Presented at 3rd Annual Solar Heating & Cooling R&D Contractors' Meeting, Washington D.C., September 24-27, 1978.

LBL-8391
c.2

RECEIVED
LAWRENCE
BERKELEY LABORATORY

DEC 4 1978

LIBRARY AND
DOCUMENTS SECTION

TWO-WEEK LOAN COPY

This is a Library Circulating Copy
which may be borrowed for two weeks.
For a personal retention copy, call
Tech. Info. Division, Ext. 6782

Energy and Environment Division

Measurement of Circumsolar Radiation — Status Report

Donald F. Grether, Arlon Hunt, David Evans, and Michael Wahlig

September 1978

Lawrence Berkeley Laboratory University of California/Berkeley

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

LBL-8391
c.2

LEGAL NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

MEASUREMENT OF CIRCUMSOLAR RADIATION - Status Report*

LAWRENCE BERKELEY LABORATORY
Contract Number
W-7405-ENG-48

Donald F. Grether, Arlon Hunt, David Evans, Michael Wahlig

OCTOBER 1977 - SEPTEMBER 1978

OBJECTIVE

The primary objective of this project is to provide solar radiation measurements necessary for accurate prediction of the performance of solar energy conversion systems employing concentrating collectors. Pyrheliometers, the standard instruments used to estimate the "direct" solar flux, typically have a field of view of 6° (compared to the 1/2° angle subtended by the sun) and thus include a substantial portion of the circumsolar radiation within the measurement. Depending on the solar application, the pyrheliometer measurement either underestimates or overestimates the amount of solar radiation that would be collected. This project will obtain accurate measurements of the true "direct" solar flux from the sun's disc and also the detailed radiation from the circumsolar region between the edge of the sun's disc and the 6° field of view of a pyrheliometer.

CONCEPT

The measurements are made by scanning telescopes that determine the flux of energy from the sun and the circumsolar region (the small-angle region around the sun) as a function of angle, wavelength, and atmospheric conditions. The circumsolar radiation arises from forward scattering of sunlight from aerosols, ice crystals, or water droplets in thin clouds. This dependence on meteorological variables leads to large regional and seasonal variations. The angular and wavelength measurements provided by the project allow detailed considerations of the actual performance of the concentrating system. The data can be used as input to optimization of receiver sizes, characterization of a site or region, and comparisons between competing designs at a given location.

SUMMARY

The major accomplishments of this project include the design, construction, and deployment of four complete circumsolar telescope systems. The telescopes have been maintained and data have been collected from a total of nine sites over the past two years. The data upon reaching LBL have been compiled, validated and analyzed for dissemination to DOE and other users. LBL has been collaborating with other national laboratories to quantify the impact of circumsolar radiation on specific solar collector designs. Requests for data from a wide variety of solar users have been fulfilled.

*During fiscal year 1978 this project was co-sponsored by the Solar Heating and Cooling Research and Development Branch, Office of Conservation and Solar Applications; and Solar Thermal Power Systems, Division of Solar Technology, Office of Energy Technology; both of the U.S. Department of Energy.

TECHNICAL ACCOMPLISHMENTS

- Four instruments systems have been constructed, each of which contains a "scanning telescope" to make the circumsolar measurements, and includes standard solar and meteorological instruments. The telescopes were developed at LBL. They are deployed at sites of interest to various DOE programs utilizing concentrating collectors systems. The telescopes remain more or less in the same place for a period on the order of a year, so that seasonal variations can be quantified. Some of the instruments have been operated at one site for longer periods of time in order to examine year-to-year variations. The instrument systems are sufficiently portable that they can be used for short-term measurements in support of other DOE solar projects. The instruments were first deployed in 1976 and have operated for a year or more at the following sites: Albuquerque, NM, China Lake, CA, Barstow, CA, Ft. Hood, TX, Argonne, IL, Atlanta, GA, and for shorter periods at Berkeley, CA, Boardman, OR, and Colstrip, MT.

- The data from the instrument systems are stored and processed at LBL with the results made available to the various solar concentrating collector projects in a form appropriate to each project. These forms include: 1) sample scans of the telescope for a particular time (e.g., when a nearby heliostat was operating) or for a variety of conditions (clear, hazy); 2) variation in solar and circumsolar radiation over the course of a day, month or year; and 3) detailed data suitable for input to computer-based simulations of solar energy conversion systems. Once they are in this form, the data can be used to help optimize the solar system design (e.g., by influencing the choice of receiver aperture size), or help determine the size of a heliostat field necessary for a specified power output.

- In addition to the more detailed data sets, a series of studies has summarized the average and instantaneous amounts of circumsolar radiation at each of the long-term sites. The results of these studies are given in a series of three reports. The contents of the first report permit a rapid evaluation of the effects of circumsolar radiation on: 1) the average errors in pyrheliometer readings; 2) the energy losses from idealized collectors with varying angular aperatures and insolation thresholds; and 3) average time of day variations for several climate types. These data are presented on a monthly basis for periods a year or more for each site. The second report presents data on the instantaneous values of circumsolar radiation and indicates that in mid-day substantial amounts of circumsolar radiation are often present. The third report addresses the average sensitivity to circumsolar radiation of two conceptual designs for a 10 MWe solar pilot plant.

FUTURE ACTIVITIES

Continued data collection is planned to characterize circumsolar effects in other climate types of interest for solar energy collection. Analysis of the data in cooperation with other DOE laboratories, will be expanded to determine the impact of circumsolar radiation on line focus receivers, the relative efficiencies of imaging and non-imaging solar collectors, the design of large scale solar thermal power plants, and the performance of concentrating photovoltaic collectors.

In particular, SERI (Solar Energy Research Institute) has been requested by DOE to undertake the analysis for solar thermal applications. SERI's initial study considered only one axis concentrators and non-imaging concentrators (e.g., CPC's). Collaboration is continuing with Sandia Laboratories at Livermore and Albuquerque to determine effects of circumsolar radiation on large solar central power systems and the 5 MW STTF. In addition, interest has been expressed by Sandia Albuquerque in the spectral data for application in determining the performance of concentrating photovoltaic systems.

Other work underway will provide an automatic sunphotometer that mounts directly on the circumsolar telescope, to study whether a relationship exists between the data from the previously established network of sunphotometers and the amount of circumsolar radiation.

A correlation analysis will examine whether some combination of routinely measured solar/meteorological variables, together with a model, can provide adequate estimates of circumsolar radiation for some applications in the solar program.

Another analysis will investigate whether the circumsolar radiation can be characterized by a small number of parameters that can be measured by simpler instruments. If so, a simplified instrument would be designed to take advantage of the fact. Construction and testing of a prototype instrument would indicate whether it would be suitable for commercial manufacture.

REFERENCES

Bibliography for Measurement of Circumsolar Radiation Project:

1. "Measurement of Circumsolar Radiation," Progress Report No. 1, D. F. Grether, J. E. Nelson, and M. Wahlig, UCID - 3705, January 31, 1975; National Science Foundation Report No. NSF/RANN/SE/AG-536/PR/7474.

2. "Measurement of Circumsolar Radiation," D. F. Grether, J. E. Nelson, and M. Wahlig, Energy and Environment Division Annual Report 1974, Lawrence Berkeley Laboratory Report LBL-3253, p. 41.

3. "Measurement of Circumsolar Radiation," Donald Grether, Jerry Nelson, and Michael Wahlig, Proceedings of the Symposium on Optics in Solar Energy Utilization, at the 19th Annual Technical Symposium of the Society of Photo-Optical Instrumentation Engineers, San Diego, California, August 1975, also LBL - 3280, July 1975.

4. "Measurement of Circumsolar Radiation," D. F. Grether, A. J. Hunt and M. Wahlig, Energy and Environment Division Annual Report 1975, Lawrence Berkeley Laboratory Report LBL - 5299, p. 46.

5. "Results from Circumsolar Radiation Measurements," D. F. Grether, A. J. Hunt and M. Wahlig, in the Proceedings of the International Solar Energy Society Meeting, Winnipeg, Canada, August 16-20, 1976.

6. "Measurement of Circumsolar Radiation," Donald F. Grether, Arlon J. Hunt and Michael Wahlig, Energy and Environment Division Annual Report 1976, Lawrence Berkeley Laboratory, Report LBL - 5982, p. 75.

7. "Atmospheric Aerosol Data from Circumsolar Telesope Measurements," D. F. Grether, A. J. Hunt, and M. Wahlig, in the proceedings of the OSA/NASA Topical Meeting on Atmospheric Aerosols, their Optical Properties and Effects, Williamsburg, VA., December 13-15, 1976.

8. "Circumsolar Radiation Data for Central Receiver Simulation," A. J. Hunt, D. F. Grether, and M. Wahlig, in the proceedings of the ERDA Solar Workshop on Methods for Optical Analysis of Central Receiver Systems, Houston, Texas, August, 1977.

9. "Measurement of Circumsolar Radiation," D. F. Grether, A. J. Hunt and M. Wahlig, Energy and Environment Division Annual Report 1977, Lawrence Berkeley Laboratory, Report LBL 6877, p. 26.

10. "The Circumsolar Measurement Program: Assessment of the Effects of Atmospheric Scattering on Solar Energy Conversion," A. J. Hunt, D. F. Grether, and M. Wahlig. Presented at the 4th Joint Conference on Sensing of Environmental Pollutants, November 6-11, 1977, New Orleans.

11. "Circumsolar Radiation" Monthly Summaries of Effect on Focusing Solar Energy Collection Systems," D. F. Grether, A. J. Hunt, M. Wahlig, October, 1977 (to be published).

12. "Circumsolar Radiation: Sensitivity Analysis for Central Receiver Designs," D. F. Grether, A. J. Hunt, M. Wahlig, October, 1977 (to be published).

13. "Circumsolar Radiation: Correlations with Solar Radiation," D. F. Grether, A. J. Hunt, M. Wahlig, October, 1977 (to be published).

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

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720