Title
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MEASUREMENT AND ANALYSIS OF CIRCUMSOLAR RADIATION

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Introduction

This project uses specially developed instruments to measure the solar and circumsolar radiation for application to solar energy systems that employ concentrating collectors. Circumsolar radiation results from the scattering of direct sunlight through small angles by atmospheric aerosols (dust, ice crystals in thin clouds, etc.). The solar energy system will collect the direct solar radiation and some fraction of the circumsolar, the exact fraction depending upon the geometry of the system and the nature of the circumsolar radiation.

Four instrument systems have been and are currently in use at locations and climate types of interest to concentrating solar energy systems. The data are processed at Lawrence Berkeley Laboratory (LBL) and then used at LBL, and at other DOE supported institutions, in analyses of the performance of such systems. These analyses help determine the optimum geometry of a system, allow comparisons of competing systems at a given location, and help characterize the suitability of a particular region for focusing systems. In addition, efforts are underway to establish correlations of the circumsolar radiation to other more commonly available meteorological or climatological parameters. The intent is to extend the analyses to areas not covered by one of the existing instruments.

Each instrument consists of a scanning telescope mounted on a precision solar tracker, an electronic controller and data recorder, and various pieces of auxiliary equipment. The latter include a pyrheliometer and two pyranometers (one tracking the sun and one horizontal). The telescope scans thru a total angle of 6 degrees, with the sun at the center of the scan. The telescope and pyrheliometer have matched ten position filter wheels: one clear (or open) filter, eight colored filters that divide the solar spectrum into eight bands of roughly equal energy content, and one opaque filter to monitor detector noise.

Measurement and Routine Monitoring Program

Three of the telescopes are in operation at Albuquerque, Barstow, and Atlanta. Engineering and technical support for these instruments continues, as does the routine data processing for data quality control.

The fourth telescope is at LBL for maintenance. The return of this instrument provided an opportunity to examine, under laboratory conditions, the effects of over two years of weathering. A number of parts have been redesigned or new versions ordered in an attempt to improve the weatherability. When the telescope is again operating, it will be used briefly at LBL to test a automated sunphotometer that is mounted on the solar tracker. The telescope will then be ready for relocation.

Data Processing

As a first step is processing the data to a directly usable form, the information from the original data tapes (one per week per telescope), with various organizational problems fixed, is transferred to a mass storage system (the GSS).

In the next step, the GSS is used as the starting point to create a preliminary version of a Reduced Data Base (RDB). Calibration factors are applied and the data are condensed. At this point various statistical methods are employed to look for and, when necessary, devise correction factor for faulty data. A revised

RDB is then produced.

The following table summarizes the status of the data from the various locations.

Scope	Location	From	To	GSS(a)	RDB(b)	RDB(c)
1	Boardman,OR	3/77	5/77	5/77	5/77	5/77(d)
	Colstrip,MT	5/77	5/77	5/77	5/77	5/77
	Atlanta	6/77	current	12/78	6/78	6/78
2	Albuquerque	5/76	current	1/79	1/79	12/77(d)
3	Ft. Hood,TX	7/76	7/77	7/77	7/77	7/77
	Argonne,IL	7/77	10/78	10/78	6/78	12/77
	Berkeley	11/78	current	-	-	-
4	China Lake	7/76	5/77	5/77	5/77	5/77
	Barstow	6/77	current	12/78	6/78	6/78

(a) Mass storage on GSS complete thru indicated date.
(b) Preliminary Reduced Data Base complete thru indicated date.
(c) Revised RDB complete thru indicated date.
(d) Portions of these data have residual difficulties.

Correction of Atlanta Data

The intial data from Atlanta had periods of time when the pyrheliometer was not working properly (the problem was eventually traced to a faulty cable) or was at the manufacturers. A method was developed to use correlations between the pyrheliometer and other parameters during "good" periods, and then to use these parameters to estimate the pyrheliometer value during "bad" periods. The parameters used were the output of the tracking pyranometer, and of the telescope scan (in arbitrary units of the pyroelectric detector) integrated over the field-of-view of the pyrheliometer. A variation of a "clear-solar-noon" analysis was used to establish that the tracking pyranometer and pyroelectric detector behaved consistently during the bad periods as compared to the good periods.

Figure 1 plots pyrheliometer values vs the time of day for two days during periods when the pyrheliometer was working properly. Figure 1(a) is for a generally clear day with broken clouds, and 1(b) for an overcast day. The solid curve is for the actual pyrheliometer reading and the dotted the estimate based on the tracking pyranometer and the telescope scan.

Data Supplied to Others

SERI has undertaken an analysis of the effect of circumsolar radiation on various concentrating collectors. Orginally, the analysis was based on 16 "standard profiles" that represent the type of profiles (brightness of the sun and circumsolar region as a function of angular distance from the center of the sun) often encountered in the data. The actual data were to be conveyed to SERI in the form of tables of the frequency of occurance of the standard profiles. However, this process proved inefficient. It was then agreed that LBL would supply hourly average values of the various quantities measured by the telescopes. A data base of hourly values has been created, and a sample tape sent to SERI.

As discussed by D. Watt at this meeting, a collaborative effort is underway with Watt Engineering to develop a model for circumsolar radiation. Various forms of the data have been prepared, including a magnetic tape with hourly average pyrheliometer and circumsolar values.

A tape of hourly averages of the pyrheliometer and the corresponding horizontal pyranometer readings was prepared for Sandia, Albuquerque. The tape is to be used in studies of the relationship between normal incidence and total horizontal radiation.

In late calender year 1978 and early 1979 a series of tests were made at the Central Receiver Solar Thermal Test Facility at Albuquerque of the Boeing Brayton cycle receiver design. Work is underway at LBL to process the circumsolar data taken at the same time (the telescope is adjacent to the test facility) to a form that can be input to the Sandia analysis program Helios, for comparison of the predicted to the actual performance.

Colored Filter Data

Figure 2a shows the nominal colored filter pass bands superposed on the solar spectrum for air mass = 2. Until recently, the emphasis in the project has been on processing and analyzing the "clear" (or no) filter data. Correspondingly, the Reduced Data Base contains the colored filter data for the pyrheliometer but not for the telescope scans. Further, the filter values on the RDB are the actual pyrheliometer readings, and thus refer to the amounts of energy that were transmitted thru the filters, rather than the actual energy content of that part of the solar spectrum corresponding to a given filter's passband. To obtain this quantity requires an accurate knowledge of the filters' transmission properties. While transmission curves were supplied by the filter manufacturer, an independent check is desirable and a knowledge of the change in characteristics with time crucial. To obtain this information, two efforts are underway. First, the filters from the telescope currently at LBL are being measured on a spectrophotometer. Second, a method is being developed to use the data themselves to determine the overall transmission of each filter as a function of time. The basic approach is similiar to a "Langley Plot"; the pyrheliometer readings on clear days are extrapolated to zero air mass. By comparison to the extraterrestrial solar spectrum, a calibration factor for each filter can in principle be determined. Results to date have indicated that the filters have not suffered marked changes in their properties. As an illustration, Figure 2b shows the extrapolation to zero air mass of the ratio of a colored to the clear filter for one and one-half years worth of data at China Lake/Barstow. The plot is reasonably flat. When the calibration factors have been determined, the present RDB together with a table of calibration factors (or, equivalently, a revised RDB) will provide pyrheliometer values in each of the eight wavelength bands. When the calibration has been achieved for the pyrheliometer filters, then the filtered scan data will be addressed.

Comparison of Atlanta to Barstow Data

Various techniques for presenting the effect of the circumsolar radiation on concentrating systems have been discussed at previous meetings. Data have been presented for Albuquerque, China Lake/Barstow, Ft. Hood, and Argonne. However, data for Atlanta have not been shown because of the difficulties discussed above.

For this meeting the emphasis will thus be on the Atlanta data. For comparison purposes data from Barstow will also be shown.

Figure 3 plots the circumsolar radiation (the integral of the brightness from the edge of the sun out to 3 degrees from the center) vs the pyrheliometer reading for a months worth of data at Barstow and at Atlanta. There is significant variation from month-to-month at both locations, but the general features evident in these plots are rather characteristic of the two locations. Similiar plots to that for Barstow have been shown before. There is a clump of high pyrheliometer and low circumsolar values, a tail of rapidly decreasing pyrheliometer values corresponding to times near sunrise and sunset, and a "crescent" of high circumsolar values that corresponds to periods during the middle portion of the day when atmospheric scattering dominates. For Atlanta, the plot does not have such distinctive features. A much wider range of pyrheliometer and circumsolar conbinations is evident, as are the generally lower solar radiation values.

Figure 4 presents the average effect of the circumsolar radiation over a years period at the two sites. The quantity plotted is the overestimate that would be made by a pyrheliometer in estimating the solar radiation available to a concentrating solar plant, where the plant is described in terms of two simplified parameters. The first is the operating threshold; the plant is assumed to be in operating whenever the solar radiation exceeds the threshold. The second is the effective aperture radius (half the field of view) of the receiver. The figure is for a threshold of 50 watts/meter squared and for various radii as indicated. The overestimate is generally greater for Atlanta (corresponding to generally higher circumsolar levels). At least for this year, the two locations appear to have quite different seasonal dependencies.

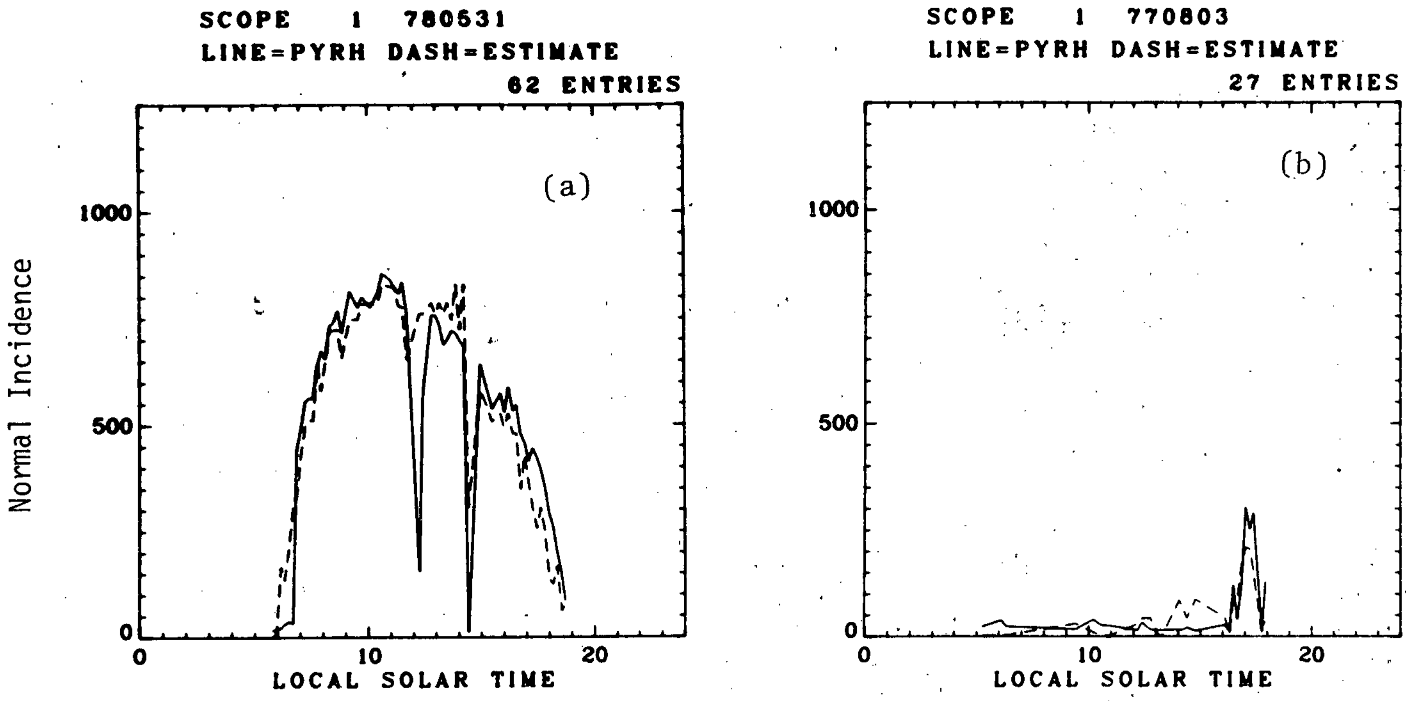

Figure 1

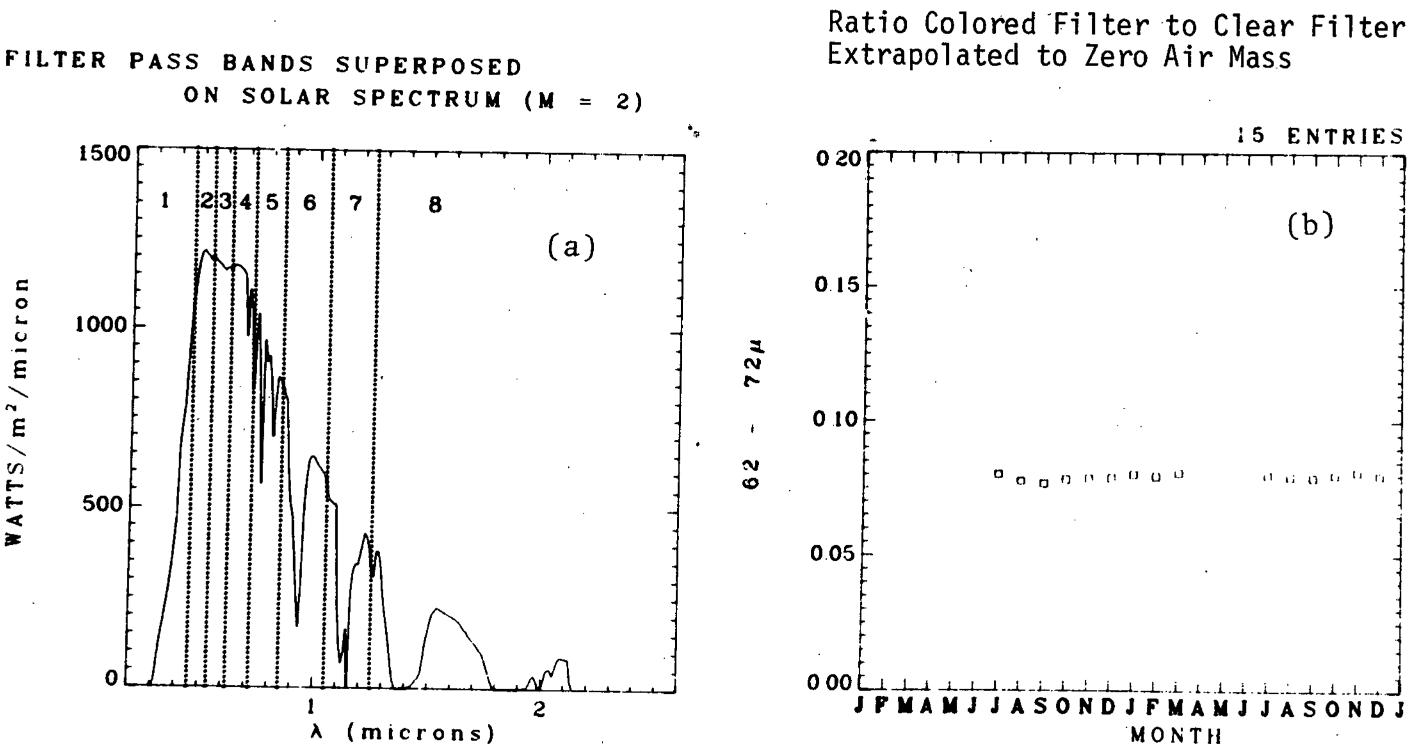

Figure 2

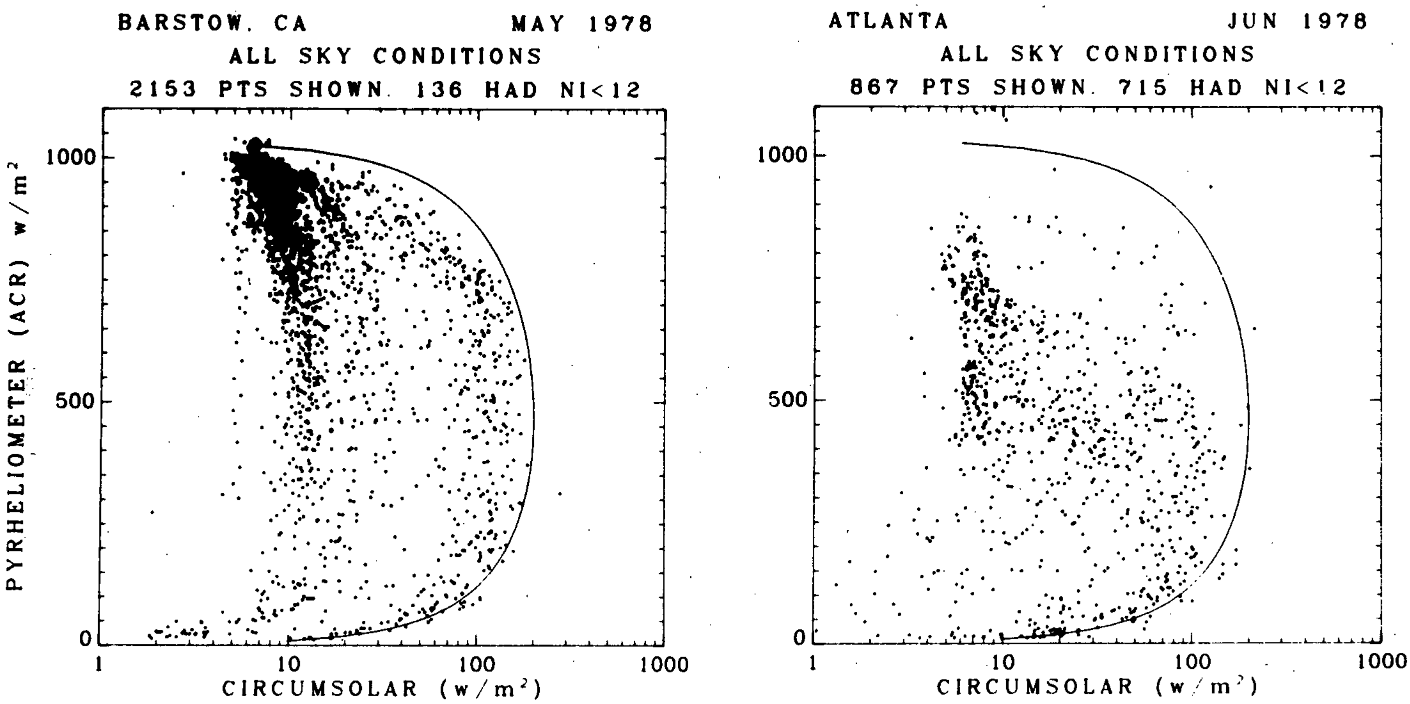

Figure 3

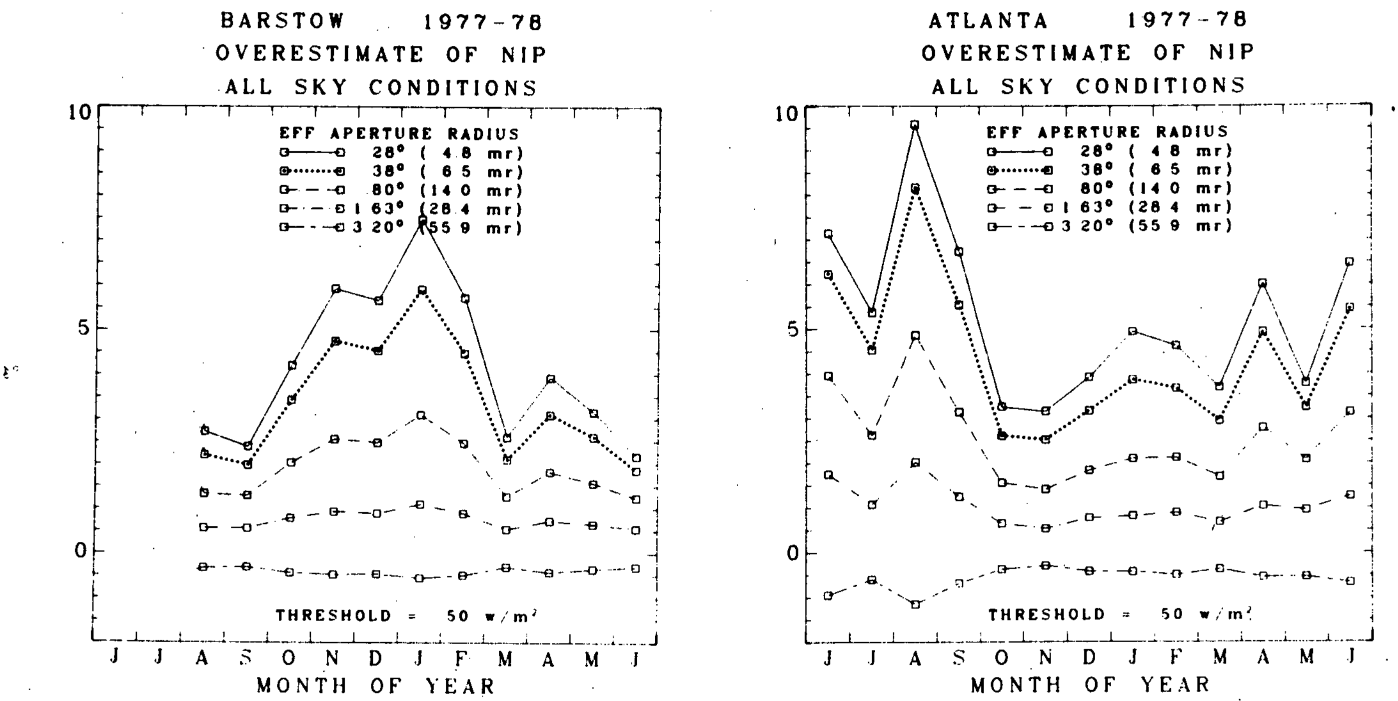

Figure 4

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