

Latitude 32.8° Longitude 116.9° Elevation 300E

Directions for finding station Make arrangements with Rob Taylor. Instrument is on roof of building used for district equipment/ construction operations.

Contact person: Name ~~Robin Taylor, S.D.G.&~~E.

Address ~~101 Ash Stre~~et

~~San Diego, California 9~~2112

Phone ~~(714) 232-4252 ext. 1~~861

or Chuck Lischer
Doyle Miller

Insolation data: (measured)

	hourly	daily	monthly	Frequency (recorded)
Total (global)		X		strip charts
Direct				
Sunshine Hours				
Cloud Cover				
Other				

Weather Data:

	Yes	No	Frequency
Temperature (dry bulb)		X	
(wet bulb)		X	
Wind Speed (Ht.___)		X	
Wind Direction		X	
Other		X	

Description of Solar Radiation Measuring Instruments

Manufacturer Eppley

Model 8-48

Serial No. 13872

Date of Installation October 1975

Calibration Constant 10.55×10^{-6} v/Wm^2

Last Calibration Date from factory

Condition of: Dome ok

Dessicant pink

Sensor ok

Leads ok

Level out of circle

Contact for Station History:

Name ~~Robin Taylor, SDG&E~~

Address ~~101 Ash Street~~

~~San Diego, CA 92112~~

Phone ~~(714)232-4252 x1861~~

Instrument Location on 4' x 2x4" attached to base of HVAC equipment on roof

Description of Recording Instrument

Manufacturer Bristol

Model 71A-1PH760-51

Serial No. 75A-10304

Scale Units 0-2.01y

Description also has integrator chart

Type of Record

Strip Chart [X]

Magnetic Tape [ ]

Circular Chart [ ]

Hand Recorded [ ]

Other same type of recorder is used at other 5 stations

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [X] No [ ]

Describe Process Daily totals are obtained by reading the number of peaks on integrator chart for each day. Hourly values could possibly be obtained from these charts.

Maintenance & Calibration Procedure

Frequency

Solar Radiometer/Recorder No calibration since receipt from factory. Will be checked against traveling reference pyronometer (West Assoc.) in future. Dessicant routinely changed when needed.

Results of Cross-Calibration with LBL Instruments

Instrument average 1.6% higher than LBL PSP.

Period(s) of Data Collection

Since October 1975.

Solar Data Stored at: Contact ~~Rob Taylor / San Diego Gas & Electric~~

Address ~~101 Ash St.~~

~~San Diego, CA 921~~12

Phone ~~(714) 232-4252 x1861~~

Miscellaneous Comments: Instrument is subject to vibrations from HVAC equipment to which it is attached.

Station Name Folsom Dam

Date October 13, 1976

Organization U.S. Bureau of Reclamation

Time of Visit 3:45 p.m.

Visited By Anson

Latitude 38° 42'N Longitude 121° 09W Elevation 350'

Directions for finding station Take U.S. 50 from Sacramento eastbound. Turn off toward Folsom Dam and travel ~ 5 miles to U.S.B.R. offices near west end of dam. Weather station is ~ ½ mile east of station near west end of dam.

Contact person: Name Bill Grangood (also Corky Millsap)

Address or Tom Perez

Phone (916) 988-1707

Insolation data: (measured)	hourly	daily	monthly	Frequency (recorded)
Total (global)	☐	☒ X	☐	
Direct	☐	☐	☐	
Sunshine Hours	☐	☐	☐	
Cloud Cover	☐	☐	☐	
Other				

Weather Data:	Yes	No	Frequency
Temperature (dry bulb)	X		
(wet bulb)	X		
Wind Speed (Ht. 8')	X		
Wind Direction		X	
Other Evaporation	X		

Description of Solar Radiation Measuring Instruments

Manufacturer Matrix, Inc., Phoenix, Arizona

Model Mark XIV (Sol-A-Meter)

Serial No. 2419

Date of Installation April 1976

Calibration Constant .294 cal cm^{-2}

Last Calibration Date April 20, 1976

Condition of: Dome some dust

Dessicant white

Sensor o.k.

Leads n/a

Level o.k.

Contact for Station History:

Name ~~Gordon Lyford, U.S.B.R.~~

Address ~~Room W2212~~ ~~2800 Cottage Way~~ ~~Sacramento, California~~

Phone ~~(916) 484-4656~~

Instrument Location Inside fenced area on 5' mast of 3" diameter pipe.

Description of Recording Instrument

Manufacturer same unit as above

Model

Serial No.

Scale Units 0-2 ly meter; digital integrator readout

Type of Record

Strip Chart ☐

Magnetic Tape ☐

Circular Chart ☐

Hand Recorded ☒ X

Other Recorder gives both instantaneous values and daily totals.

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes ☒ X No ☐

Describe Process Data is reported to Gordon Lyford at U.S.B.R. in Sacramento, who uses calibration constant and computer program to tabulate data.

Maintenance & Calibration Procedure

	Frequency
Solar Radiometer/Recorder checked beside old (previous) instrument used at this site, calibration constant changed on new instrument to agree with old.	none

Results of Cross-Calibration with LBL Instruments No measurements made due to lack of available 110 vac electrical power. Option available to arrange a return visit.

Period(s) of Data Collection Copy of data obtained; June 1974 to present.

Solar Data Stored at: Contact ~~U.S. Bureau of Reclamation~~

Address ~~2800 Cottage Way~~

~~Sacramento, California~~

Phone ~~(916) 484-4656~~

Miscellaneous Comments: Instrument no. 1173 was previously located at Folsom Dam. It is now at the Institute of Forest Genetics, Placerville. This instrument has a mechanical meter readout (e.g., gas meter type). Meter was recently changed and so calibration constant is now .183 (was .294). Instrument no. 1173 was used to calibrate no. 2419 which now operates at this site.

John Monteith (U.S.B.R.) commented that mechanical meters were frequently mis-read. Digital displays have somewhat solved this problem, although there are still 1-2 errors per month.

No observations near instrument, but possible problem with nearby flood lights that are turned on at night.

Station Name Fresno | Date October 1, 1976

Organization California State University, Dept. of Geography | Time of Visit 1:45 p.m.

Visited By Anson

Latitude 36° 49'N Longitude 119° 44'W Elevation 335'

Directions for finding station Meteorology shelter is located on east side of campus near perimeter road. Contact Department of Geography for access.

Contact person: Name Don Morgan ~~(Prof.)~~

Address ~~Dept. of Geography~~

~~Calif. State University~~

Phone ~~Fresno, California~~

(209) 487-2431, also, Bill Slusser (x1034) Met. Tech. or, Dept. of Geography 487-2797

Insolation data: (measured)

	hourly	daily	monthly	Frequency (recorded)
Total (global)	[ ]	[X]	[ ]	strip chart
Direct	[ ]	[ ]	[ ]	
Sunshine Hours	[ ]	[ ]	[ ]	
Cloud Cover	[ ]	[ ]	[ ]	
Other				

Weather Data:

	Yes	No	Frequency
Temperature (dry bulb)	X		
(wet bulb)	X		
Wind Speed (Ht. ~ 25')	X		
Wind Direction	X		
Other air quality	X		

Description of Solar Radiation Measuring Instruments

Manufacturer Eppley

Model 2 (precision type)

Serial No. 10569 F4

Date of Installation fall 1972

Calibration Constant 4.69 mv/ly/min

Last Calibration Date August 14, 1970

Condition of: Dome ~ 9 white specks

Dessicant blue/pink

Temp. Comp. -40°-20°C

Sensor o.k.

Leads o.k.

Level slightly off

Contact for Station History:

Name ~~Don Morgan~~

Address ~~Dept. of Geography~~

~~CSU-Fresno~~

Phone ~~(209) 487-2431~~

Instrument Location On roof of 15' brick building.

Description of Recording Instrument

Manufacturer Bristol

Model Dynamaster

Serial No. 64A-EL-1PH1X760-51

Scale Units 0-2 $ly\ min^{-1}$

Description

Type of Record

Strip Chart [X]

Magnetic Tape [ ]

Circular Chart [ ]

Hand Recorded [ ]

Other

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [ ] No [X]

Describe Process Data is stored in department, not processed or recorded.

Maintenance & Calibration Procedure — Frequency

Solar Radiometer Weather Bureau (NWS) in Fresno/is called several times per year to check reading.

Recorder: Adjusted to match calibration on pyranometer.

Results of Cross-Calibration with LBL Instruments: Station instrument averaged 5.7% higher than LBL-PSP.

Period(s) of Data Collection fall 1972 to present

Solar Data Stored at: Contact ~~Don Morgan/Bill Slusser~~

Address ~~Dept. of Geography~~

~~CSU/Fresno~~

Phone ~~(209) 487-2431~~

Miscellaneous Comments: Possible shading from rapidly growing Eucalyptus trees to SW.

Station Name Fresno

Organization National Weather Service NOAA

Date October 1, 1976

Time of Visit 10:30 a.m.

Visited By Anson

Latitude 36° 49'N Longitude 119° 44'W Elevation 335'

Directions for finding station Located at Fresno Airport. Instrument is on roof of small building near parking lot. NWS office is inside terminal.

Contact person: Name Ron Stevens, NWS

Address Fresno Air Terminal

Fresno, California

Phone (209) 555-5593 also, Tom Crossan, meteorologist in charge.

Insolation data: (measured)		hourly	daily	monthly	Frequency (recorded)
	Total (global)	[ ]	[X]	[ ]	
	Direct	[ ]	[ ]	[ ]	
	Sunshine Hours	[ ]	[X]	[ ]	Sunshine switch*
	Cloud Cover	[X]	[ ]	[ ]	
	Other *Foster Mfg. Co.				

Weather Data:		Yes	No	Frequency
	Temperature (dry bulb)	X		
	(wet bulb)	X		
	Wind Speed (Ht.____)	X		
	Wind Direction	X		
	Other precip.	X		

Description of Solar Radiation Measuring Instruments

Manufacturer Eppley

Model 2 (no Eppley label)

Serial No. 114 41 F3

Date of Installation 1974-75

Calibration Constant 2.4*mV/ly min. (on instr.)

Last Calibration Date n/a

Condition of: Dome clean (cleaned weekly)

Dessicant pink

Sensor o.k.

Leads o.k.

Level o.k.

Temperature compensated -40 to + 40°C

Contact for Station History:

Name ~~Tom Crossan NWS~~

Address ~~Fresno Air Terminal~~

~~Fresno, California~~

Phone ~~(209) 555-5593~~

Instrument Location on roof of 10' high block building, on 2' mast (new instruments on order).

*2.28 on NWS records

Description of Recording Instrument

Manufacturer Honeywell

Model Electronik 151y15401826-01-(01)-0-000-002-07

Serial No. F6520638002

Scale Units 0-2 ly

Description chart reads 0-40

Other Recorder is ~ 1 block from instrument (380').

Type of Record

Strip Chart [X]

Magnetic Tape [ ]

Circular Chart [ ]

Hand Recorded [ ]

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [ ] No [X]

Describe Process Solar noon value is only one recorded.

Maintenance & Calibration Procedure — Frequency

Solar Radiometer/Recorder Clear solar noon calculation made and compared with measured value and then reported to Asheville.

Results of Cross-Calibration with LBL Instruments

Station instrument averaged 8.9% higher than LBL-PSP.

Period(s) of Data Collection 1961 to present.

Solar Data Stored at: Contact ~~National Climatic Center~~

Address ~~Environmental Data Service~~

~~Federal Building~~

Phone ~~Asheville, NC 28801~~

Miscellaneous Comments: Possible reflections onto sensor from nearby aluminum dome.

Station Name Gerber
Organization Dept. of Water Resources

Date 10/26/76
Time of Visit 12:45 p.m. PDST
Visited By Anson

Latitude 40° 02'N Longitude 122° 09'W Elevation 230'

Directions for finding station Located in an irrigated pasture about 5 miles south of Red Bluff. Make arrangements with Clyde Muir for a visit.

Contact person: Name Clyde Muir
Address P. O. Box 607
Red Bluff, California 96080
Phone (916) 527-6530

Insolation data: (measured)		hourly	daily	monthly	Frequency (recorded)
	Total (global)	[ ]	[x] +	[x]	
	Direct	[ ]	[ ]	[ ]	
	Sunshine Hours	[ ]	[ ]	[ ]	
	Cloud Cover	[ ]	[ ]	[ ]	
	Other				

Weather Data:		Yes	No	Frequency
	Temperature (dry bulb)	x		
	(wet bulb)	x		
	Wind Speed (Ht. ∿ 2m)	x		
	Wind Direction		x	
	Other evaporation	x		

Description of Solar Radiation Measuring Instruments

Manufacturer Belfort Instrument Co.
Model Catalog no. 5-3850-pyranograph
Serial No. 762 (DWR #D3408)
Date of Installation n/a
Calibration Constant n/a
Last Calibration Date June 1976
Condition of: Dome clean
Dessicant n/a
Sensor some black flakes missing and some streaks.
Leads n/a
Level tilted slightly to south

Case darkened by rust in places grey/green in color.

Contact for Station History:
Name ~~Clyde Muir, DWR~~
Address ~~P. O. Box 607~~
~~Red Bluff, California 96080~~
Phone ~~(916) 527-6530~~
Instrument Location: In open, irrigated pasture.

Description of Recording Instrument

Manufacturer same as above
Model
Serial No.
Scale Units
Description

Type of Record
Strip Chart [x]
Magnetic Tape [ ]
Circular Chart [ ]
Hand Recorded [ ]

Other

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [x] No [ ]

Describe Process Charts are planimetered to get daily totals.

Maintenance & Calibration Procedure

	Frequency
Solar Radiometer/Recorder Instruments are taken to Davis and operated for 2-3 weeks every June/December, "comparison" done, average deviation between 0-10%	

Results of Cross-Calibration with LBL Instruments Not performed.

Period(s) of Data Collection Since 1966. First calibrated Jan. 1967.

Solar Data Stored at: Contact ~~Clyde Muir~~ /DWR
Address ~~PO Box 607~~
~~Red Bluff, CA 96080~~
Phone ~~(916) 527-6530~~

Miscellaneous Comments:

Station Name: Las Vegas
Date: December 26, 1976
Organization: NWS
Time of Visit: 1:15 PST
Visited By: Berdahl

Latitude: 36° 5' Longitude: 115° 10' Elevation: 2162'

Directions for finding station: West side of the Las Vegas Airport on top of building. Near the new Hughes Air charter terminal.

Contact person: Name: Frank Taylor
Address: NWS Office 6000 Las Vegas Blvd. S.
Las Vegas, Nevada
Phone:

Insolation data: (measured)

	hourly	daily	monthly	Frequency (recorded)
Total (global)		X		
Direct				
Sunshine ~~Hours~~ minutes		X		
Cloud Cover	X			
Other				

Weather Data:

	Yes	No	Frequency
Temperature (dry bulb)	X		
(wet bulb)	X		
Wind Speed (Ht. 20') (above ground level)	X		
Wind Direction	X		
Other: rain gauges	X		

Description of Solar Radiation Measuring Instruments

Manufacturer: Eppley
Model: 2 (PSP type)
Serial No.: 10504 F3
Date of Installation: December 1976
Calibration Constant: 2.33 Mv $(Lmin)^{-1}$ IPS
Last Calibration Date: n/a
Condition of: Dome: light dust
Dessicant: blue
Sensor: black central surface
Leads: o.k.
Level: n/a

Contact for Station History:
Name: ~~Frank Taylor, NWS~~
Address: ~~6000 Las Vegas Blvd. S.~~
Las Vegas, ~~Nevada~~
Phone:
Instrument Location: 7' pole
5 lb. force moves top 1/2"
7' above 1½ story building.

Description of Recording Instrument

Manufacturer: Brown Electronik
Model: Y152x14v-x-11v
Serial No.: 341062
Scale Units: full scale = 2 cal cm^{-2} min^{-1}
Description: 10" radius circular chart
Other: Has integrator which displays running numerical total.

Type of Record
- Strip Chart [ ]
- Magnetic Tape [ ]
- Circular Chart [X]
- Hand Recorded [ ]

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [ ] No [X]

Describe Process: Send in daily circular chart. Reading of pyranometer at solar noon sent in if it is clear.

Maintenance & Calibration Procedure — Frequency
Solar Radiometer/Recorder: n/a

Results of Cross-Calibration with LBL Instruments: Not performed.

Period(s) of Data Collection: 1949 to present.

Solar Data Stored at: Contact: ~~National Climatic Center~~
Address: ~~Federal Building~~
~~Asheville, NC 28801~~
Phone:

Miscellaneous Comments: Previous instrument was struck by lightning. Present instrument seems to be a temporary set-up; they have a new instrument that may not be installed for several months.

Station Name Livermore

Date September 23, 1976

Organization U.C. Lawrence Livermore Laboratory

Time of Visit 11:50 a.m.

Visited By Anson

Latitude 37.6° Longitude 121.6° Elevation 500E

Directions for finding station Call ahead of time (several days) and arrange for visitor's pass and escort onto lab.

Contact person: Name Gary Roseme/Arnold Clark

Address Lawrence Livermore Laboratory
Livermore, California

Phone (8) x5331

Insolation data: (measured)		hourly	daily	monthly	Frequency (recorded)
	Total (global)	x			
	Direct				planned
	Sunshine Hours				
	Cloud Cover				
	Other				

Weather Data:		Yes	No	Frequency
	Temperature (dry bulb)	x		strip charts
	(wet bulb)		x	
	Wind Speed (Ht.)	x		
	Wind Direction	x		
	Other			

Description of Solar Radiation Measuring Instruments

Manufacturer Eppley

Model 8-48

Serial No. 13570

Date of Installation approx. 1974

Calibration Constant 11.0. x 10^{-6} v/wm^{-2}

Last Calibration Date April 27, 1976

Condition of: Dome dust marks from dew

Dessicant pink and blue

Sensor o.k.

Leads o.k.

Level o.k.

Contact for Station History:

Name ~~Gary Roseme~~

Address ~~LLL~~
~~Livermore, California~~

Phone ~~x8693~~

Instrument Location roof of building 121 (LLL), attached to HVAC box

Description of Recording Instrument

Manufacturer Leeds Northrup

Model unknown

Serial No. (1962)

Scale Units 0-1000 w/m^2

Description

Other

Type of Record

Strip Chart [x]

Magnetic Tape [ ]

Circular Chart [ ]

Hand Recorded [ ]

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [x] No [ ]

Describe Process Strip chart is photographed, then digitized with a film scanner. Data is stored on a photo chip.

Maintenance & Calibration Procedure

Frequency

Solar Radiometer/Recorder lab (inside) pyranometer used to check B&W on roof (monthly-quarterly?) Recorder: twice daily. Precision voltage inserted at pyranometer via relay and timer; gives 1 ly reading, morning reading gives correction factor which is automatically included into data reduction.

Results of Cross-Calibration with LBL Instruments LLL instrument averaged 4% lower than LBL PSP.

Period(s) of Data Collection approx. 2 years, data begins Jan 1974 - Oct. '76.

Solar Data Stored at: Contact ~~Dick Neifert~~

Address ~~Lawrence Livermore Laboratory~~
~~Livermore, California~~

Phone

Miscellaneous Comments: Recorder calibrations: 1) 0 reading; 2) 1 ly reading

Station Name: Long Beach
Date: September 29, 1976
Organization: Calif. State University
Time of Visit: 11:20 a.m.
Visited By: Anson

Latitude: 33° 46' Longitude: 118° 11' Elevation: 35'

Directions for finding station: Contact John Kimura in the Geography Department for access to instrument which is on top of adjacent building.

Contact person: Name: John Kimura (Prof.)
Address: Dept. of Geography (Bldg. LA4, Room 105)
Cal. State University, Long Beach, 1250 Bellflower Blvd. Long Beach, CA 90840
Phone: (213) 498-4977

Insolation data: (measured)

	hourly	daily	monthly	Frequency (recorded)
Total (global)		X		
Direct				
Sunshine Hours		X		not in use
Cloud Cover		X		occasional
Other				

Weather Data:

	Yes	No	Frequency
Temperature (dry bulb)	X		daily
(wet bulb)	X		daily
Wind Speed (Ht. ~80')	X		daily
Wind Direction	X		daily
Other precipitation air quality	X		daily

Description of Solar Radiation Measuring Instruments

Manufacturer: Kahlisco
Model: Star Pyranometer
Serial No.: 962
Date of Installation: approx. 1974
Calibration Constant: n/a
Last Calibration Date: n/a
Condition of: Dome: clean
Dessicant: underneath, n/a
Sensor: black sections have white streaks
Leads: "bubbled" i.e., overheated by sun
Level: o.k.

Contact for Station History:
Name: John Kimura
Address: Dept. of Geography
CSU-Long Beach
Phone: (213) 498-4950
Instrument Location: On roof of 4 story Business Admin. Bldg.

Description of Recording Instrument

Manufacturer: Weather Measure
Model: R12 V-1
Serial No.: 101
Scale Units: 0-2.5 ly full scale
Description:

Type of Record
Strip Chart [X]
Magnetic Tape [ ]
Circular Chart [ ]
Hand Recorded [ ]

Other:

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [X] No [ ]
Describe Process: half hour values are summed and multiplied by 30 to give daily totals.

Maintenance & Calibration Procedure

Frequency

Solar Radiometer /Recorder: None for pyranometer; recorder is checked against chart of clear day values to check for problems. Recorder is ~ 5 years old, jams occasionally, calibrated 2 years ago (?); values suspected to be ~ 10% off.

Results of Cross-Calibration with LBL Instruments: Station instrument averaged 15% lower than LBL-PSP.

Period(s) of Data Collection: approx. 1971, solar data may be more recent.

Solar Data Stored at: Contact: Prof. John Kimura
Address: Dept. of Geography
CSU, Long Beach, CA 90840
Phone:

Miscellaneous Comments: 1) Sunshine recorder: Campbell - Stokes, glass ball type. 2) Previous instrument used for solar data until approx. 1974, very old model Eppley (Model R411) serial number 108; twice the size of most Eppley light bulb types.

Station Name Los Angeles Airport   Date July 26, 1976
Organization National Weather Service   Time of Visit 10:00 a.m.
Visited By Martin

Latitude 33°56'   Longitude 118°24'   Elevation 105'

Directions for finding station From Century Blvd., turn south on Sepulveda and turn right approx. 100 feet through break in fence, proceed parallel to Sepulveda and turn right at guard house just before runway.

Contact person: Name Stan Bryte, Director
Address 11000 Wilshire Blvd.
Los Angeles, California 90024
Phone (213) 824-7216

Insolation data: (measured)

	hourly	daily	monthly	Frequency (recorded)
Total (global)		X		
Direct				
Sunshine Hours				
Cloud Cover				
Other				

Weather Data:

	Yes	No	Frequency
Temperature (dry bulb)	X		
(wet bulb)	X		
Wind Speed (Ht.)	X		
Wind Direction	X		
Other	X		

Description of Solar Radiation Measuring Instruments

Manufacturer Eppley
Model Model 10
Serial No. n/a
Date of Installation n/a
Calibration Constant n/a
Last Calibration Date n/a monthly
Condition of: Dome n/a
Dessicant n/a
Sensor n/a
Leads n/a
Level n/a

Contact for Station History:
Name David ~~Rogers NWS/NOAA~~
Address ~~11000 Wilshire Blvd.~~
~~Los Angeles, California 90024~~
Phone (213) ~~824-7216~~
Instrument Location on roof of 1-story building next to an aluminum dome 5 feet in diameter.

Description of Recording Instrument

Manufacturer Brown Co.
Model n/a
Serial No. n/a
Scale Units 0-2 ly
Description has integrator that totals radiation at 30 second intervals and accumulates daily totals.
Other

Type of Record
Strip Chart [ ]
Magnetic Tape [ ]
Circular Chart [X]
Hand Recorded [ ]

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [ ] No [X]
Describe Process

Maintenance & Calibration Procedure   Frequency
Solar Radiometer/Recorder Monthly checks are made for noon values on clear days and reported as percent of possible sunshine; e.g., noon value = % possible extraterrestrial

Results of Cross-Calibration with LBL Instruments LA NWS station averaged 17% high.

Period(s) of Data Collection 1949 to present.

Solar Data Stored at: Contact U.S. Dept. of Commerce
Address National Climatic Center, Federal Bldg.
Asheville, N.C. 28801
Phone

Miscellaneous Comments: The aluminum dome may contribute 10% additional energy in late afternoon by reflection. Dome was installed August 26, 1975.

Station Name Monterey
Date November 11, 1976
Organization U.S. Navy-Post Graduate School
Time of Visit 11:45 a.m.
Visited By Anson

Latitude 36°36' Longitude 121°52' Elevation NSL

Directions for finding station Instrument is on roof of Building 235 (Roof Hall), recorder is in lobby outside Room 119. Take Highway 101 to Del Monte (PGS sign).

Contact person: Name Mike McDermott
Address USN - PGS, Code 63
Monterey, California 93940
Phone (408) 646-2295
also: Bob Reynard 646-2295

Insolation data: (measured)

	hourly	daily	monthly	Frequency (recorded)
Total (global)	[ ]	[x]	[ ]	
Direct	[ ]	[ ]	[ ]	
Sunshine Hours	[x]	[ ]	[ ]	now inoperative
Cloud Cover	[ ]	[ ]	[ ]	
Other				

Weather Data:

	Yes	No	Frequency
Temperature (dry bulb)	x		
(wet bulb)		x	
Wind Speed (Ht.)	x		
Wind Direction	x		
Other			

Description of Solar Radiation Measuring Instruments (FIRST INSTRUMENT)

Manufacturer Eppley
Model 50
Serial No. 3677
Date of Installation n/a
Calibration Constant 8.75 mV/cal cm^{-2} min^{-1}
Last Calibration Date n/a
Condition of: Dome clean except for 3/8" dia. bird dropping
Dessicant n/a
Sensor o.k.
Leads o.k.
Level tilts to SW

Contact for Station History:
Name Mike McDermott
Address USN PGS, Code 63
Monterey, CA 93940
Phone
Instrument Location On roof of one-story building, located in a recessed hole of the roof of an instrument enclosure.

Description of Recording Instrument

Manufacturer Belfort Instrument Co.
Model AW (AN/GMQ - 14B)
Serial No. 32921
Scale Units 0-5 millamperes
Description
Other

Type of Record
Strip Chart [x]
Magnetic Tape [ ]
Circular Chart [ ]
Hand Recorded [ ]

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [ ] No [x]
Describe Process stored, would be willing to provide and coordinate more if interest or program was available.

Description of Solar Radiation Measuring Instruments (SECOND INSTRUMENT)

Manufacturer Sol-A-Meter
Model Mark IV
Serial No. 1209
Date of Installation n/a
Calibration Constant n/a
Last Calibration Date n/a
Condition of: Dome n/a
Dessicant unable to see
Sensor purple
Leads none
Level slightly off

Contact for Station History:
Name Mike McDermott
Address
Phone
Instrument Location

Description of Recording Instrument

Manufacturer n/a
Model n/a
Serial No. n/a
Scale Units 0-2 ly min^{-1}
Description ampere hour meters (ie gas meters) 2½ amps, 330 rev/ah. Sold by Weathermeasure, Sacramento DTI Div, Talley Industries, Tempe, Arizona
Other
NO SPOTCHECK MADE. Instrument is not really being used currently.

Type of Record
Strip Chart [ ]
Magnetic Tape [ ]
Circular Chart [ ]
Hand Recorded [x]

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [ ] No [ ]
Describe Process

Maintenance & Calibration Procedure

	Frequency
Solar Radiometer/Recorder none	

Results of Cross-Calibration with LBL Instruments No data available.

Period(s) of Data Collection About 3 1/2 years of data.

Solar Data Stored at: Contact Mike McDermott
Address USN PGS, Code 63
Monterey, CA 93940
Phone (408) 646-2295

Miscellaneous Comments: recorder (DVM) problems. The pyranometer does not have an unobstructed view of the horizon since it is recessed into a hole at the peak of the roof of an instrument enclosure.

Station Name Redding

Date October 26, 1976

Organization Shasta College/DWR

Time of Visit 3:00 p.m.

Visited By Anson

Latitude $40^{o}35'$ Longitude $122^{o}34'$ Elevation 580'

Directions for finding station Located in fenced area with other weather instruments on campus.

Contact person: Name Clyde Muir /DWR

Address P. O. Box 607
Red Bluff, Ca. 96080

Phone (916) 527-6530

Insolation data: (measured)

	hourly	daily	monthly	Frequency (recorded)
Total (global)		X		
Direct				
Sunshine Hours				
Cloud Cover				
Other				

Weather Data:

	Yes	No	Frequency
Temperature (dry bulb)	X		
(wet bulb)	X		
Wind Speed (Ht. 5')	X		
Wind Direction	X		
Other evaporation	X		

Description of Solar Radiation Measuring Instruments

Manufacturer Instrument Corp. (pyranograph)

Model 5-5850

Serial No. 225

Date of Installation approx. 1969

Calibration Constant n/a

Last Calibration Date n/a

Condition of: Dome clean

Dessicant n/a

Sensor n/a

Leads n/a

Level n/a

Contact for Station History:

Name ~~Clyde Muir/DWR~~

Address ~~PO Box 607~~
~~Red Bluff, CA 96080~~

Phone ~~(916) 527-6530~~

Instrument Location on Shasta College campus

Description of Recording Instrument

Manufacturer Instrument Corp.

Model 5-5850

Serial No. 225

Scale Units 0 - 2 ly

Description (same unit as sensor)

Other

Type of Record

Strip Chart	X
Magnetic Tape	
Circular Chart	
Hand Recorded	

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [X] No [ ]

Describe Process Charts are sent to Clyde Muir (DWR, Red Bluff) for planimetering.

Maintenance & Calibration Procedure

Frequency

Solar Radiometer/Recorder taken to Davis and operated every 2-3 weeks, twice a year; average deviation 0-10%. Changes rarely made.

Results of Cross-Calibration with LBL Instruments; Pyranograph averaged 24.8% higher than LBL-PSP.

Period(s) of Data Collection Since approximately 1969.

Solar Data Stored at: Contact ~~Clyde Muir/DWR~~

Address ~~PO Box 607~~
~~Red Bluff, CA 96080~~

Phone (916) 527-6530

Miscellaneous Comments:

Station Name Redwood City

Date Sept. 21, 1976

Organization Bay Area Air Pollution Control District

Time of Visit 1:00 p.m.

Visited By Anson

Latitude 37.4° Longitude 122.3° Elevation NSL

Directions for finding station Travel south of San Francisco on the Bayshore Freeway (Hwy. 101). Turn off at Hwy 84 west/Woodside Road and take a left at the second intersection - Bay Road. Go 1/2 mile to Barron and turn right.

Contact person: Name Alan Butler

Address 897 Barron
Redwood City, CA

Phone 365-2876

Insolation data: (measured)

	hourly	daily	monthly	Frequency (recorded)
Total (global)	X			daily
Direct				
Sunshine Hours				
Cloud Cover		X		daily
Other				

Weather Data:

	Yes	No	Frequency
Temperature (dry bulb)	X		hourly
(wet bulb)	X		hourly
Wind Speed (Ht. ~ 18')	X		hourly
Wind Direction	X		hourly
Other air pollution instruments	X		hourly

Description of Solar Radiation Measuring Instruments

Manufacturer Eppley

Model 50

Serial No. 7736

Date of Installation N/A

Calibration Constant 5.5 mV/cal cm^{-2} min^{-1}

Last Calibration Date N/A

Condition of: Dome clean

Dessicant n/a

Sensor greenish tinge with white oxidation streaks

Leads o.k.

Level too large of a bubble

Contact for Station History:

Name ~~Mike Basso (BAAPCD)~~

Address ~~939 Ellis Street~~
~~San Francisco, California 94109~~

Phone ~~(415) 771-6000~~

Instrument Location roof of 1 story building-on unstable 8' mast - moves in wind

Description of Recording Instrument

Manufacturer Esterline Angus

Model 602

Serial No. 163754

Scale Units 0-1 milliamps

Description 2 channel recorder

Other

Type of Record

- Strip Chart [X]
- Magnetic Tape [ ]
- Circular Chart [ ]
- Hand Recorded [ ]

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [X] No [ ]

Describe Process Hourly data from previous day is taken from strip chart, values are interpolated for each hour and totaled for day. Chart reading is multipled by 2 and then by .6 when entered on the recording sheet sent to main office.

Maintenance & Calibration Procedure

Solar Radiometer/Recorder checked about 4 months ago by Chuck Kingsley, S.F. Office. Recorder: None

Frequency: No apparent routine

Results of Cross-Calibration with LBL Instrument Model 50 averaged 7.5% lower than LBL-PSP.

Period(s) of Data Collection 1964 to present.

Solar Data Stored at: Contact ~~Mike Basso - BAAPCD~~

Address ~~939 Ellis St.~~
~~San Francisco, CA 94109~~

Phone ~~(415) 771-6000~~

Miscellaneous Comments:

Station Name Reno

Date October 22, 1976

Organization National Weather Service (COOP)

Time of Visit 2:30 p.m.

Visited By Anson

Latitude 39° 30'N Longitude 119° 47'W Elevation 4408'

Directions for finding station At Reno airport between main terminal and red building (NOAA/NWS office).

Contact person: Name Doug Armstrong/Dan Gudgel
Address 2601 E. Plumb Lane
Reno, Nevada 89502
Phone (702) 784-5462

Insolation data: (measured)		hourly	daily	monthly	Frequency (recorded)
	Total (global)	☐	☒	☐	daily
	Direct	☐	☐	☐	
	Sunshine Hours	☐	☒	☐	
	Cloud Cover	☐	☐	☐	
	Other				

Weather Data:		Yes	No	Frequency
	Temperature (dry bulb)	X		
	(wet bulb)	X		
	Wind Speed (Ht. 10 m)	X		
	Wind Direction	X		
	Other precipitation	X		

Description of Solar Radiation Measuring Instruments

Manufacturer Eppley
Model 10 (rebuilt)
Serial No. 6102
Date of Installation approx. 1965
Calibration Constant 1.64 mV/ly min^{-1}
Last Calibration Date 3-17-75 (rebuilt)
Condition of: Dome some dust
Dessicant o.k.
Sensor o.k.
Leads o.k.
Level slightly off

Contact for Station History:
Name ~~Joe Ganser~~
Address ~~2601 Plumb Lane~~
~~Reno, Nevada 89502~~
Phone ~~(702) 784-5462~~
Instrument Location on top of 1 story bldg.

Description of Recording Instrument

Manufacturer Electronik
Model 18
Serial No. n/a
Scale Units 0-10 (0-2 ly)
Description
5 mV input

Type of Record
Strip Chart ☒
Magnetic Tape ☐
Circular Chart ☐
Hand Recorded ☐

Other Sunshine switch: U.S. Dept. Comm. #137229 WB-Z factor added to data to account for mtns. on horizon. Calibrated 2-28-69. Also mechanical counter-integrator.

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes ☐ No ☒

Describe Process Value taken off counter, subtracted from previous day's reading and # ly read onto chart.

Maintenance & Calibration Procedure

	Frequency
Solar Radiometer/Recorder Calibration by U. of Nevada Dept. Plant, Soil & Water Science (702) 784-6947	

Results of Cross-Calibration with LBL Instruments No data available.

Period(s) of Data Collection February 1967 to present. Possibly 1964-65 at U. of Nevada.

Solar Data Stored at: Contact ~~Joe Ganser /NWS~~
Address ~~2601 Plumb Lane~~
~~Reno, Nevada 89502~~
Phone ~~(702) 784-5462~~

Miscellaneous Comments: NWS station collects solar data for U. of Nevada Desert Research Institute. Instrument belongs to U. of Nevada.
Contacts: Vern Smiley, DRI

Station Name Riverside

Date November 4, 1976

Organization NWS/U.C. Riverside

Time of Visit 11:00 a.m.

Visited By Anson

Latitude 33° 57' Longitude 117° 23' Elevation 840'

Directions for finding station Contact NWS/NOAA personnel in office listed below.

Contact person: Name Ron Hamilton/Walt Bartlett

Address Room 1161 Bachelor Hall

University of California, Riverside, CA.

Phone (714) 787-1012

Insolation data: (measured)

	hourly	daily	monthly	Frequency (recorded)
Total (global)	X			noon value
Direct				
Sunshine Hours				
Cloud Cover				
Other				

Weather Data:

	Yes	No	Frequency
Temperature (dry bulb)	X		
(wet bulb)	X		
Wind Speed (Ht.)	X		
Wind Direction	X		
Other air pollution	X		
evaporation	X		

Description of Solar Radiation Measuring Instruments

Manufacturer Eppley

Model 10 (light bulb type)

Serial No. 3741

Date of Installation June 1972

Calibration Constant 2.39 mV/ly

Last Calibration Date October 1976

Condition of: Dome dusty

Dessicant n/a

Sensor greenish, w/white oxidation

Leads o.k.

Level tilts to S.E.

Contact for Station History:

Name ~~Jim Sessions~~

Address ~~NWS Forecast Office~~

~~11000 Wilshire Blvd.~~

Phone ~~L.A., CA (213)824-7215~~

Instrument Location On N.E. corner of roof on 1 story concrete block building ∿ 16' high

Description of Recording Instrument

Manufacturer Leeds and Northrup

Model Speedmax

Serial No. 67-40283-1-1

Scale Units 0-2 ly

Description

Type of Record

Strip Chart	X
Magnetic Tape	
Circular Chart	
Hand Recorded	

Other has hourly integrator

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [X] No [ ]

Describe Process noon value is reported; hourly values are taken from an integrator

Maintenance & Calibration Procedure

Frequency

Recorder Within the last month by Verle Wolfe, an electronics technician from NWS at the Federal Building in W. L.A.

Results of Cross-Calibration with LBL Instruments

Station instrument averaged 6.3% higher than LBL-PSP.

Period(s) of Data Collection Since 1930.

Solar Data Stored at: Contact ~~National Climatic Center~~

Address ~~Federal Building~~

~~Asheville, North Carolina~~ 28801

Phone

Miscellaneous Comments: Some trouble with integrator on recorder--recorder is quite new.

Station Name San Francisco

Date September 16, 1976

Organization Bay Area A.P.C.D.

Time of Visit 4 pm

Visited By Anson & Berdahl

Latitude 37° 46' Longitude 122° 24' Elevation 65'

Directions for finding station On roof of 8 story BAAPCD office building

Contact person: Name Dan Borst (Met. Tech)

Address 939 Ellis Street

San Francisco, CA

Phone (415) 771-6000 x 236

Insolation data: (measured)

	hourly	daily	monthly	Frequency (recorded)
Total (global)		X		
Direct				
Sunshine Hours				
Cloud Cover		X		daily
Other				

Weather Data:

	Yes	No	Frequency
Temperature (dry bulb)	X		
(wet bulb)	X		
Wind Speed (Ht. ?)	X		
Wind Direction	X		
Other air pollution	X		

Description of Solar Radiation Measuring Instruments

Manufacturer Eppley

Model 8-48

Serial No. 11499

Date of Installation ∿ 1972

Calibration Constant 6.84 $mV/ly\ min^{-1}$

Last Calibration Date n/a

Condition of: Dome clean

Dessicant pink

Sensor dark green patches, white frosting

Leads o.k.

Level tilted to north

Contact for Station History:

Name ~~Mike Basso~~

Address ~~939 Ellis Street~~

~~San Francisco, California~~

Phone ~~(415) 771-6000~~

Instrument Location on roof of 8th floor; anemometer mast is subject to movement.

Description of Recording Instrument

Manufacturer Esterline Angus

Model 602

Serial No. 187431

Scale Units 0-1 milliamperes d.c.

Description

Type of Record

Strip Chart	X
Magnetic Tape	
Circular Chart	
Hand Recorded	

Other

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [X] No [ ]

Describe Process chart reading is multiplied by 2 to give a full scale value of 2 ly (chart actually reads 0-1 ly), daily totals recorded. Data reduced by a factor of 40%.

Maintenance & Calibration Procedure

	Frequency
Recorder zero adjust and full scale voltage check	

Results of Cross-Calibration with LBL Instruments

Instrument averaged 3.6% lower than LBL-PSP.

Period(s) of Data Collection since ∿ 1972

Solar Data Stored at: Contact ~~Mike Basso~~ / BAAPCD

Address ~~939 Ellis St.~~

~~San Francisco, CA~~

Phone ~~(415) 771-6000~~

Miscellaneous Comments: Tower sway in wind 5-10 mph. Station log book kept for last two years only.

Station Name: San Jose
Date: August 6, 1976
Organization: Bay Area Air Pollution Control District
Time of Visit: 1:00 p.m.
Visited By: Berdahl

Latitude: 37° 20' Longitude: 121° 54' Elevation: 90'

Directions for finding station:

Contact person: Name: Clayton Ong
Address: 120 B North 4th Street, San Jose, California
Phone: (408) 295-0692

Insolation data: (measured)		hourly	daily	monthly	Frequency (recorded)
	Total (global)		X		
	Direct				
	Sunshine Hours				
	Cloud Cover				
	Other				

Weather Data:		Yes	No	Frequency
	Temperature (dry bulb)	X		
	(wet bulb)	X		
	Wind Speed (Ht.____)	X		
	Wind Direction	X		
	Other air quality	X		

Description of Solar Radiation Measuring Instruments

Manufacturer: Eppley
Model: n/a
Serial No.: n/a
Date of Installation: ∿ 9/72
Calibration Constant: n/a
Last Calibration Date: n/a
Condition of: Dome: some dust
Dessicant: n/a
Sensor: n/a
Leads: n/a
Level: n/a

Contact for Station History:
Name: ~~Mike Basso~~
Address: ~~939 Ellis Street~~
~~San Francisco, California~~
Phone:
Instrument Location: top of 1 story building on 10' pole

Description of Recording Instrument

Manufacturer: Esterline Angus
Model: 602
Serial No.: n/a
Scale Units: 0-2 ly
Description:

Type of Record
Strip Chart [X]
Magnetic Tape [ ]
Circular Chart [ ]
Hand Recorded [ ]

Other:

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [ ] No [ ]

Describe Process: Average hourly values are taken from strip chart, recorded, and sent to SF office.

Maintenance & Calibration Procedure

Frequency

~~Solar Radiometer~~ /Recorder: zero adjust and calibration checked from time to time. No routine calibration of pyranometer.

Results of Cross-Calibration with LBL Instruments: LBL B&W averaged 5.2% lower than LBL PSP.

Period(s) of Data Collection: 1972 to present

Solar Data Stored at: Contact: ~~Mike Basso (BAAPCD)~~
Address: ~~939 Ellis Street~~
~~San Francisco,~~ California
Phone:

Miscellaneous Comments: Fairly unobstructed for an urban site. Close visual inspection not possible.

Station Name San Jose

Date September 24, 1976

Organization San Jose State University

Time of Visit 11:00 a.m.

Visited By Anson

Latitude 37° 20'N Longitude 121° 53'W Elevation 90'

Directions for finding station Located on roof of Duncan Hall, arrange for a visit with Albert Miller in Department of Meteorology Office.

Contact person: Name Albert Miller

Address Department of Meteorology

San Jose State University

Phone San Jose, California

(408) 277-2311

Also: Alex Liu - technician

Insolation data: (measured)	hourly	daily	monthly	Frequency (recorded)
Total (global)	x	x	x	
Direct				for teaching only
Sunshine Hours				
Cloud Cover		x		1500 PST
Other				

Weather Data:	Yes	No	Frequency
Temperature (dry bulb)	X		
(wet bulb)	X		
Wind Speed (Ht. 241')	X		
Wind Direction	X		
Other air quality	X		
meteorology research 3 radar antennas, etc.	X		

Description of Solar Radiation Measuring Instruments (OLD INSTRUMENT)

Manufacturer Eppley

Model 50 (light bulb)

Serial No. 4310

Date of Installation -

Calibration Constant 8.01 mv/cal $cm^{-2}min^{-1}$

Last Calibration Date -

Condition of: Dome some dust

Dessicant n/a

Sensor greenish/white

Leads o.k.

Level doesn't work

Contact for Station History:

Name ~~Albert Miller~~

Address ~~Dept. Of Meteorology~~

~~San Jose State University~~

Phone

Instrument Location roof of 8th floor on 3" diameter pipe mast, ~8' high

Description of Recording Instrument

Manufacturer Leeds & Northrup

Model Speedomax G

Serial No. B62-49527 ..1-1

Scale Units 0-2 ly

Description

Other

Type of Record

Strip Chart	X
Magnetic Tape	
Circular Chart	
Hand Recorded	

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [X] No [ ]

Describe Process Data is read off strip chart with a plastic scale equal to the length of dial on recorder, and then recorded on monthly summary.

Description of Solar Radiation Measuring Instruments (NEW INSTRUMENT)

Manufacturer Eppley

Model 8-48

Serial No. 13120

Date of Installation 9-10-76

Calibration Constant 10.52×10^{-6} v/wm^2

Last Calibration Date at factory

Condition of: Dome some dust

Dessicant pinkish-blue

Sensor o.k.

Leads o.k.

Level o.k.

Contact for Station History:

Name Albert Miller

Address Dept. of Meteorology

San Jose State Univ.

San Jose, CA

Phone

Instrument Location roof (8th floor) on 3" diameter pipe mast.

Description of Recording Instrument

Manufacturer Same as old instrument.

Model

Serial No.

Scale Units

Description

Other

Type of Record

Strip Chart	x
Magnetic Tape	
Circular Chart	
Hand Recorded	

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [ ] No [ ]

Describe Process

Maintenance & Calibration Procedure

Frequency

Solar Radiometer /~~Recorder~~ is checked with voltmeter twice yearly to check output. Recorder is checked every summer.

Results of Cross-Calibration with LBL Instruments

1) Old light bulb type instrument averaged 11.1% lower than LBL-PSP

2) new B&W averaged 17.2% lower than LBL-PSP

Period(s) of Data Collection since ~ 1965

Solar Data Stored at: Contact ~~Albert Miller~~

Address ~~Dept. of Meteorology, SJSU~~

~~San Jose, California~~

Phone ~~(408) 277-2311~~

Miscellaneous Comments: New B&W is being operated beside old light bulb type for about a month for calibration reference check.

Station Name: Vacaville

Date: October 12, 1976

Organization: Solano Irrigation District

Time of Visit: 1:00 p.m.

Visited By: Anson

Latitude: 38° 22' Longitude: 121° 57' Elevation: 100'

Directions for finding station: Take I-80, turn-off at Mason or Elmira Road. Travel east for about 1 mile and turn right onto driveway for S.I.D. Weather instruments are located in small, fenced area south of main building.

Contact person: Name: Vince LaNovara
Address: 508 Elmira Road, Vacaville, Calif. 95688
Phone: (707) 448-6847

Insolation data: (measured)		hourly	daily	monthly	Frequency (recorded)
	Total (global)		X		
	Direct				
	Sunshine Hours				
	Cloud Cover				
	Other				

Weather Data:		Yes	No	Frequency
	Temperature (dry bulb)	X		daily
	(wet bulb)	X		daily
	Wind Speed (Ht. 6')	X		daily
	Wind Direction		X	
	Other evaporation	X		daily

Description of Solar Radiation Measuring Instruments

Manufacturer: Matrix, Inc. Phoenix, Arizona
Model: Mark XIV
Serial No.: 2418
Date of Installation: May 1976
Calibration Constant: .233 cal cm^{-2}
Last Calibration Date: June 1975
Condition of: Dome: o.k.
Dessicant: pink
Sensor: o.k.
Leads: n/a
Level: o.k.

Contact for Station History:
Name: Gor~~don Lyford (U.S.B.R.)~~
Address: ~~Rm. W-2212~~
2800 ~~Cottage Way, Sacramento~~
Phone: ~~(916) 484-4636~~
Instrument Location: Inside 10' x 10' chain-link fence enclosure on top of 4' x 4' post.

Description of Recording Instrument

Manufacturer: Matrix, Inc. Phoenix, Arizona
Model: Mark XIV
Serial No.: 2418 (same as unit sensor)
Scale Units: 0-2 ly-meter; digital integrator readout

Type of Record	
Strip Chart	
Magnetic Tape	
Circular Chart	
Hand Recorded	X

Other: Recorder gives both instantaneous values and daily totals.

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [X] No [ ]

Describe Process: Raw data is reported to Gordon Lyford. Gordon then uses calibration constant and computer program to tabulate data and for use in evaporation/irrigation requirement studies.

Maintenance & Calibration Procedure

	Frequency
Solar Radiometer/Recorder: Calibrated at factory - no other except comparison with other USBR instruments. Batteries checked periodically.	

Results of Cross-Calibration with LBL Instruments: Instrument averaged 5.5% higher than LBL-PSP

Period(s) of Data Collection: May 1976 to present.
*Data is also available from Vince La Novara at SID in both raw and reduced form.

Solar Data Stored at: Contact: ~~Gordon Lyford, U.S. Bureau of Reclamation~~
Address: ~~Room W2212, 2800 Cottage Way~~
~~Sacramento, California~~
Phone: ~~(916) 484-4656~~

Miscellaneous Comments: Recorder responds to having battery-charging solar cells covered, by about a 0.05 ly/min dip in meter reading.
Weather shelter to north of sensor is a probable source of reflected sunlight. Also, shadows from chain-link fense cross sensor.

Station Name Walnut/Los Angeles
Date November 18, 1976
Organization Southern California
Time of Visit noon
Visited By Anson

Latitude $34^{\circ}01'$ Longitude $117^{\circ}47'$ Elevation ~270'

Directions for finding station Take Pomona Freeway to San Gabriel Blvd., go north and turn right at Standard station onto Walnut Grove.

Contact person: Name Nick Patapoff /SCE
Address 2244 Walnut Grove
Rosemead, Calif. 91770
Phone (213) 572-2961
also: Allan Hood (213) 570-1822

Insolation data: (measured)

	hourly	daily	monthly	Frequency (recorded)
Total (global)	X	X		
Direct				
Sunshine Hours				
Cloud Cover				
Other				

Weather Data:

	Yes	No	Frequency
Temperature (dry bulb)	X		
(wet bulb)		X	
Wind Speed (Ht.)		X	
Wind Direction		X	
Other		X	

Description of Solar Radiation Measuring Instruments

Manufacturer Eppley
Model 8-48
Serial No. 13117
Date of Installation August 1975
Calibration Constant $10.52 \times 10^{-6} v/wm^{-2}$
Last Calibration Date n/a
Condition of: Dome o.k.
Dessicant dark blue
Sensor o.k.
Leads o.k.
Level slightly off

Contact for Station History:
Name ~~Nick Patapoff/SCE~~
Address ~~2244 Walnut Grove~~
~~Rosemead, California 91770~~
Phone ~~(213) 572-2961~~
Instrument Location On roof of 1 story building at electrical substation

Description of Recording Instrument

Manufacturer Westinghouse
Model WR-4C
Serial No. 200918S
Scale Units 0-1500 w/m^2; 0-1500 pulses
Description per 15 minutes

Type of Record
Strip Chart [ ]
Magnetic Tape [X]
Circular Chart [ ]
Hand Recorded [ ]

Magnetic tape cartridge with mechanical register, 4 channel recorder - 1) time, pulse every 15 min, 2) solar, total, 3) solar direct (not used), 4) temperature

Data Processing Information

Is Raw Data Processed (integrated, converted, etc.)? Yes [X] No [ ]
Describe Process pulse converted (counted) and related to insolation.

Maintenance & Calibration Procedure

Frequency

Solar Radiometer/Recorder Every six months - spot check against reference B&W, Recorder: Weekly inspection of electronics, dome cleaned; spot check of pulse count versus reasonable insolation; monthly: check of tape, pulses versus dial readings.

Results of Cross-Calibration with LBL Instruments
Instrument averaged 1.1% lower than LBL-PSP.

Period(s) of Data Collection Since September 1975

Solar Data Stored at: Contact ~~Nick Patapoff, Southern California~~ Edison
Address ~~2244 Walnut Grove Avenue~~
~~Rosemead, California 91770~~
Phone ~~(213) 572-2961~~

Miscellaneous Comments: measurements taken on SCE DVM

Appendix H
DATA CORRECTION FACTORS

CORRECTIONS APPLIED TO SOLAR RADIATION DATA   31 JAN 1977

```
RICHMOND             BAAPCD     07428
 1970     FROM  1 JAN  TO  17 FEB  *** DELETE INTERVAL ***
 1970     FROM 18 FEB  TO  11 NOV  INCREASE DAILY VALUES BY  13 PERCENT
 1970     FROM 12 NOV  TO  31 DEC  *** DELETE INTERVAL ***
 1971     FROM  1 JAN  TO  19 FEB  *** DELETE INTERVAL ***
 1971     FROM 20 FEB  TO  31 DEC  INCREASE DAILY VALUES BY   8 PERCENT
 1972     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***

RICHMOND             BAAPCD     07433
 1972     FROM  1 JAN  TO  27 FEB  INCREASE DAILY VALUES BY   8 PERCENT
 1972     FROM 28 FEB  TO  31 DEC  INCREASE DAILY VALUES BY   9 PERCENT
 1973     FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY  12 PERCENT
 1974     FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY  15 PERCENT

PITTSBURG            BAAPCD     07430
 1970     FROM  1 JAN  TO  31 OCT  DECREASE DAILY VALUES BY   6 PERCENT
 1970     FROM  1 NOV  TO  31 DEC  *** DELETE INTERVAL ***
 1971     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1972     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   2 PERCENT
 1973     FROM  1 JAN  TO  19 JAN  DECREASE DAILY VALUES BY   2 PERCENT
 1973     FROM 20 JAN  TO  31 DEC  INCREASE DAILY VALUES BY   1 PERCENT
 1974     FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY   1 PERCENT

SAN RAFAEL           BAAPCD     21451
 1970     FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY   8 PERCENT
 1971     FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY   8 PERCENT
 1972     FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY   9 PERCENT
 1973     FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY  11 PERCENT
 1974     FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY  12 PERCENT

SAN RAFAEL           BAAPCD       (KEYFUNCHED DATA)
 1975     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1976     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***

NAPA                 BAAPCD     28783
 1972     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1973     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1974     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***

NAPA                 BAAPCD       (KEYFUNCHED DATA)
 1974     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***

REDWOOD CITY         BAAPCD     41541
 1970     FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY   2 PERCENT
 1971     FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY   2 PERCENT
 1972     FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY   4 PERCENT
 1973     FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY   4 PERCENT
 1974     FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY   4 PERCENT

REDWOOD CITY         BAAPCD       (KEYFUNCHED DATA)
 1975     FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY   7 PERCENT
 1976     FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY   7 PERCENT

BURLINGAME           BAAPCD     41544
 1970     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1971     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
```

```
 1972     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***

BURLINGAME           BAAPCD    41545
 1973     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***
 1974     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***

BURLINGAME           BAAPCD      (KEYPUNCHED DATA)
 1974     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***
 1975     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***
 1976     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***

SAN JOSE             BAAPCD    43376
 1970     FROM  1 JAN   TO   31 DEC  INCREASE DAILY VALUES BY   6 PERCENT

SAN JOSE             BAAPCD    43379
 1971     FROM  1 JAN   TO   31 DEC  INCREASE DAILY VALUES BY   4 PERCENT
 1972     FROM  1 JAN   TO   31 DEC  INCREASE DAILY VALUES BY   4 PERCENT

SAN JOSE             BAAPCD    43382
 1973     FROM  1 JAN   TO   24 JAN  INCREASE DAILY VALUES BY   4 PERCENT
 1973     FROM 25 JAN   TO   31 DEC  INCREASE DAILY VALUES BY   1 PERCENT
 1974     FROM  1 JAN   TO   31 DEC  INCREASE DAILY VALUES BY   1 PERCENT

SAN JOSE             BAAPCD      (KEYPUNCHED DATA)
 1974     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***
 1975     FROM  1 JAN   TO   31 DEC  INCREASE DAILY VALUES BY  11 PERCENT
 1976     FROM  1 JAN   TO   31 DEC  INCREASE DAILY VALUES BY  11 PERCENT

SUNNYVALE            BAAPCD    43384
 1973     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***
 1974     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***

VALLEJO              BAAPCD    48874
 1972     FROM  1 JAN   TO   31 DEC  DECREASE DAILY VALUES BY   2 PERCENT
 1973     FROM  1 JAN   TO   31 DEC  DECREASE DAILY VALUES BY   2 PERCENT
 1974     FROM  1 JAN   TO   31 DEC  DECREASE DAILY VALUES BY   2 PERCENT

SANTA ROSA           BAAPCD    49884
 1972     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***
 1973     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***
 1974     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***

FREMONT              BAAPCD    60333
 1970     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***

FREMONT              BAAPCD    60336
 1970     FROM  1 JAN   TO   31 DEC  INCREASE DAILY VALUES BY   5 PERCENT
 1971     FROM  1 JAN   TO   31 DEC  INCREASE DAILY VALUES BY   3 PERCENT
 1972     FROM  1 JAN   TO   21 AUG  INCREASE DAILY VALUES BY   2 PERCENT
 1972     FROM 22 AUG   TO   31 DEC  *** DELETE INTERVAL ***
 1973     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***
 1974     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***

FREMONT              BAAPCD      (KEYPUNCHED DATA)
 1974     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***
 1975     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***
 1976     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***

LIVERMORE            BAAPCD    60335
 1971     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***
 1972     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***
 1973     FROM  1 JAN   TO   31 DEC  *** DELETE INTERVAL ***
```

```
 1974     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***

SAN FRANCISCO         BAAPCD    90303
 1970     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   1 PERCENT
 1971     FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY   3 PERCENT
 1972     FROM  1 JAN  TO   6 MAR  INCREASE DAILY VALUES BY   6 PERCENT
 1972     FROM  7 MAR  TO  31 DEC  *** DELETE INTERVAL ***
 1973     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1974     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***

SAN FRANCISCO         BAAPCD      (KEYPUNCHED DATA)
 1975     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1976     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***

LOS ANGELES          NATIONAL  93134
 1952     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   7 PERCENT
 1953     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   7 PERCENT
 1954     FROM  1 JAN  TO  27 SEP  DECREASE DAILY VALUES BY   8 PERCENT
 1954     FROM 28 SEP  TO  31 DEC  DECREASE DAILY VALUES BY   2 PERCENT
 1955     FROM  1 JAN  TO  26 JAN  DECREASE DAILY VALUES BY   2 PERCENT
 1955     FROM 27 JAN  TO   5 JUN  DECREASE DAILY VALUES BY   8 PERCENT
 1955     FROM  6 JUN  TO  31 DEC  DECREASE DAILY VALUES BY   7 PERCENT
 1956     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   7 PERCENT
 1957     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   7 PERCENT
 1958     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   7 PERCENT
 1959     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   7 PERCENT
 1960     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   7 PERCENT
 1961     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   7 PERCENT
 1962     FROM  1 JAN  TO  23 APR  DECREASE DAILY VALUES BY   7 PERCENT
 1962     FROM 24 APR  TO  31 DEC  *** DELETE INTERVAL ***
 1963     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1964     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1965     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1966     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1967     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1968     FROM  1 JAN  TO  31 JUL  *** DELETE INTERVAL ***
 1968     FROM  1 AUG  TO  31 DEC  DECREASE DAILY VALUES BY   6 PERCENT
 1969     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   6 PERCENT
 1970     FROM  1 JAN  TO  31 MAY  *** DELETE INTERVAL ***
 1970     FROM  1 JUN  TO  31 DEC  DECREASE DAILY VALUES BY   6 PERCENT
 1971     FROM  1 JAN  TO  28 FEB  DECREASE DAILY VALUES BY   6 PERCENT
 1971     FROM  1 MAR  TO  31 AUG  *** DELETE INTERVAL ***
 1971     FROM  1 SEP  TO  31 DEC  DECREASE DAILY VALUES BY   1 PERCENT
 1972     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   1 PERCENT
 1973     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1974     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***

RIVERSIDE            NATIONAL  -7473
 1952     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1953     FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1954     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   9 PERCENT
 1955     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   9 PERCENT
 1956     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   9 PERCENT
 1957     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   9 PERCENT
 1958     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   9 PERCENT
 1959     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   9 PERCENT
 1960     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   9 PERCENT
 1961     FROM  1 JAN  TO   9 APR  *** DELETE INTERVAL ***
 1961     FROM 10 APR  TO  31 DEC  *** DELETE INTERVAL ***
 1962     FROM  1 JAN  TO  28 FEB  *** DELETE INTERVAL ***
 1962     FROM  1 MAR  TO  31 DEC  DECREASE DAILY VALUES BY   8 PERCENT
 1963     FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   8 PERCENT
```

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 1964     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1965     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1966     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1967     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1968     FROM  1 JAN   TO   14 OCT   *** DELETE INTERVAL ***
 1968     FROM 15 OCT   TO   31 DEC   DECREASE DAILY VALUES BY  10 PERCENT
 1969     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY  10 PERCENT
 1970     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY  10 PERCENT
 1971     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY  10 PERCENT
 1972     FROM  1 JAN   TO   31 MAY   DECREASE DAILY VALUES BY  10 PERCENT
 1972     FROM  1 JUN   TO   31 DEC   *** DELETE INTERVAL ***
 1973     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1974     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1975     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***

SANTA MARIA          NATIONAL   23236
 1952     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1953     FROM  1 JAN   TO   21 SEP   *** DELETE INTERVAL ***
 1953     FROM 22 SEP   TO   31 DEC   DECREASE DAILY VALUES BY  10 PERCENT
 1954     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY  10 PERCENT

SANTA MARIA          NATIONAL   23273
 1955     FROM  1 JAN   TO   29 JUN   DECREASE DAILY VALUES BY  10 PERCENT
 1955     FROM 30 JUN   TO   31 DEC   *** DELETE INTERVAL ***
 1956     FROM  1 JAN   TO   16 MAR   *** DELETE INTERVAL ***
 1956     FROM 17 MAR   TO   31 DEC   DECREASE DAILY VALUES BY  10 PERCENT
 1957     FROM  1 JAN   TO    3 JUN   DECREASE DAILY VALUES BY  10 PERCENT
 1957     FROM  4 JUN   TO   31 DEC   *** DELETE INTERVAL ***
 1958     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1959     FROM  1 JAN   TO   21 FEB   *** DELETE INTERVAL ***
 1959     FROM 22 FEB   TO   12 NOV   DECREASE DAILY VALUES BY   9 PERCENT
 1959     FROM 13 NOV   TO   31 DEC   *** DELETE INTERVAL ***
 1960     FROM  1 JAN   TO    4 MAY   *** DELETE INTERVAL ***
 1960     FROM  5 MAY   TO   31 DEC   DECREASE DAILY VALUES BY  12 PERCENT
 1961     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY  12 PERCENT
 1962     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY  12 PERCENT
 1963     FROM  1 JAN   TO   26 NOV   *** DELETE INTERVAL ***
 1963     FROM 27 NOV   TO   31 DEC   DECREASE DAILY VALUES BY   4 PERCENT
 1964     FROM  1 JAN   TO   30 JUN   DECREASE DAILY VALUES BY   3 PERCENT
 1964     FROM  1 JUL   TO   31 DEC   DECREASE DAILY VALUES BY   2 PERCENT
 1965     FROM  1 JAN   TO   30 JUN   DECREASE DAILY VALUES BY   1 PERCENT
 1965     FROM  1 JUL   TO   31 DEC   DECREASE DAILY VALUES BY   0 PERCENT
 1966     FROM  1 JAN   TO   30 JUN   INCREASE DAILY VALUES BY   1 PERCENT
 1966     FROM  1 JUL   TO   31 DEC   INCREASE DAILY VALUES BY   2 PERCENT
 1967     FROM  1 JAN   TO    6 FEB   INCREASE DAILY VALUES BY   3 PERCENT
 1967     FROM  7 FEB   TO   31 DEC   DECREASE DAILY VALUES BY   4 PERCENT
 1968     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY   4 PERCENT
 1969     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY   4 PERCENT
 1970     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY   4 PERCENT
 1971     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY   4 PERCENT
 1972     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY   2 PERCENT
 1973     FROM  1 JAN   TO    8 JUL   DECREASE DAILY VALUES BY   0 PERCENT
 1973     FROM  9 JUL   TO   31 DEC   DECREASE DAILY VALUES BY   0 PERCENT
 1974     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY   0 PERCENT
 1975     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY   0 PERCENT

LAS VEGAS            NATIONAL   23169
 1952     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1953     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1954     FROM  1 JAN   TO   30 JUN   *** DELETE INTERVAL ***
 1954     FROM  1 JUL   TO   31 DEC   DECREASE DAILY VALUES BY   9 PERCENT
 1955     FROM  1 JUL   TO   31 DEC   DECREASE DAILY VALUES BY   9 PERCENT
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 1956    FROM  1 JUL   TO   30 SEP   DECREASE DAILY VALUES BY    9 PERCENT
 1956    FROM  1 OCT   TO   31 DEC   *** DELETE INTERVAL ***
 1957    FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1958    FROM  1 JAN   TO   19 JUL   *** DELETE INTERVAL ***
 1958    FROM 20 JUL   TO   31 DEC   DECREASE DAILY VALUES BY    7 PERCENT
 1959    FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    7 PERCENT
 1960    FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    7 PERCENT
 1961    FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    7 PERCENT
 1962    FROM  1 JAN   TO    9 JAN   DECREASE DAILY VALUES BY    7 PERCENT
 1962    FROM 10 JAN   TO    8 MAY   *** DELETE INTERVAL ***
 1962    FROM  9 AUG   TO   31 DEC   DECREASE DAILY VALUES BY    8 PERCENT
 1963    FROM  1 JAN   TO   30 JUL   DECREASE DAILY VALUES BY    8 PERCENT
 1963    FROM 31 JUL   TO   31 DEC   DECREASE DAILY VALUES BY    5 PERCENT
 1964    FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    5 PERCENT
 1965    FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    6 PERCENT
 1966    FROM  1 JAN   TO   19 JUL   DECREASE DAILY VALUES BY    6 PERCENT
 1966    FROM 20 JUL   TO   31 DEC   DECREASE DAILY VALUES BY    5 PERCENT
 1967    FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    5 PERCENT
 1968    FROM  1 JAN   TO   17 FEB   DECREASE DAILY VALUES BY    5 PERCENT
 1968    FROM 28 FEB   TO   31 DEC   *** DELETE INTERVAL ***
 1969    FROM  1 JAN   TO   31 JUL   *** DELETE INTERVAL ***
 1969    FROM  1 AUG   TO   31 DEC   DECREASE DAILY VALUES BY    1 PERCENT
 1970    FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    1 PERCENT
 1971    FROM  1 JAN   TO    7 OCT   DECREASE DAILY VALUES BY    2 PERCENT
 1971    FROM  8 OCT   TO   31 DEC   *** DELETE INTERVAL ***
 1972    FROM  1 JAN   TO   30 JUN   *** DELETE INTERVAL ***
 1972    FROM  1 JUL   TO   31 DEC   DECREASE DAILY VALUES BY    0 PERCENT
 1973    FROM  1 JAN   TO   30 SEP   DECREASE DAILY VALUES BY    0 PERCENT
 1973    FROM  1 OCT   TO   31 DEC   *** DELETE INTERVAL ***
 1974    FROM  1 JAN   TO   30 JUN   *** DELETE INTERVAL ***
 1974    FROM  1 JUL   TO   31 DEC   INCREASE DAILY VALUES BY    2 PERCENT
 1975    FROM  1 JAN   TO   22 JUN   INCREASE DAILY VALUES BY    2 PERCENT
 1975    FROM 23 JUN   TO   31 DEC   *** DELETE INTERVAL ***

DAVIS                  NATIONAL  -2294
 1952    FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1953    FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1954    FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1955    FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1956    FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1957    FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    5 PERCENT
 1958    FROM  1 JAN   TO   15 AUG   DECREASE DAILY VALUES BY    3 PERCENT
 1958    FROM 16 OCT   TO   17 OCT   INCREASE DAILY VALUES BY    3 PERCENT
 1958    FROM 18 OCT   TO   31 DEC   DECREASE DAILY VALUES BY    2 PERCENT
 1959    FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    2 PERCENT
 1960    FROM  1 JAN   TO   31 JAN   DECREASE DAILY VALUES BY    2 PERCENT
 1960    FROM  1 FEB   TO   29 FEB   *** DELETE INTERVAL ***
 1960    FROM  1 MAR   TO   31 DEC   DECREASE DAILY VALUES BY    4 PERCENT
 1961    FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    5 PERCENT
 1962    FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    5 PERCENT
 1963    FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    6 PERCENT
 1964    FROM  1 JAN   TO   31 JAN   DECREASE DAILY VALUES BY    6 PERCENT
 1964    FROM  1 FEB   TO   31 MAY   *** DELETE INTERVAL ***
 1964    FROM  1 JUN   TO   25 AUG   DECREASE DAILY VALUES BY    3 PERCENT
 1964    FROM 26 AUG   TO   31 DEC   INCREASE DAILY VALUES BY    6 PERCENT
 1965    FROM  1 JAN   TO   28 FEB   *** DELETE INTERVAL ***
 1965    FROM  1 MAR   TO   31 AUG   INCREASE DAILY VALUES BY    2 PERCENT
 1965    FROM  1 NOV   TO   31 DEC   INCREASE DAILY VALUES BY    2 PERCENT
 1966    FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    2 PERCENT
 1967    FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    2 PERCENT
 1968    FROM  1 JAN   TO   31 MAR   DECREASE DAILY VALUES BY    2 PERCENT
 1968    FROM  1 APR   TO   31 DEC   DECREASE DAILY VALUES BY    4 PERCENT
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1969	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	4 PERCENT
1970	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	4 PERCENT
1971	FROM	1 JAN	TO	30 APR	*** DELETE INTERVAL ***	
1971	FROM	1 MAY	TO	31 DEC	DECREASE DAILY VALUES BY	2 PERCENT
1972	FROM	1 JAN	TO	30 APR	*** DELETE INTERVAL ***	
1972	FROM	1 MAY	TO	31 DEC	DECREASE DAILY VALUES BY	2 PERCENT
1973	FROM	1 JAN	TO	30 NOV	DECREASE DAILY VALUES BY	4 PERCENT
1973	FROM	1 DEC	TO	31 DEC	*** DELETE INTERVAL ***	
1974	FROM	1 JAN	TO	31 MAY	*** DELETE INTERVAL ***	
1974	FROM	1 JUN	TO	31 DEC	DECREASE DAILY VALUES BY	3 PERCENT
1975	FROM	1 JAN	TO	31 MAY	DECREASE DAILY VALUES BY	3 PERCENT
1975	FROM	1 JUN	TO	30 JUN	*** DELETE INTERVAL ***	
1975	FROM	1 JUL	TO	31 DEC	INCREASE DAILY VALUES BY	1 PERCENT
FRESNO			NATIONAL	93193		
1952	FROM	1 JAN	TO	31 DEC	*** DELETE INTERVAL ***	
1953	FROM	1 JAN	TO	31 DEC	*** DELETE INTERVAL ***	
1954	FROM	1 JAN	TO	31 DEC	*** DELETE INTERVAL ***	
1955	FROM	1 JAN	TO	31 DEC	*** DELETE INTERVAL ***	
1956	FROM	1 JAN	TO	31 DEC	*** DELETE INTERVAL ***	
1957	FROM	1 JAN	TO	31 DEC	*** DELETE INTERVAL ***	
1958	FROM	1 JAN	TO	31 DEC	*** DELETE INTERVAL ***	
1959	FROM	1 JAN	TO	31 DEC	INCREASE DAILY VALUES BY	6 PERCENT
1960	FROM	1 JAN	TO	31 DEC	INCREASE DAILY VALUES BY	7 PERCENT
1961	FROM	1 JAN	TO	31 DEC	INCREASE DAILY VALUES BY	7 PERCENT
1962	FROM	1 JAN	TO	7 JUN	INCREASE DAILY VALUES BY	8 PERCENT
1962	FROM	8 JUN	TO	31 DEC	DECREASE DAILY VALUES BY	5 PERCENT
1963	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	4 PERCENT
1964	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	3 PERCENT
1965	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	3 PERCENT
1966	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	2 PERCENT
1967	FROM	1 JAN	TO	7 FEB	DECREASE DAILY VALUES BY	1 PERCENT
1967	FROM	8 FEB	TO	31 DEC	DECREASE DAILY VALUES BY	2 PERCENT
1968	FROM	1 JAN	TO	31 MAY	DECREASE DAILY VALUES BY	2 PERCENT
1968	FROM	1 JUN	TO	10 OCT	*** DELETE INTERVAL ***	
1968	FROM	11 OCT	TO	31 DEC	INCREASE DAILY VALUES BY	5 PERCENT
1969	FROM	1 JAN	TO	31 DEC	INCREASE DAILY VALUES BY	5 PERCENT
1970	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	3 PERCENT
1971	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	2 PERCENT
1972	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	0 PERCENT
1973	FROM	1 JAN	TO	31 DEC	INCREASE DAILY VALUES BY	1 PERCENT
1974	FROM	1 JAN	TO	18 DEC	INCREASE DAILY VALUES BY	2 PERCENT
1974	FROM	19 DEC	TO	31 DEC	INCREASE DAILY VALUES BY	2 PERCENT
1975	FROM	1 JAN	TO	31 DEC	INCREASE DAILY VALUES BY	2 PERCENT
RENO			NATIONAL	23185		
1965	FROM	1 JAN	TO	31 DEC	INCREASE DAILY VALUES BY	2 PERCENT
1966	FROM	1 JAN	TO	31 DEC	INCREASE DAILY VALUES BY	2 PERCENT
1967	FROM	1 JAN	TO	31 DEC	INCREASE DAILY VALUES BY	2 PERCENT
1968	FROM	1 JAN	TO	31 DEC	INCREASE DAILY VALUES BY	2 PERCENT
1969	FROM	1 JAN	TO	30 NOV	INCREASE DAILY VALUES BY	2 PERCENT
1969	FROM	1 DEC	TO	31 DEC	*** DELETE INTERVAL ***	
1970	FROM	1 JAN	TO	31 DEC	*** DELETE INTERVAL ***	
1971	FROM	1 JAN	TO	31 DEC	*** DELETE INTERVAL ***	
1972	FROM	1 JAN	TO	31 DEC	*** DELETE INTERVAL ***	
1973	FROM	1 JAN	TO	31 DEC	INCREASE DAILY VALUES BY	6 PERCENT
1974	FROM	1 JAN	TO	25 FEB	INCREASE DAILY VALUES BY	6 PERCENT
1974	FROM	26 FEB	TO	31 DEC	*** DELETE INTERVAL ***	
1975	FROM	1 JAN	TO	31 DEC	*** DELETE INTERVAL ***	
MEDFORD			NATIONAL	24225		
1951	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	10 PERCENT

1952	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	10	PERCENT
1953	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	10	PERCENT
1954	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	10	PERCENT
1955	FROM	1 JAN	TO	7 JUN	DECREASE DAILY VALUES BY	10	PERCENT
1955	FROM	8 JUN	TO	31 DEC	*** DELETE INTERVAL ***		
1956	FROM	1 JAN	TO	31 MAY	*** DELETE INTERVAL ***		
1956	FROM	1 JUN	TO	31 DEC	DECREASE DAILY VALUES BY	1	PERCENT
1957	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	1	PERCENT
1958	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	1	PERCENT
1959	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	1	PERCENT
1960	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	1	PERCENT
1961	FROM	1 JAN	TO	27 MAR	DECREASE DAILY VALUES BY	1	PERCENT
1961	FROM	28 MAR	TO	31 DEC	DECREASE DAILY VALUES BY	4	PERCENT
1962	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	4	PERCENT
1963	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	4	PERCENT
1964	FROM	1 JAN	TO	22 SEP	DECREASE DAILY VALUES BY	4	PERCENT
1964	FROM	23 SEP	TO	31 DEC	*** DELETE INTERVAL ***		
1965	FROM	1 JAN	TO	9 MAY	*** DELETE INTERVAL ***		
1965	FROM	10 MAY	TO	31 DEC	DECREASE DAILY VALUES BY	5	PERCENT
1966	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	5	PERCENT
1967	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	5	PERCENT
1968	FROM	1 JAN	TO	24 MAR	DECREASE DAILY VALUES BY	5	PERCENT
1968	FROM	25 MAR	TO	31 DEC	DECREASE DAILY VALUES BY	7	PERCENT
1969	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	7	PERCENT
1970	FROM	1 JAN	TO	18 JAN	DECREASE DAILY VALUES BY	7	PERCENT
1970	FROM	19 JAN	TO	31 DEC	*** DELETE INTERVAL ***		
1971	FROM	1 JAN	TO	31 DEC	*** DELETE INTERVAL ***		
1972	FROM	1 JAN	TO	31 DEC	*** DELETE INTERVAL ***		
1973	FROM	1 JAN	TO	28 FEB	*** DELETE INTERVAL ***		
1973	FROM	1 MAR	TO	31 DEC	DECREASE DAILY VALUES BY	2	PERCENT
1974	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	2	PERCENT

INYOKERN NATIONAL -4279

1952	FROM	1 JAN	TO	31 DEC	*** DELETE INTERVAL ***		
1953	FROM	1 JAN	TO	31 DEC	*** DELETE INTERVAL ***		
1954	FROM	1 JAN	TO	30 APR	*** DELETE INTERVAL ***		
1954	FROM	1 MAY	TO	31 DEC	DECREASE DAILY VALUES BY	12	PERCENT
1955	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	12	PERCENT
1956	FROM	1 JAN	TO	31 JAN	DECREASE DAILY VALUES BY	12	PERCENT
1956	FROM	1 FEB	TO	31 DEC	DECREASE DAILY VALUES BY	14	PERCENT
1957	FROM	1 JAN	TO	21 APR	DECREASE DAILY VALUES BY	14	PERCENT
1957	FROM	22 APR	TO	28 APR	*** DELETE INTERVAL ***		
1957	FROM	29 APR	TO	31 DEC	DECREASE DAILY VALUES BY	14	PERCENT
1958	FROM	1 JAN	TO	6 JUN	DECREASE DAILY VALUES BY	14	PERCENT
1958	FROM	7 JUN	TO	31 DEC	DECREASE DAILY VALUES BY	14	PERCENT
1959	FROM	1 JAN	TO	31 MAR	DECREASE DAILY VALUES BY	15	PERCENT
1959	FROM	1 APR	TO	30 JUN	DECREASE DAILY VALUES BY	16	PERCENT
1959	FROM	1 JUL	TO	30 SEP	DECREASE DAILY VALUES BY	17	PERCENT
1959	FROM	1 OCT	TO	31 DEC	DECREASE DAILY VALUES BY	18	PERCENT
1960	FROM	1 JAN	TO	29 FEB	DECREASE DAILY VALUES BY	19	PERCENT
1960	FROM	1 MAR	TO	18 MAY	*** DELETE INTERVAL ***		
1960	FROM	19 MAY	TO	31 DEC	DECREASE DAILY VALUES BY	21	PERCENT
1961	FROM	1 JAN	TO	22 MAY	DECREASE DAILY VALUES BY	21	PERCENT
1961	FROM	23 MAY	TO	31 DEC	*** DELETE INTERVAL ***		
1962	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	19	PERCENT
1963	FROM	1 JAN	TO	31 DEC	DECREASE DAILY VALUES BY	19	PERCENT
1964	FROM	1 JAN	TO	31 DEC	*** DELETE INTERVAL ***		
1965	FROM	1 JAN	TO	31 DEC	*** DELETE INTERVAL ***		
1966	FROM	1 JAN	TO	31 DEC	*** DELETE INTERVAL ***		
1967	FROM	1 JAN	TO	4 OCT	*** DELETE INTERVAL ***		
1967	FROM	5 OCT	TO	31 DEC	INCREASE DAILY VALUES BY	2	PERCENT
1968	FROM	1 JAN	TO	21 SEP	INCREASE DAILY VALUES BY	2	PERCENT

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 1968     FROM 22 SEP   TO   24 OCT   *** DELETE INTERVAL ***
 1968     FROM 25 OCT   TO   31 DEC   INCREASE DAILY VALUES BY    2 PERCENT
 1969     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY    2 PERCENT
 1970     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY    2 PERCENT
 1971     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY    2 PERCENT

INYOKERN               NATIONAL    (KEYPUNCHED DATA)
 1971     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY    6 PERCENT
 1972     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY    6 PERCENT
 1973     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY    7 PERCENT
 1974     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY    9 PERCENT
 1975     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY   10 PERCENT

EL CENTRO              NATIONAL   -2718
 1963     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1964     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1965     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1966     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1967     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1968     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY    4 PERCENT
 1969     FROM  1 JAN   TO   31 JAN   INCREASE DAILY VALUES BY    4 PERCENT
 1969     FROM  1 FEB   TO   31 DEC   *** DELETE INTERVAL ***
 1970     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1971     FROM  1 JAN   TO    5 OCT   *** DELETE INTERVAL ***
 1971     FROM  6 OCT   TO   31 DEC   INCREASE DAILY VALUES BY    4 PERCENT
 1972     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY    4 PERCENT
 1973     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY    2 PERCENT
 1974     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY    2 PERCENT
 1975     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY    2 PERCENT

LOS ANGELES            NATIONAL   23174
 1951     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1952     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1953     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1954     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1955     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1956     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1957     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    6 PERCENT
 1958     FROM  1 JAN   TO   31 AUG   DECREASE DAILY VALUES BY    6 PERCENT
 1958     FROM  1 SEP   TO   31 DEC   *** DELETE INTERVAL ***
 1959     FROM  1 NOV   TO   31 DEC   DECREASE DAILY VALUES BY    4 PERCENT
 1960     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    4 PERCENT
 1961     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    5 PERCENT
 1962     FROM  1 JAN   TO   17 APR   DECREASE DAILY VALUES BY    6 PERCENT
 1962     FROM 18 APR   TO   16 OCT   DECREASE DAILY VALUES BY    3 PERCENT
 1962     FROM 17 OCT   TO   31 DEC   DECREASE DAILY VALUES BY    5 PERCENT
 1963     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    5 PERCENT
 1964     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    4 PERCENT
 1965     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    4 PERCENT
 1966     FROM  1 JAN   TO   22 MAY   DECREASE DAILY VALUES BY    4 PERCENT
 1966     FROM 23 MAY   TO   31 DEC   DECREASE DAILY VALUES BY    4 PERCENT
 1967     FROM  1 JAN   TO   15 FEB   DECREASE DAILY VALUES BY    4 PERCENT
 1967     FROM 16 FEB   TO   31 DEC   DECREASE DAILY VALUES BY   10 PERCENT
 1968     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    9 PERCENT
 1969     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    8 PERCENT
 1970     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    6 PERCENT
 1971     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    5 PERCENT
 1972     FROM  1 JAN   TO   31 MAY   DECREASE DAILY VALUES BY    4 PERCENT
 1972     FROM  1 JUN   TO   31 JUL   *** DELETE INTERVAL ***
 1972     FROM  1 AUG   TO   31 DEC   INCREASE DAILY VALUES BY    1 PERCENT
 1973     FROM  1 JAN   TO    5 AUG   INCREASE DAILY VALUES BY    1 PERCENT
 1973     FROM  6 AUG   TO   31 DEC   DECREASE DAILY VALUES BY    5 PERCENT
```

```
 1974    FROM  1 JAN  TO  31 MAR  DECREASE DAILY VALUES BY   5 PERCENT
 1974    FROM  1 APR  TO  30 APR  *** DELETE INTERVAL ***
 1974    FROM  1 MAY  TO  31 DEC  DECREASE DAILY VALUES BY   5 PERCENT
 1975    FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   5 PERCENT

ALTURAS              PG+E         (KEYPUNCHED DATA)
 1958    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1959    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1962    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1963    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1964    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1969    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***

ARVIN                PG+E         (KEYPUNCHED DATA)
 1959    FROM  1 JAN  TO  31 MAY  *** DELETE INTERVAL ***
 1959    FROM  1 JUN  TO  31 DEC  DECREASE DAILY VALUES BY   0 PERCENT
 1960    FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   0 PERCENT
 1961    FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY   1 PERCENT
 1962    FROM  1 JAN  TO  28 DEC  INCREASE DAILY VALUES BY   2 PERCENT
 1962    FROM 30 DEC  TO  31 DEC  INCREASE DAILY VALUES BY   2 PERCENT
 1963    FROM  1 JAN  TO  30 SEP  INCREASE DAILY VALUES BY   2 PERCENT
 1963    FROM  1 OCT  TO  31 DEC  *** DELETE INTERVAL ***
 1964    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1965    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***

NEWVILLE             PG+E         (KEYPUNCHED DATA)
 1966    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1967    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1968    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1969    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1970    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***

SIERRA               PG+E         (KEYPUNCHED DATA)
 1946    FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   7 PERCENT
 1947    FROM  1 JAN  TO  31 DEC  DECREASE DAILY VALUES BY   9 PERCENT
 1948    FROM  1 JAN  TO  19 DEC  DECREASE DAILY VALUES BY  11 PERCENT
 1948    FROM 20 DEC  TO  31 DEC  *** DELETE INTERVAL ***
 1949    FROM  1 JAN  TO   6 MAY  *** DELETE INTERVAL ***
 1949    FROM  7 MAY  TO  31 DEC  DECREASE DAILY VALUES BY  12 PERCENT
 1950    FROM  1 JAN  TO  12 SEP  DECREASE DAILY VALUES BY  15 PERCENT
 1950    FROM 13 SEP  TO  31 DEC  *** DELETE INTERVAL ***
 1951    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1952    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***

SAN JOSE             PG+E         (KEYPUNCHED DATA)
 1963    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1964    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1965    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1966    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1967    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1968    FROM  1 JAN  TO  31 DEC  *** DELETE INTERVAL ***
 1969    FROM  1 JAN  TO   7 OCT  *** DELETE INTERVAL ***
 1969    FROM  8 OCT  TO  31 DEC  INCREASE DAILY VALUES BY   5 PERCENT
 1970    FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY   5 PERCENT
 1971    FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY   5 PERCENT
 1972    FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY   5 PERCENT
 1973    FROM  1 JAN  TO  13 FEB  INCREASE DAILY VALUES BY   5 PERCENT
 1973    FROM 14 FEB  TO   4 NOV  *** DELETE INTERVAL ***
 1973    FROM  5 NOV  TO  31 DEC  INCREASE DAILY VALUES BY  10 PERCENT
 1974    FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY  10 PERCENT
 1975    FROM  1 JAN  TO  31 DEC  INCREASE DAILY VALUES BY  10 PERCENT
```

```
LA JOLLA              NATIONAL     (KEYPUNCHED DATA)
 1929     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1930     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1931     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1932     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1933     FROM  1 JAN   TO    9 AUG   *** DELETE INTERVAL ***
 1933     FROM 10 AUG   TO   31 DEC   DECREASE DAILY VALUES BY   3 PERCENT
 1934     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY   3 PERCENT
 1935     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY   0 PERCENT
 1936     FROM  1 JAN   TO   30 JUN   *** DELETE INTERVAL ***
 1936     FROM  1 JUL   TO   31 DEC   DECREASE DAILY VALUES BY   1 PERCENT
 1937     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY   1 PERCENT
 1938     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY   0 PERCENT
 1939     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY   1 PERCENT
 1940     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY   0 PERCENT
 1941     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY   1 PERCENT
 1942     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY   0 PERCENT

INYOKERN              NATIONAL   -4279
 1967     FROM  1 JAN   TO   30 SEP   *** DELETE INTERVAL ***
 1967     FROM  1 OCT   TO   31 DEC   INCREASE DAILY VALUES BY   2 PERCENT
 1968     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY   2 PERCENT
 1969     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY   2 PERCENT
 1970     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY   2 PERCENT
 1971     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY   3 PERCENT
 1972     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY   5 PERCENT
 1973     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY   7 PERCENT
 1974     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY   9 PERCENT
 1975     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY  10 PERCENT

BUTLER VALLEY RANCH USCE           (KEYPUNCHED DATA)
 1971     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY   7 PERCENT
 1972     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY   7 PERCENT
 1973     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY   7 PERCENT
 1974     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY   7 PERCENT
 1975     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY   7 PERCENT

SCHRAMM RANCH         HARZA        (KEYPUNCHED DATA)
 1975     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1976     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***

COIT RANCH            HARZA        (KEYPUNCHED DATA)
 1974     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1975     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1976     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***

ALLEN RANCH           HARZA        (KEYPUNCHED DATA)
 1975     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1976     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***

FIVE POINTS           USBR         (KEYPUNCHED DATA)
 1972     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1973     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1974     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1975     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1976     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***

COACHELLA VALLEY      WATER DIST   (KEYPUNCHED DATA)
 1971     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY  13 PERCENT
 1972     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY  13 PERCENT
 1973     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1974     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
```

```
 1975     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1976     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***

BARRETT RESEVOIR       USGS          (KEYPUNCHED DATA)
 1959     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    3 PERCENT
 1960     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    3 PERCENT
 1961     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    3 PERCENT

LAKE MOJAVE            USGS          (KEYPUNCHED DATA)
 1959     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    4 PERCENT
 1960     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    4 PERCENT
 1961     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    4 PERCENT

SAN VICENTE RESEVOIRUSGS             (KEYPUNCHED DATA)
 1957     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    4 PERCENT
 1958     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    4 PERCENT
 1959     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    5 PERCENT

LAKE MEAD              USGS          (KEYPUNCHED DATA)
 1952     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    3 PERCENT
 1953     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    5 PERCENT

LAKE SKINNER           USGS          (KEYPUNCHED DATA)
 1973     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY    2 PERCENT
 1974     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY    2 PERCENT

SALTON SEA             USGS          (KEYPUNCHED DATA)
 1967     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    0 PERCENT
 1968     FROM  1 JAN   TO   31 DEC   DECREASE DAILY VALUES BY    0 PERCENT

COTTONWOOD             USGS          (KEYPUNCHED DATA)
 1973     FROM  1 JAN   TO   31 AUG   INCREASE DAILY VALUES BY    2 PERCENT
 1973     FROM  1 SEP   TO   30 SEP   *** DELETE INTERVAL ***
 1973     FROM  1 OCT   TO   31 DEC   INCREASE DAILY VALUES BY    2 PERCENT
 1974     FROM  1 OCT   TO   31 DEC   INCREASE DAILY VALUES BY    2 PERCENT
 1974     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY    2 PERCENT

FOLSOM DAM             USBR          (KEYPUNCHED DATA)
 1974     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1975     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***
 1976     FROM  1 JAN   TO   31 DEC   *** DELETE INTERVAL ***

SHAFTER                USDA          (KEYPUNCHED DATA)
 1975     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY    2 PERCENT
 1976     FROM  1 JAN   TO   31 DEC   INCREASE DAILY VALUES BY    2 PERCENT

END OF DATA ADJUSTMENT DECK
```

Appendix I
THE REGIONALIZATION OF CALIFORNIA FOR SOLAR MONITORING

THE REGIONALIZATION OF CALIFORNIA FOR SOLAR MONITORING*

by

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INTRODUCTION

In response to a request from the Lawrence Berkeley Laboratory, Berkeley, California, the Laboratory of Climatology at Arizona State University has contracted to divide the state into regions that are relatively uniform in their receipts of solar energy. The basis of the regionalization was to be of a meteorological-climatological nature. After preliminary investigations and consultations with outside experts, the final divisions were made and an oral report rendered to the Berkeley group on 16 September 1977. This report is a finalization of the oral report.

LIMITATIONS OF THE STUDY

To accomplish the regionalization, the ideal procedure would be to establish a relatively dense network of well-calibrated and well-maintained solar sensors for a number of years. From the data base thus created, solar regions may be established. A second procedure would be to perform detailed meteorological studies of the state for the winter and summer seasons. After regionalization, the two seasons could be combined into one annual regionalization. This procedure has been endorsed by at least one of the outside consultants. Time and monetary constraints, however, render these approaches impractical.

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*Prepared for Energy and Environment Division, Lawrence Berkeley Laboratory, University of California, Berkeley, September 1977.

In their place, analyses of several variables were performed. The data bases were, for the most part, based upon information supplied from unique sites, e.g. airfields, and probably will reflect a certain bias due to their unique microclimatological settings. There may thus arise honest differences in interpretations of these data.

The analyses were performed in the realization that variations in the solar energy receipts will show a variation within each selected zone. The guiding principles used were that the variations in each zone should be smaller than the variations between zones, and that the variations within zones should be kept to a minumum consistent with establishing a reasonably small number of zones.

FACTORS CONSIDERED

After a careful review of a draft of "Analysis of the California Solar Resource," especially chapters IV and V, considerable attention was devoted to those climatological factors that are important in attenuating the solar beam. The factors chosen (not necessarily in order of importance or consideration) are:

1. The regional Weather Bureau Forecast Zones
2. Mean annual cloudiness
3. Mean January cloudiness
4. Mean July cloudiness
5. Diurnal cloud patterns
6. Annual change in cloudiness
7. Percent of possible sunshine in January
8. Percent of possible sunshine in July
9. Annual change in percent of possible sunshine
10. Solar energy received in January
11. Solar energy received in July
12. Annual change in received solar energy
13. Number of days of dense fog (visibility less than 1/4 mile)
14. Sea-land breezes
15. Areas of smog and dust
16. Topographical maps

17. Vegetation maps
18. Air masses affecting the state
19. Subjective judgments

Various elements were then combined to produce a first solar climatic regionalization of California. This first regionalization was then subjected to the critical scrutiny of these independent climatologists. Their suggestions and criticisms were then evaluated and integrated into the final model.

METHODOLOGY

The first regionalization was based upon the annual mean cloudiness and the annual percentage of possible sunshine from sunrise to sunset over California. Isolines of 3.0, 4.0 and 5.0 tenths of cloudiness and 65, 75, and 85 percent of the annual possible sunshine were plotted on Fig.I-1. This configuration suggests three possible regions; a region of comparatively low solar availability in the north and northwestern portions of the state, a region of comparatively high solar availability in the southeastern part of the state, and an intermediate region. (The region of southeastern California and southwestern Arizona has the highest solar availability in the entire U. S.)

It should be noted here that the analysis of the mean sky cover was based upon ten points within California, and three points in Nevada and Arizona. Further, the percentages of possible sunshine are based upon six points within California and three points in Nevada and Arizona. Both these analyses are smoothed, i.e., no effort has been made to take into account possible variations of the data at nearby points.

The second analysis, shown on Fig. I-2, shows the variation of the percent of the possible sunshine between January and July. This mapping was produced by plotting the percentage availabilities during January and July, and performing a graphical subtraction. For the sake of clarity, only the differences are shown here. This mapping suggests three separate regions: the San Joaquin Valley with an extension to the northeastern part of the state, characterized by a large seasonal change (up to 45%) in the availability of sunshine; a region of small seasonal change (from almost 0% near

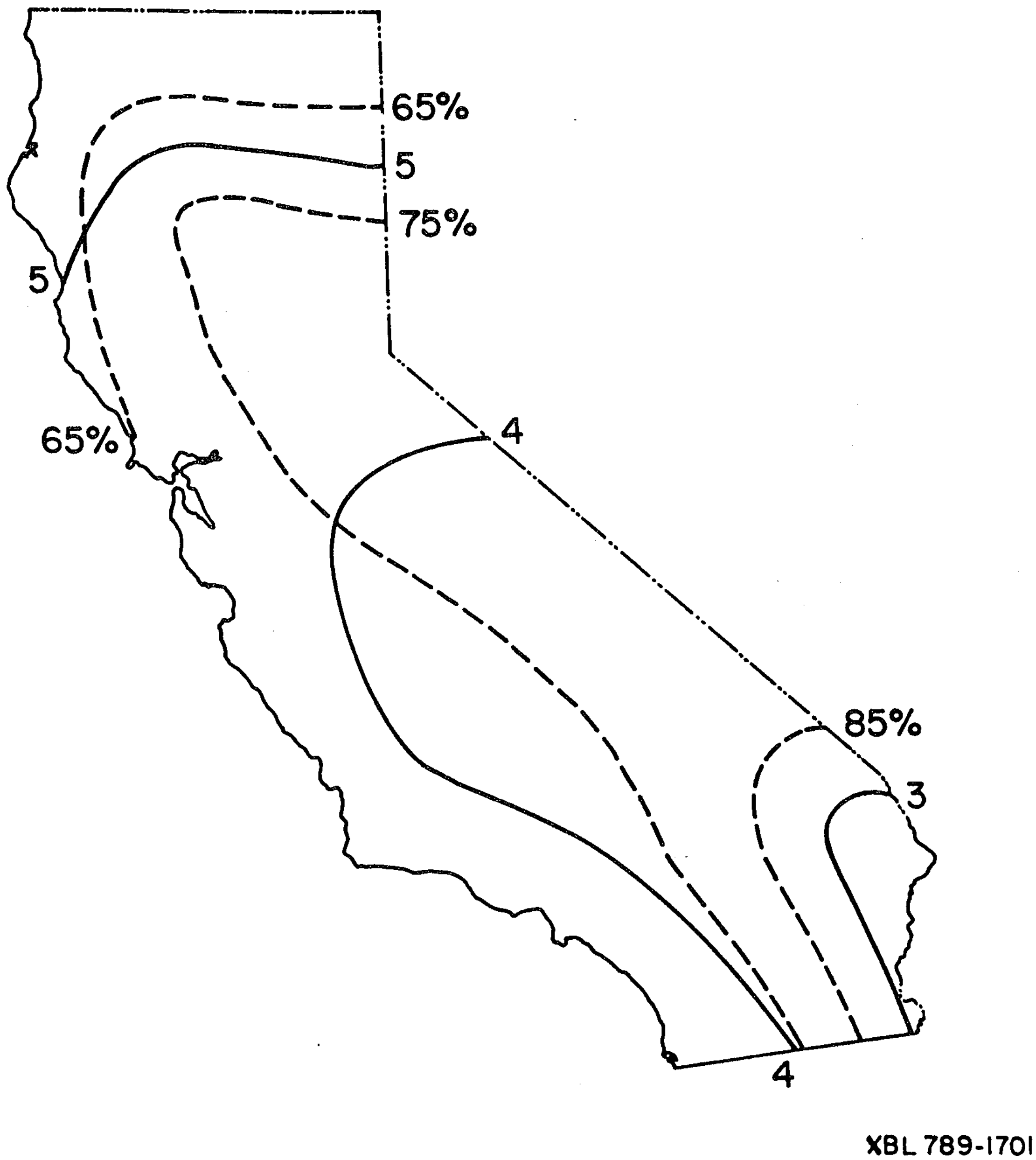


Figure I-1. Tenths of mean annual sky cover (——) and percent of possible sunshine (----).

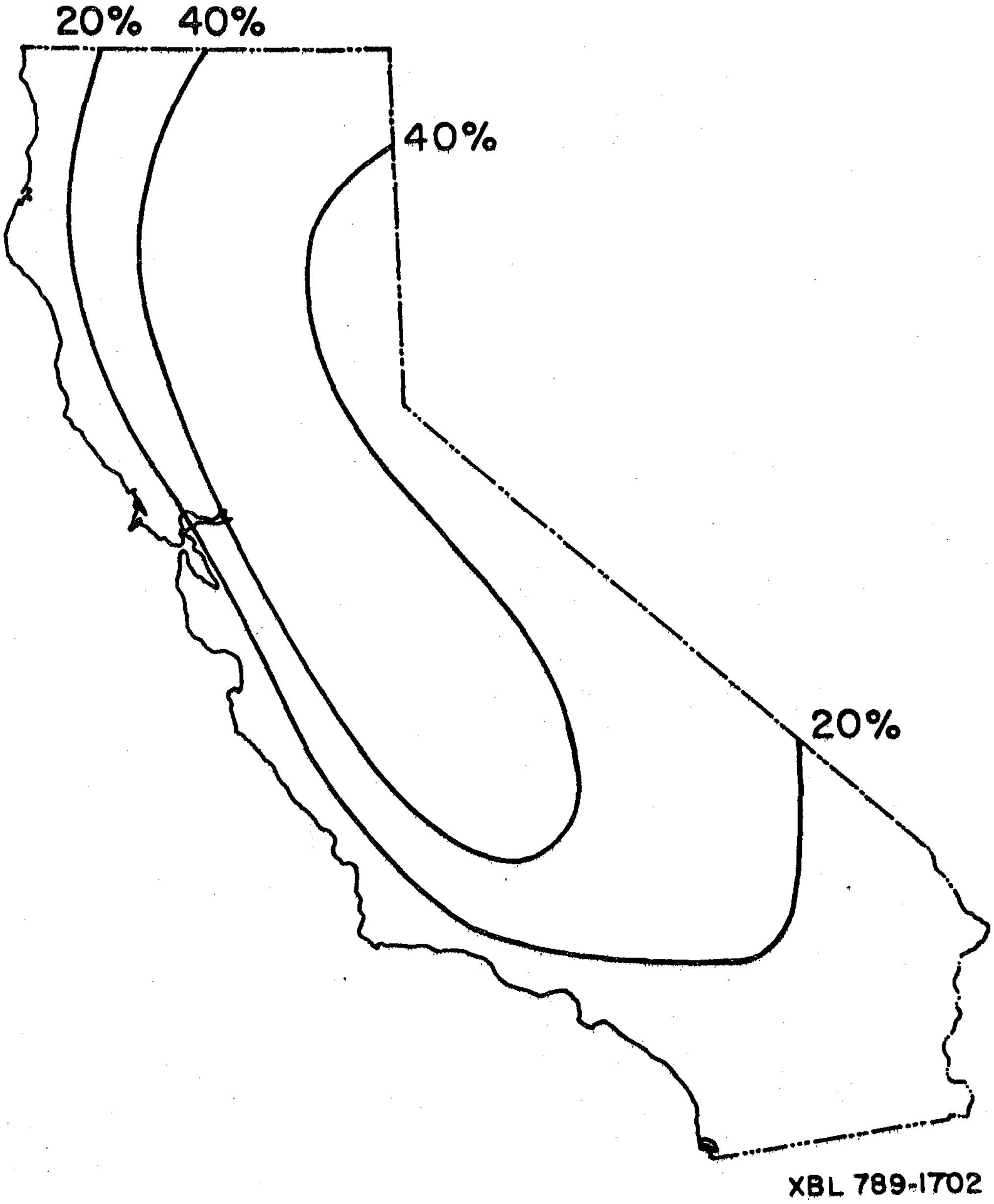


Figure I-2. Change of the percent of possible sunshine between January and July 1977.

Crescent City and Eureka to up to 20% in the southeastern part of the state); and an intermediate zone along the Sierras and central ranges. It should be noted that smoothed analyses were used here; thus, local variations will not be displayed.

The third analysis, shown on Fig. I-3, combines Figs. I-1 and I-2 to divide California into five regions. These range from an area in the northwest, characterized by an approximate 60-65% annual solar availability and a small seasonal variation, to the southeastern region, characterized by at least 85% availability of sunshine and less than 20% seasonal variation. The San Joaquin Valley emerges as a separate region by virtue of its large seasonal variation in solar availability.

The fourth analysis (Fig. I-4) was produced by subjecting the third analysis to topographical restraints and/or, as a general integrator, comparison with native vegetation maps. Based upon these considerations, the following areas are now identified:

1. Northern California is divided into three unique regions.
2. The Cotati, Napa, Santa Clara, and Monterey Valleys appear as extensions of the coastal plains.
3. The coastal area bounded by (approximately) San Luis Obispo on the north and Santa Barbara on the south.
4. The Coastal Plain from Los Angeles southward.
5. The eastern portion of the central Sierra boundary is moved to the Lake Tahoe area.
6. Based upon topographical considerations, the low and high deserts are differentiated.

A further analysis, shown on Fig. I-5, takes into account days of dense fog, sea land breeze considerations, and smog. Implicit in this consideration is the winter season stagnating air masses in the San Joaquin Valley where dense fogs may persist for up to ten consecutive days. The area thus concerned extends from approximately Marysville to Fresno. The tops of the fog/cloud masses are commonly from 200 to 2500 feet msl. The 2500-foot contour on the west side of the Sierras thus forms a boundary for this region.

Figure I-3. The regionalization of California (1).

XBL 789-1704

Figure I-4. The regionalization of California (2).

XBL 789-1705

Figure I-5. The regionalization of California (3).

Sea breezes will be effective along the major valleys extending from the coast. The sea breezes, blowing from the ocean during the day, will bring hazy sea air over the affected areas, and thus attenuate the solar beam. In addition, if the sea breeze passes over a large urban area, various pollutants will be injected into the atmosphere, further reducing the solar energy streams over the areas affected by the sea breezes. The Cotati, Napa, Santa Clara, and Monterey Valleys, and a relatively large area east of Los Angeles, including San Bernardino and Riverside, are thus affected.

Since the only opening of any consequence from the ocean into the San Joaquin Valley lies in the Carquinez Straits, the sea breeze now charged with the pollution of the greater San Francisco area is advected into the valley, where it spreads northwest and southeast.

A further analysis, considering the seasonal air masses and their trajectories, season cloud height and amount patterns, as well as the diurnal cloud patterns, is shown in Fig. I-6. The important changes made here concern the San Joaquin Valley and southeastern portion of the state. The eastern boundary along the Sierras is now located at approximately the 4500-5000 foot contour to reflect the winter season cloud tops. The boundary along the crest is retained to reflect the cloud bases during the summer season. Due to the high daytime temperatures and low humidity of the air, the convection condensation level will be frequently at 12,000 feet or more msl; therefore, afternoon convective clouds will form near the crest, whether the air moves from the southwest or southeast. The coastal ranges, especially south of San Francisco, are sufficiently low that during the summer season they project above the West Coast inversion. Their most important effect is to prevent the marine air from penetrating into the San Joaquin Valley.

The diurnal cloud variations within the valley appear to be rather constant in amount during both winter and summer seasons, although the average cloud cover is greater in the winter than summer season. On the other hand, along the coast, during the winter season the diurnal cloud amount remains relatively constant, but during the summer season the maximum cloudiness is in the early morning hours, and rapidly sinks to a minimum value in the early afternoon. The coastal ranges thus mark a boundary for the diurnal cloud regions.

In the final analysis, shown on Fig. I-7, actual solar receipts in California (Goodridge, 1977) are considered. Energy receipt during January

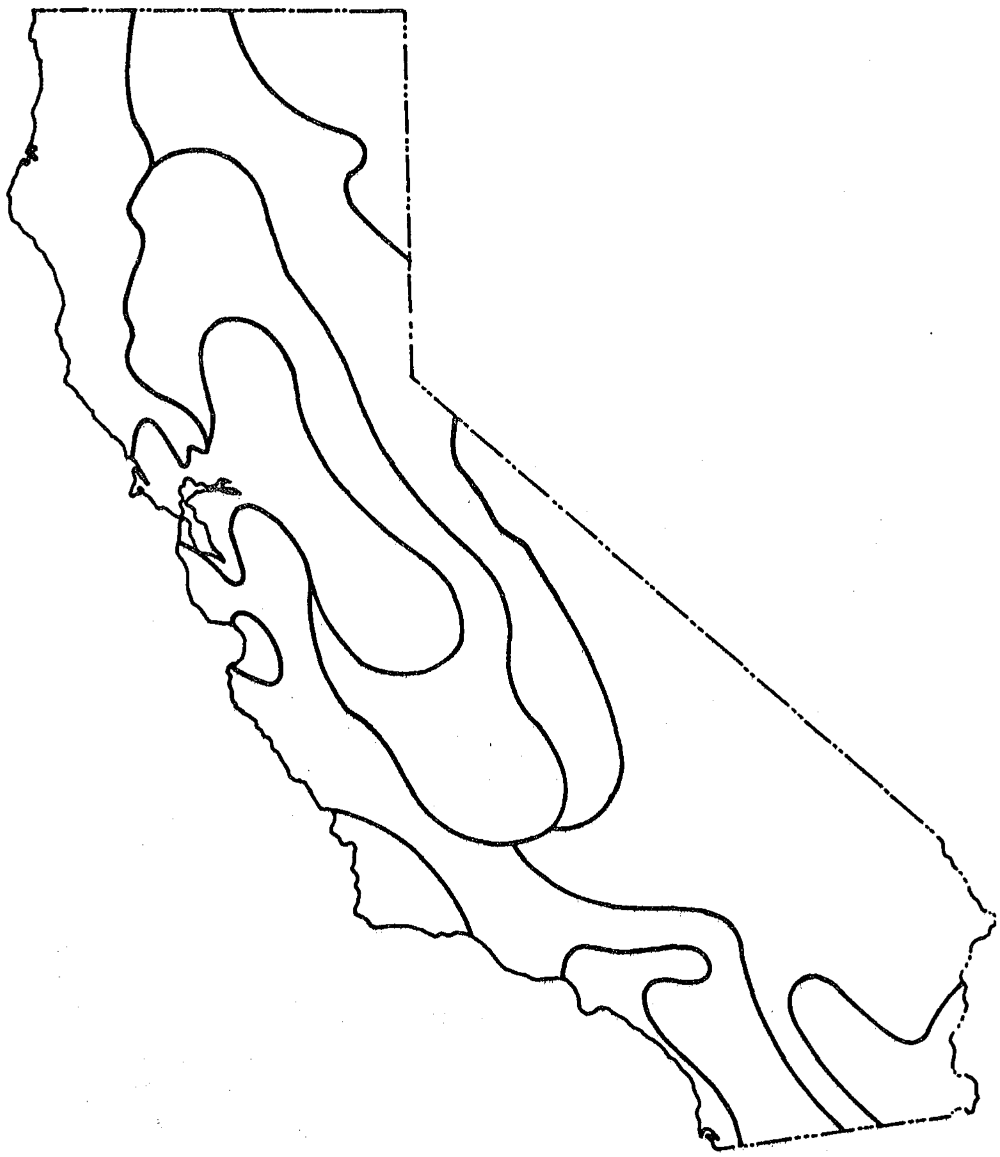


Figure I-6. The regionalization of California (4).

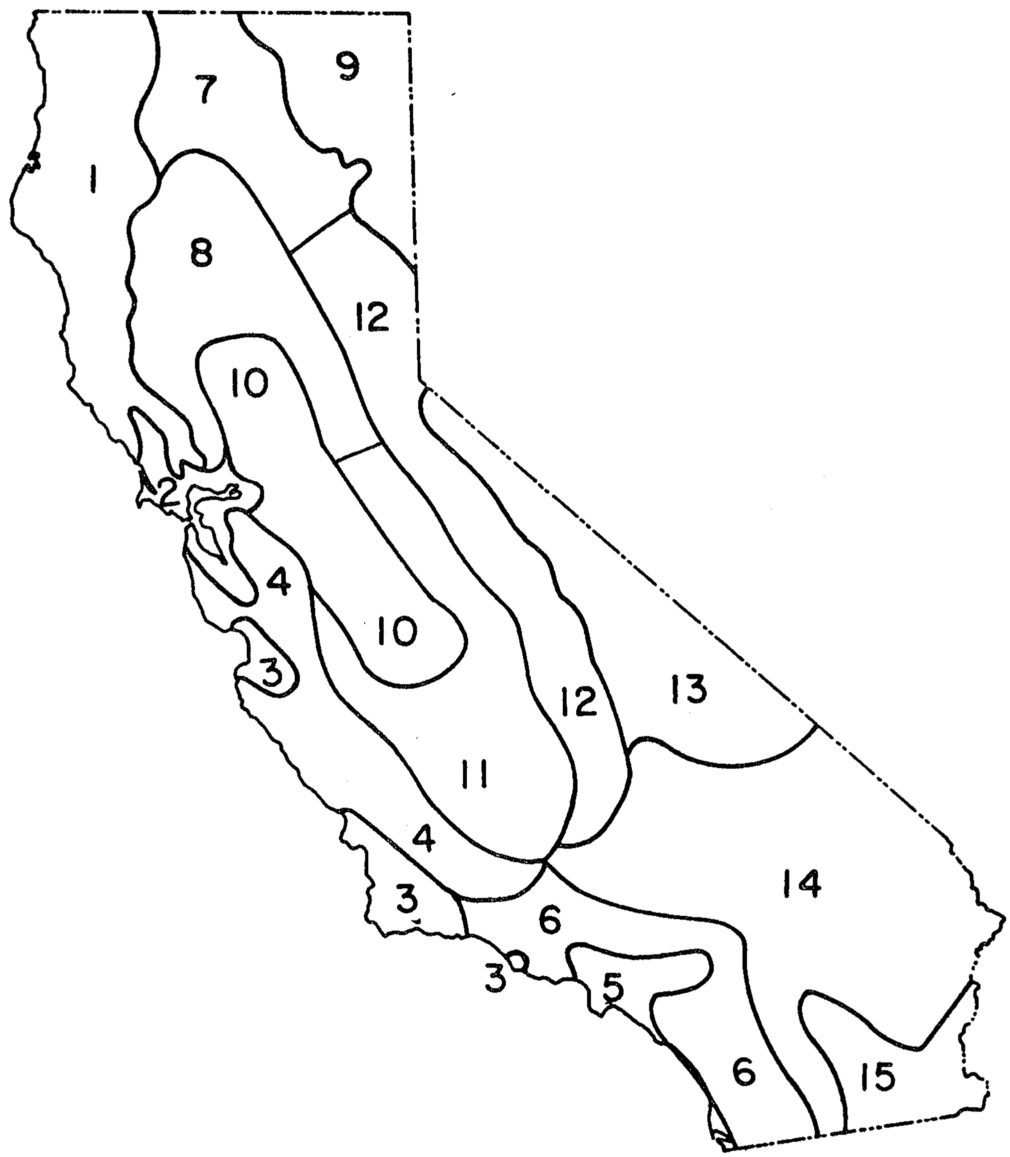


Figure I-7. The regionalization of California (5).

and July was plotted and analyzed, and differences in patterns noted. Because several records were short, and some instruments are not of high precision, the data were used subjectively. Latitudinal refinements and some topographical refinements were also introduced. Thus, a boundary has been introduced into the northeast to reflect annual cloud cover, and a boundary has been introduced to separate the high deserts from the mountain valley terrain in the east. Topography also indicated the need for a boundary to separate the coastal and transverse ranges.

ACKNOWLEDGMENTS

The independent consultants with whom the project was reviewed provided several valuable inputs. Mr. Loren Crow suggested several considerations, especially in the Sierra region. Dr. Arnold Court, from his tremendous store of detailed knowledge, especially about Southern California, provided many valuable suggestions. Mr. Sidney Frank made several valuable methodology suggestions. Special thanks are given to Dr. Robert Durrenberger, who provided special insights and continuing support throughout the project. The contributions of each of these individuals are gratefully acknowledged.

SHORT BIBLIOGRAPHY

Baily, H. P., 1966. The Climate of Southern California. Berkeley and Los Angeles, U. C. Press.

Durrenberger, R. W., 1976. A Cloud Atlas of the American Southwest. Tempe, State Climatologist for Arizona, Arizona Resources Information Systems Cooperative Publication, No. 9.

Goodridge, J., 1974. Solar Radiation Measurements in California. Sacramento, State of California Department of Water Resources.

Kistler Graphics, 1968. California in 3D. Denver, Kistler Graphics.

Rumney, G. R., 1968. Climatology and the World's Climates. New York, MacMillan.

U. S. Department of Commerce, 1962. Summary of Hourly Observations. Decennial Census of the U. S. Climate, Climatography of the U. S. (California Series). Washington, D.C., Supt. of Documents.

_____, 1974. Local Climatological Data (for California locations). Asheville, North Carolina, NOAA, EDS, Federal Building.

Wang, J. Y., 1967. Agricultural Meteorology. San Jose, Agricultural Weather Information Service.

Appendix J
PARTICIPANTS AT THE SOLAR DATA MANAGEMENT CONFERENCE
19 NOVEMBER 1976

Participants at the Solar Data Management Conference
19 November 1976

Nick Patapoff, Southern California Edison Co., Rosemead, California

Stanley Blois, Pacific Gas and Electric Co., San Francisco, California

Michael Basso, Bay Area Air Pollution Control District, San Francisco, California

Frederick Koomanoff, ERDA, Washington, D.C.

James Lerner, Energy Resources Conservation and Development Commission, Sacramento, California

Mat Ginosar, Energy Resources Conservation and Development Commission, Sacramento, California

James Goodridge, Department of Water Resources, Sacramento, California

John Cummings, Electric Power Research Institute, Palo Alto, California

Kinsell Coulson, Department of Land, Air and Water Resources, Atmospheric Sciences Section, University of California, Davis, California

MacGregor Reid, Jet Propulsion Laboratory, Pasadena, California

Michael Wahlig, Lawrence Berkeley Laboratory, Berkeley, California

Donald Grether, Lawrence Berkeley Laboratory, Berkeley, California

Marlo Martin, Lawrence Berkeley Laboratory, Berkeley, California

Paul Berdahl, Lawrence Berkeley Laboratory, Berkeley, California

Rob Taylor, San Diego Gas and Electric Co., San Diego, California

David Tirrell, Civil Engineering Branch, Twelth Coast Guard District, San Francisco, California

Appendix K
REHABILITATION TECHNIQUES FOR DAILY SOLAR RADIATION DATA

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 24 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 average 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. K-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

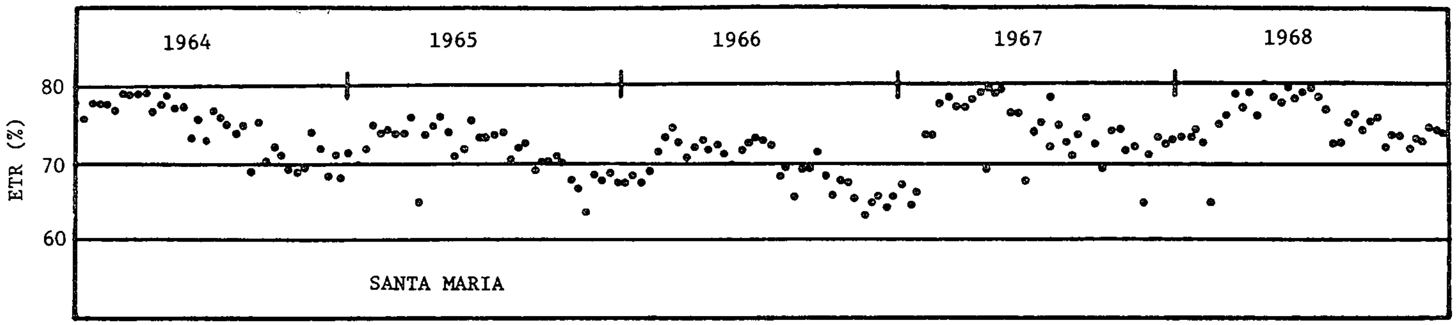


Figure K-1. Example of a "compressed" percent of ETR plot for Santa Maria insolation data. Each point on the graph represents the maximum daily percentage of extra-terrestrial radiation recorded during a 10-day interval. An approximately linear downward drift of 3% per year in the instrument calibration 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. K-2.

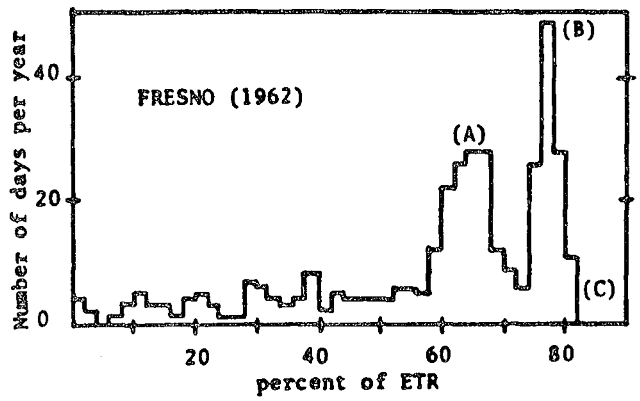
ADJUSTMENT OF THE SOLAR DATA

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. K-2. Reference to the histograms show that the clear days forming the upper

Figure K-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).



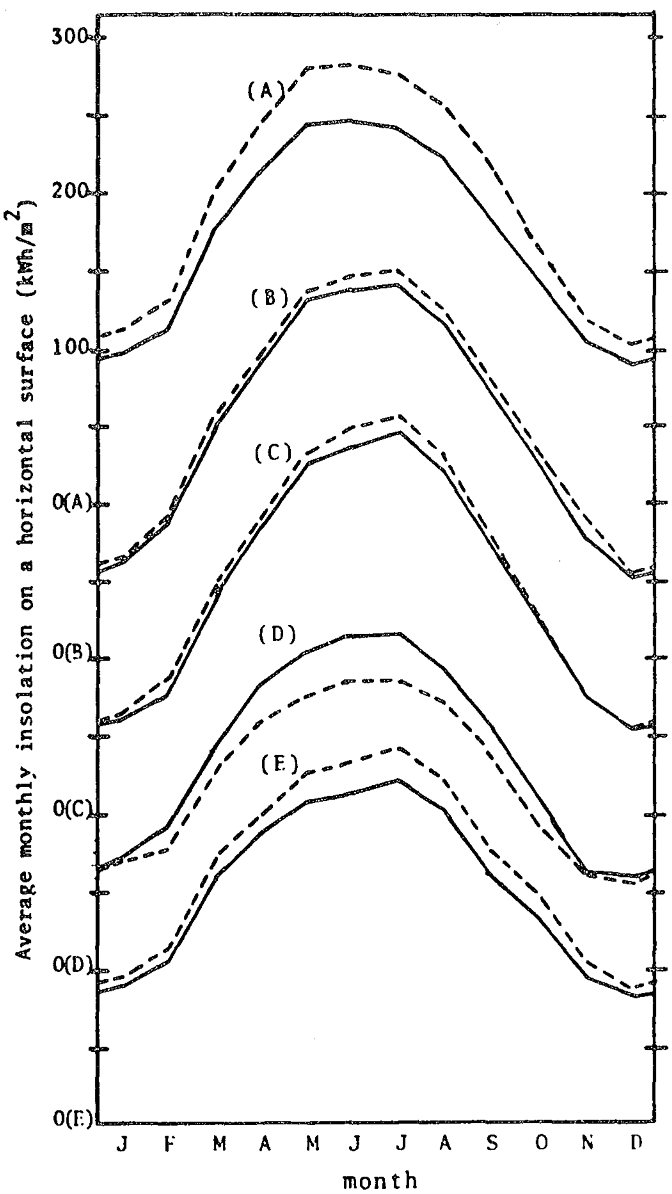


Figure K-3. Comparison of average monthly insolation levels on a horizontal surface before and after the data rehabilitation process was carried out. The dashed lines represent uncorrected data and the solid lines are the corrected monthly averages. Key: (A) China Lake/Inyokern, (B) Fresno, (C) Davis, (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 Fig. K-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/Inyokern). 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 appendix has appeared separately as LBL-7898 and in the Proceedings of the 1977 Annual Meeting of the American Section of International Solar Energy Society.

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