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MEASUREMENT OF CIRCUMSOLAR RADIATION



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# Measurement of Circumsolar Radiation*

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# MEASUREMENT OF CIRCUMSOLAR RADIATION*

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Circumsolar radiation refers to light that, to an observer on the ground, appears to originate from the region around the sun. This radiation is caused by scattering of light through small angles by particles (aerosols) in the earth's atmosphere with dimensions on the order of or greater than the wavelength of light. The aerosol particles may be composed of ice crystals or water droplets in thin clouds, dust or sea salt particles, or photochemical pollutants. The amount and character of circumsolar radiation vary widely with geographic location, climate, season, time of day and observing wavelength.

Focusing solar energy systems typically collect the direct beam solar radiation plus some fraction of the circumsolar radiation. The exact fraction depends upon many factors, but primarily upon the angular size (field of view) of the receiver. A knowledge of the circumsolar radiation can be used as input to performance prediction for specific designs, or as a factor in system optimizations. Circumsolar measurements can help in characterizing a site or region, or in comparisons between competing designs at a given location. Pyrheliometers, with their fixed field of view, measure a particular fraction of the circumsolar radiation and thus will either underestimate or overestimate the amount of radiation that will be available to any given concentrating system. Circumsolar data can provide a measure of this under-or overestimate.

Four instrument systems have been constructed to measure the circumsolar radiation. The basic instrument is a telescope that scans through a 6° arc of the sky with the sun at the center of the arc. The output is a digitization of the brightness of the sun and circumsolar region every 1.5' of arc. Auxiliary instruments include a pyrheliometer, two pyranometers (one horizontal and one tracking the sun), and weather equipment. One of the instrument systems is being operated at the Solar Thermal Test Facility at Albuquerque, New Mexico. A second telescope, originally located at China Lake, California, was moved in May, 1977 to Barstow, California, the future site of the 10 MWe Central Receiver pilot plant. A third telescope was operated at Ft. Hood, Texas (the future site of a Total Energy System) until August, 1977. The instrument was then moved to Argonne National Laboratory. This telescope has recently been returned to LBL for general maintenance and the installation of an automated sun-photometer. The fourth telescope was used in several short-term measurement programs,

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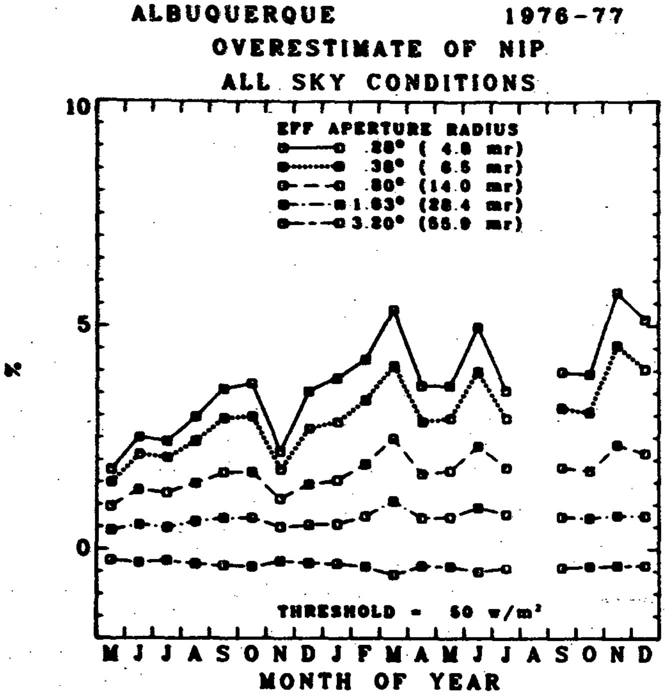
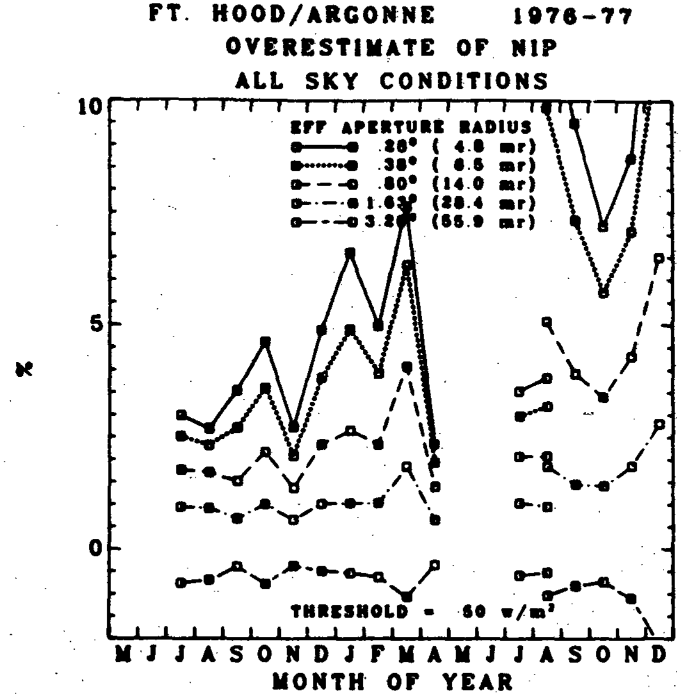
then deployed at Atlanta, Georgia in June, 1977 in connection with the 400 $Kw_t$ solar thermal test facility.

Since the last review meeting,the raw data tapes from the period June, 1977 thru June, 1978 have been transferred to a mass storage device. The Reduced Data Base, used as the data source for the analyses, was extended thru December, 1977. The data from Atlanta has some difficulties that are under investigation. A summary of the data from the other three telescopes is presented in Figure 1. The graphs are the overestimate that a NIP (Normal Incidence Pyrheliometer) would make in estimating the energy available to a point focusing solar plant with an operating threshold of 50 Watts/$m^2$ and with various receiver aperture radii(one-half the field of view) as indicated.

Two efforts are underway to correlate the circumsolar radiation with solar/ meteorological parameters. D. Watt is reporting on a climatological approach at this meeting. LBL is examining the correlation of instantaneous values with the pyrheliometer reading and the air mass. As an indication of the correlation, Figure 2 plots the circumsolar ratio (ratio of circumsolar to solar plus circumsolar) versus the pyrheliometer value for the month of November, 1977 in Barstow. Fig. 2(a) is for all values of air mass (the solid curve is from a simple scattering model that expresses energy conservation). Figs (b-d) are for various ranges of the parameter $m^*$, the relative air mass normalized to 1.0 at solar noon. These ranges clearly tend to isolate various portions of the overall distribution.

As an ancillary use of the data, a quasi minute-by-minute pyrheliometer data base was constructed for cloud transit studies at Sandia Livermore. The telescopes have a ten minute cycle, each cycle consisting of a scan and pyrheliometer measurement thru each of a clear filter, eight colored filters and an opaque filter. To construct the data base, the colored filter values were scaled to an approximate clear value. Figure 3 illustrates the steps in this process. Fig. 3(a) shows the ratio of a colored filter to the clear filter, as a function of air mass, for a month's worth of clear day data. An exponential fit (to the data delineated by the rectangular box) was then used to scale the colored filter values for all days in that month. The dependence of the coefficients of the fit on month of the year is shown in Figs. 3 (b) and (c). "C" is the filter ratio extrapolated to zero air mass and is reasonably flat. "A" expresses the air mass effect and shows some monthly variation. Fig. 3(d) shows the quasi minute-by-minute data for a day with broken clouds. A cubic-spline smoothing was used to reduce some artificial fluctuations; the resulting time resolution is about 2-3 minutes.


ALBUQUERQUE 1976-77
OVERESTIMATE OF NIP
ALL SKY CONDITIONS
EFF APERTURE RADIUS
.28° ( 4.8 mr)
.38° ( 6.5 mr)
.80° (14.0 mr)
1.63° (28.4 mr)
3.20° (55.9 mr)
THRESHOLD = 50 w/m²
%
10
5
0
M J J A S O N D J F M A M J J A S O N D
MONTH OF YEAR


FT. HOOD/ARGONNE 1976-77
OVERESTIMATE OF NIP
ALL SKY CONDITIONS
EFF APERTURE RADIUS
.28° ( 4.8 mr)
.38° ( 6.5 mr)
.80° (14.0 mr)
1.63° (28.4 mr)
3.20° (55.9 mr)
THRESHOLD = 50 w/m²
%
10
5
0
M J J A S O N D J F M A M J J A S O N D
MONTH OF YEAR

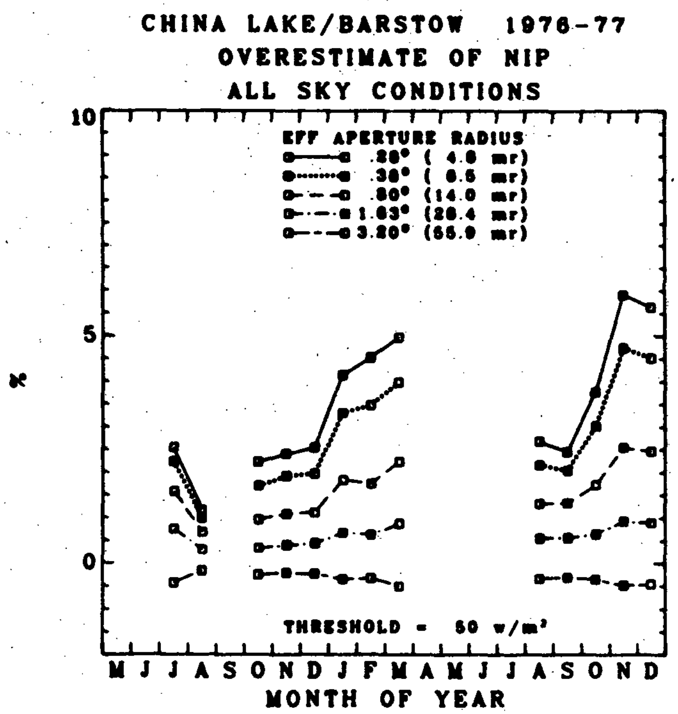

CHINA LAKE/BARSTOW 1976-77
OVERESTIMATE OF NIP
ALL SKY CONDITIONS
EFF APERTURE RADIUS
.28° ( 4.8 mr)
.38° ( 6.5 mr)
.80° (14.0 mr)
1.63° (28.4 mr)
3.20° (55.9 mr)
THRESHOLD = 50 w/m²
%
10
5
0
M J J A S O N D J F M A M J J A S O N D
MONTH OF YEAR

FIGURE 1

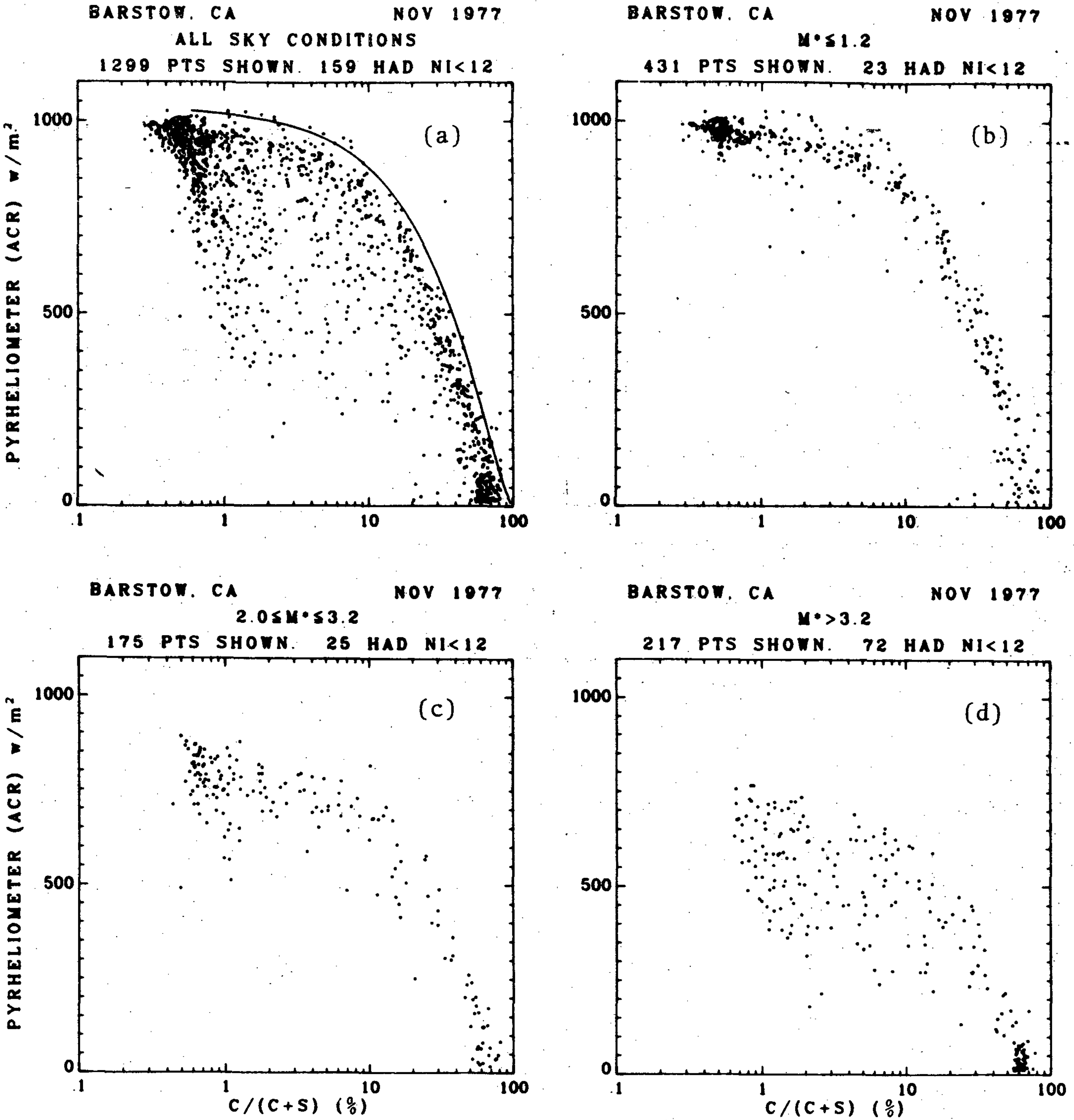

BARSTOW, CA NOV 1977
ALL SKY CONDITIONS
1299 PTS SHOWN. 159 HAD NI<12
(a)
BARSTOW, CA NOV 1977
M*≤1.2
431 PTS SHOWN. 23 HAD NI<12
(b)
BARSTOW, CA NOV 1977
2.0≤M*≤3.2
175 PTS SHOWN. 25 HAD NI<12
(c)
BARSTOW, CA NOV 1977
M*>3.2
217 PTS SHOWN. 72 HAD NI<12
(d)
PYRHELIOMETER (ACR) w/m²
C/(C+S) (%)

FIGURE 2

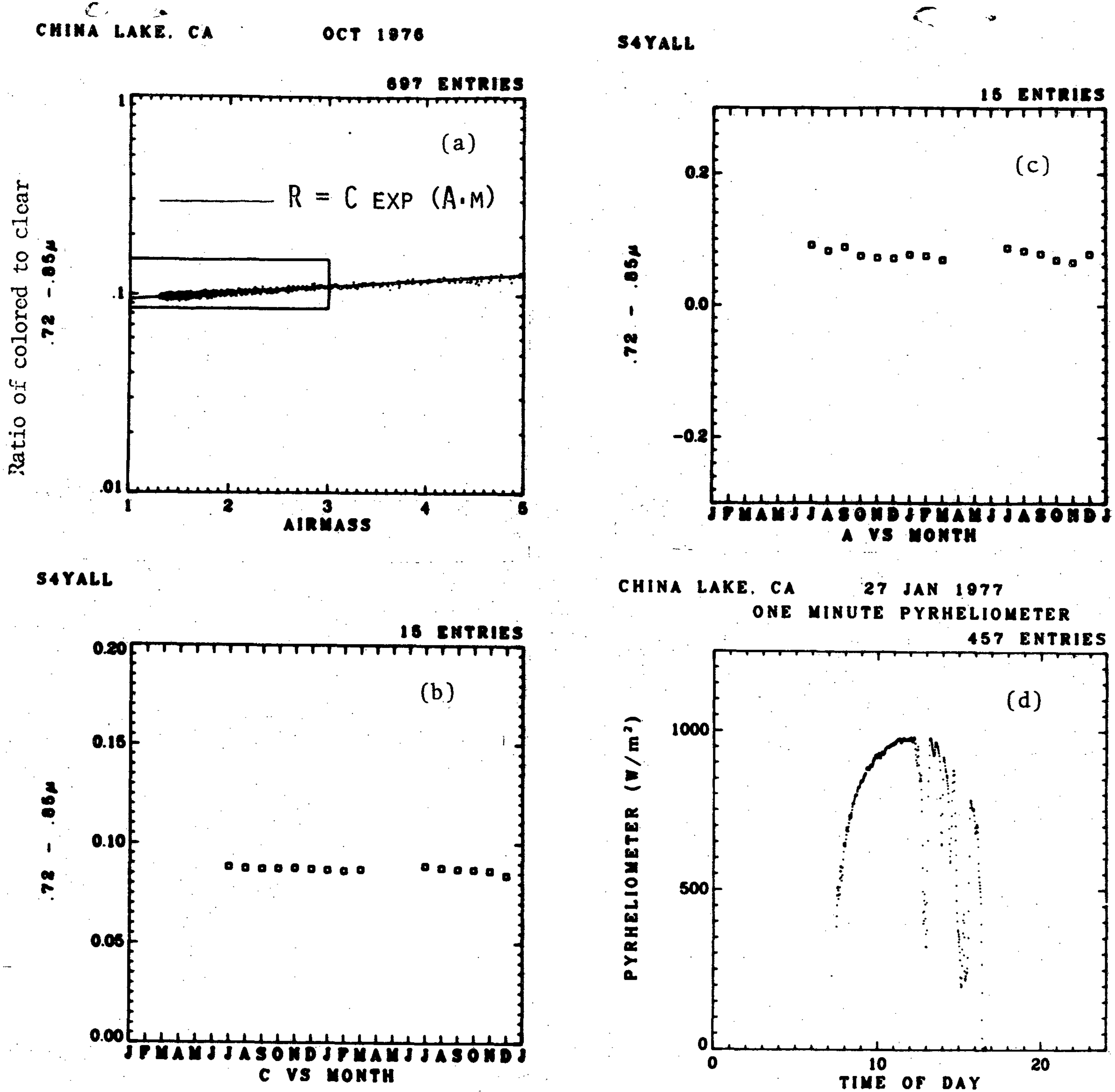

CHINA LAKE, CA OCT 1976
697 ENTRIES
(a)
R = C EXP (A·M)
Ratio of colored to clear
.72 - .85μ
AIRMASS
S4YALL
15 ENTRIES
(c)
.72 - .85μ
A VS MONTH
S4YALL
15 ENTRIES
(b)
.72 - .85μ
C VS MONTH
CHINA LAKE, CA 27 JAN 1977
ONE MINUTE PYRHELIOMETER
457 ENTRIES
(d)
PYRHELIOMETER (W/m²)
TIME OF DAY

FIGURE 3

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