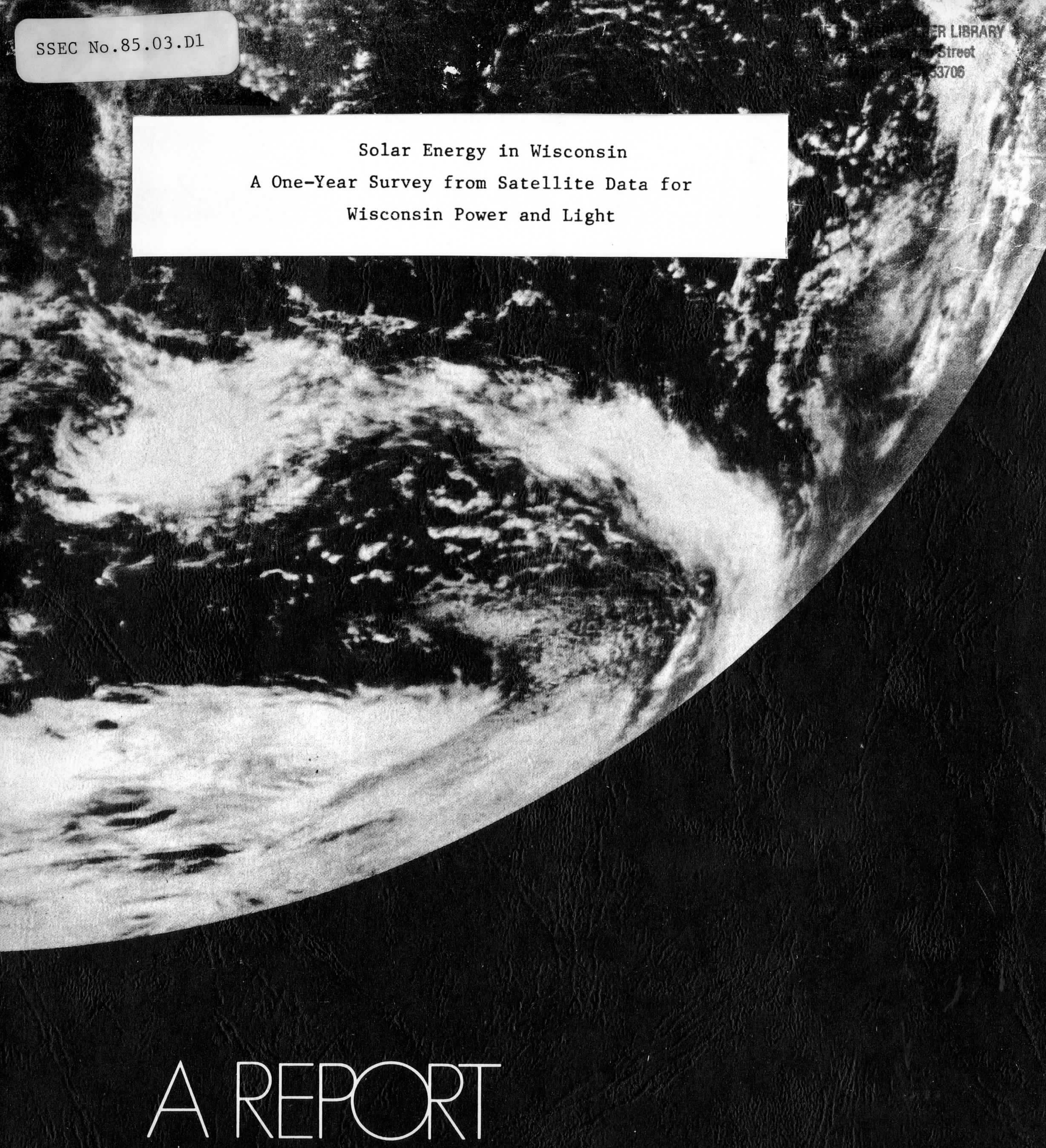
Solar Energy in Wisconsin
A One-Year Survey from Satellite Data for Wisconsin Power and Light



A REPORT

from the space science and engineering center
the university of wisconsin-madison
madison, wisconsin

Solar Energy in Wisconsin
A One-Year Survey from Satellite Data for Wisconsin Power and Light

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ACKNOWLEDGEMENTS

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ABSTRACT

A one-year study of insolation in Wisconsin is presented. The study, which was accomplished using geostationary satellite data and a physical model of the atmosphere and clouds developed at the University of Wisconsin Space Science and Engineering Center, represents one of the longest and highest-resolution insolation data sets in existence. Geographical variations in daily insolation are examined by monthly, seasonal and annual averages and comparisons made with climatological means. Results of monthly averages of hourly insolation are also presented for selected Wisconsin cities.

I. INTRODUCTION

Recent interest in solar energy as a resource and the requirement to better-document the incident surface solar energy for agriculture, weather and climate modelling and other uses have sparked the need to measure this quantity over a wide variety of space and time scales.

The existing ground-based pyranometer network produces a few solar energy measurements but is inadequate for such a variety of applications, with an average of less than one measurement per state. Attempts have been made to synthesize solar energy data on a finer scale using cloud reports at 248 National Weather Service locations across the United States (Knapp et.al. 1980). While computing insolation from cloud reports can produce quite acceptable results, the Knapp et. al. methodology does not take advantage of the most current techniques, nor is the resolution adequate to depict mesoscale (smaller than 100 km.) features and variations. The methodology also does not take into account certain local properties of the surface (most importantly surface reflectivity for snow cover) which can have a substantial effect on surface insolation.

The brightness information from geostationary satellites is well-suited to describing the geographical and temporal distribution of surface insolation and we at the University of Wisconsin Space Science and Engineering Center (SSEC) have developed a simple physical model of the atmosphere and clouds (Gautier, Diak, Masse 1980) for this purpose, which has proven accurate and reliable under a variety of circumstances.

In this article we describe the results of an ambitious experiment funded by the Wisconsin Power and Light Company to produce a one year insolation record for the state of Wisconsin at a spatial resolution of about 15 miles. The experiment to be described is unique in that the insolation results were produced in real time. Data images received from the Geostationary Satellites (GOES) at SSEC were immediately and automatically checked for quality and processed into a grid of insolation values for the state. In prior studies GOES satellite data were drawn from a tape archive maintained at SSEC, manually edited for quality, then processed. The main advantage of the real-time procedure is the cost, which is lowered by a factor of about three-quarters versus the original methodology.

II. METHODOLOGY

Detailed descriptions of the satellite data, physical models and other technical information is provided in the appendix and only a brief overview will be given here.

The simple physical model which we employ to calculate surface insolation was made possible by the calibration of the visible wavelength sensor on board the current GOES series of satellites. These satellites orbit the earth at a distance of 22,400 miles above the equator, an orbit which maintains them at a fixed location relative to the ground. They scan the earth in the visible channel at a time frequency of once every half hour from 60 degrees north latitude to 60 degrees south at a spatial resolution of approximately 1 km. A small subset of this data constitutes the data base for calculating averages of insolation for Wisconsin presented here.
In a qualitative manner, these GOES satellite images are used by weather forecasters for a visual assessment of the paths of clouds and storms and they have become a standard part of many television weather presentations. The simple physical model which we developed and employ to calculate surface insolation is a quantitative use of this data made possible by the calibration of the satellite and the development of simple atmospheric physical models to interpret the data in terms of surface insolation.

The models are based on the measurement of reflectivity by the sensors on the GOES satellites, which the calibration allows us to quantify in terms of energy received at the satellite from the earth and atmosphere. Knowing the reflectivity of the earth surface (measured during clear conditions by the satellite), we are able to determine at any time of day where clouds exist over the region. A simple model of the clear atmosphere describes the insolation in areas where there are no clouds. In areas where clouds are detected this is replaced by a cloud model which models the effect of clouds on the surface insolation based on how bright (reflective) they appear in the satellite image. Instantaneous images at intervals of one hour are used to calculate insolation values valid at one particular time of the day. The results of 6-12 of these values per day are then numerically integrated to produce insolation values for daily and longer-period insolation totals and averages.

III. RESULTS FOR MONTHLY, SEASONAL AND ANNUAL DAILY MEANS

All results are valid for regions within Wisconsin boundaries only. Climatological daily means (to be discussed) are from Clark (1981). Results for monthly mean hourly insolation (not discussed) are presented in Tables 3-14.

A. MONTHLY RESULTS

A.1 February, 1984 (Figures 1, 18a-b)

The dominant feature in February 1984 is a local maximum of insolation in the southeast portion of the state in the Kettle-Morraine area. This maximum corresponds exactly with the region of brightest snow cover conditions during this month. The augmentation of insolation due to secondary reflectance between a bright snow surface and the base of clouds is the well-known phenemenon responsible for this feature. A small minimum of insolation is evident near Lake Michigan due to cloudiness produced when cold February air masses move over the relatively warm lake water. A similar feature is noted on the south shore of Lake Superior. The climatological average of daily insolation for Madison is 2.69 KW-hrs-m^{-2}. In February 1984 all of Wisconsin was below that mean and Madison's total was 2.40.

A.2 March, 1984 (Figures 2, 19a-b)

The maximum area of insolation for March 1984 is the north-central portion of the state and is due to the persistence of snow cover in this area during the month (i.e., the previously mentioned secondary reflection between clouds and snow). Minima still exist near the lakes, as in February due to convection-induced clouds over the comparatively warm lake water. The climatological mean daily insolation for March is 3.67 KW-hrs-m^{-2} for Madison. The Madison total for March 1984 of 3.42 is slightly below this monthly mean.

A.3 April, 1984 (Figures 3, 20a-b)

April, 1984 shows the strongest spatial variations of any of the months investigated with the unusual feature of a strong maximum of insolation in the northern portion of the state. Snow cover on the ground persisted in the very northern portions of the state through part of this month, but its reflectivity was not high enough to explain the strength of the maximum. The only viable explanation for the distribution in April is the track of Spring storms through the state in this highly transitional month. Unfortunately, the timing and position of this northward progression of the polar front may vary greatly from year to year, making the annual repetition of this insolation pattern unpredictable. The average daily insolation for April in Madison is 4.54 KW-hrs-m^{-2}. In April, 1984 Madison was considerably below that value at 3.78. Parts of northern Wisconsin were above the Madison average.

A.4 May, 1984 (Figures 4, 21a-b)

Once again in May, 1984 northern portions of the state had more insolation than regions to the south. Two small and not particularly significant insolation minima exist in the southwest and southeast portions of the state. The effect of the lakes is beginning to reverse. Because the lakes are now cool relative to May air masses, their effect is to repress convection and clouds and enhance insolation. This is seen to some degree on the shores of Lake Michigan and very strongly in the area of Wisconsin adjoining Lake Superior. The average insolation for Madison in May is 5.61 KW-hrs-m^{-2}. Madison in May 1984 with 5.02 was below that total, as was the rest of the state.

A.5 June, 1984 (Figures 5, 22a-b)

In June 1984, southern portions of the state received more insolation than northern regions for the first time in three months. The highest local maxima are noted again adjacent to the lakes with a minimum in extreme northwest Wisconsin. The average daily June insolation in Madison is 6.26 KW-hrs-m^{-2} which was again above our estimate for June 1984 of 5.82 for Madison and also the entire state.

A.6 July, 1984 (Figures 6, 23a-b)

In July 1984 there were only minimal variations across the state as would be expected in the summer months, with few large storm systems and a high percentage of sunshine. Weak local maxima are again noted near Lakes Superior and Michigan. Average insolation in Madison for July is 6.24 KW-hrs-m^{-2}. Madison was close to this but still sub-average at 5.90.

A.7 August, 1984 (Figures 7, 24a-b)

August begins the transition in Wisconsin from summer to fall and on the average insolation drops about 15% from the peak months of June and July. With the August air masses being cooler and the lakes reaching their warmest temperatures, little modulations of daily solar energy are seen on the lakeshores of Wisconsin. Variations are mostly latitudinal and caused by the lower sun angle of northern versus southern regions. The average insolation in Madison for August is 5.45 KW-hrs-m^{-2}. Madison's total for July, 1984 was 5.25, very close to, but still below normal.

A.8 September, 1984 (Figures 8, 25a-b)

September 1984 was, like August, a month of mostly latitudinal variation in insolation over the state. The effects of the lakes appear to have begun their reverse toward the wintertime effect of diminishing insolation, although the trend at this time is weak and variable. The Madison mean daily insolation in September is 4.10 KW-hrs-m^{-2} slightly above the September 1984 mean of 4.03.

A.9 October, 1984 (Figures 9, 26a-b)

October 1984 was a bleak month in Wisconsin for solar energy. The Madison total of 2.11 KW-hrs-m^{-2} was 26% below the climatological mean of 2.85 and the largest monthly anomaly observed to this point in time of the survey. The month's weather was characterized by large, homogeneous cloud masses and the effects of other factors (lakes, topography) is small in comparison.

A.10 November, 1984 (Figures 10, 27a-b)

November 1984 returned to a more climatological insolation condition compared with the anomaly of the preceeding month. The strongest feature in this month is the bowing upward of the isolines of insolation in southeast Wisconsin adjacent to Lake Michigan. There is no concrete explanation of this weak maxima other than chance. The Madison climatological average for this month is 1.64 KW-hrs-m^{-2} and this is the second month in our study where Madison in 1984 came in above the average at a 1.66 reading.

A.11 December, 1984 (Figures 11, 28a-b)

December is a month characterized by large homogeneous storm systems moving across the state and this dominates over the potential effects of lakes and landforms. December 1984 was exceptionally warm compared to the average for Wisconsin, which limited snow cover and its potential enhancement of insolation. Madison in December 1984 with 1.01 KW-hrs-m^{-2} came in well below the climatological average of 1.34 for this month.

A.12 January, 1985 (Figures 12, 29a-b)

January 1985 showed a dramatic reversal of the below-normal trend of insolation for most of the previous months discussed. Madison, with average daily solar of 1.89 KW-hrs-m^{-2} was much above the climatological average of 1.34. This surge in insolation was caused by the dominance of clear, cold Canadian air masses during this month, a month which saw many low-temperature records set across the state. Weak maxima are evident in the central and southeastern portions of the state where snow reflectivity was greatest. The lakes have a negligible effect on insolation in this month.

B. SEASONAL RESULTS

B.1 Winter (Dec-Feb; Figures 13, 30a-b)

In the winter months surveyed, the dominating effect in Wisconsin on insolation is the local maxima of surface reflectivity which is a recurrent feature in the central to southeastern part of the state. It is a characteristic of farmland areas with only sparse cover of trees. Northern regions of the state, with coniferous tree cover overlying the snow, in comparison are a much darker surface and do not augment insolation nearly as much. This insolation pattern, dependent on established land use, can be expected to be a recurrent feature in winter Wisconsin. Little effect of the lakes on adjoining areas of Wisconsin was noticed in this season, although some effects occurred in the individual months. The average seasonal insolation at Madison for winter is 1.94 KW-hrs-m^{-2}. The winter months surveyed were below this average at 1.77.

B.2 Spring (Mar-May; Figures 14, 31a-b)

The spring months surveyed in this study were 12% below average in insolation for the season. The average value for spring daily insolation average is 4.61 KW-hrs-m^{-2} in Madison. By contrast, the spring months we investigated had a 4.07 total. During these months, the southern part of the state had markedly less insolation than northern regions due to a combination of factors. Of these, the dominating and unfortunately least predictable one, was the position of the storm track through the Midwest in

April. The persistence of snow cover in the northern portions of the state during the month of March and its enhancement of insolation is an effect which can be expected to recur to some degree from year to year.

B.3 Summer (Jun-Aug; Figures 15, 32a-b)

Summer is a time of year characterized by high percentage of sunshine in Wisconsin and mostly latitudinal variation in solar energy incidence. Some effect of cool Lake Michigan are seen on its western shore due to its repression of convective clouds. The same effect is noted on the south shore of Lake Superior and these effects can be expected to persist from year to year. Summertime average daily insolation in Madison is 5.98 KW-hrs-m^{-2}. The summer months we surveyed had an average value of 5.66, slightly below normal.

B.4 Fall (Sept-Nov; Figures 16, 33a-b)

In the fall months surveyed, the variation of insolation is mostly latitudinal and was dominated by the frequency of large storm systems which occurred in October and November. Some depression of insolation is noted near Lake Michigan due to local enhancement of convection in these months and this effect can be expected to repeat from year to year. Madison was notably below average in this season with an average daily value of 2.60 KW-hrs-m^{-2} compared with a climatological value of 2.86. Most of this was due to a very low monthly mean insolation in October, 1984.

C. ANNUAL RESULTS (Figures 17; 34a-b)

The annual results for the months surveyed are remarkable in their spatial uniformity over Wisconsin. Different factors which have produced higher or lower values of insolation in one month in one region have essentially been cancelled by other mechanisms at other times of year. The variation state-wide is not enough to matter to a potential solar energy over who is concerned only with the annual total of insolation. Users whose demands are month or season-dependent, however, should address the previous discussions on solar energy availability and its spatial variations in specific times of year.

The Madison average daily solar for the year surveyed was 3.52 KW-hrs-m^{-2} contrasting a climatological average of 3.85 which is about 8% below normal. These results in general agree with a recent compilation of Madison-Truax pyranometer measurements by Wisconsin State Climatologist Douglas R. Clark for the same period of time.

APPENDIX

1. Data

The geostationary satellite data set used in this study provides excellent coverage in space and time of Wisconsin and therefore the cloud variability which is known to be large on small time scales. The visible component of the visible-infrared spin scan radiometer (VISSR) on board geostationary satellites makes measurements within the .55-.75 μm band at a ground resolution of 1 km at the equator every half hour for the entire earth disk 60 degrees north latitude to 60 degrees south.

An example of a data image for Wisconsin is shown in Figure 35. This image is composed of approximately 500 by 600 individual data points (pixels) which have measured brightness coded in digital counts between 0 and 63.

2. Satellite Calibration

While exact calibration pre-flight is not known, the functional response of the VISSR detector to changes in signal in well-understood. For the detector this response can be expressed in general terms as

$$\text{Energy} = a(\text{counts}^2 - b) \qquad (1)$$

i.e., energy is proportional to the square of the digital counts. The purpose of the in flight calibration then is to determine constants a and b which allow the calibration to be used in a quantitative manner. Two reference points of known reflectance are necessary to determine the constants a and b in Eq. (1). Constant b represents a "dark current" or "offset", i.e., the counts registered when no energy is incident on the detector. It is determined easily by looking at black space. White Sands, New Mexico, one of the brightest permanent land features with an albedo of .69 in the VISSR band is used to determine constant a.

3. Navigation

Deriving daily insolation from hourly images requires the combination of measurements at different times and the accuracy of the results is linked to the ability to align images. This is realized by a procedure called "navigation".

The image navigation consists in deriving a transformation function between satellite coordinates and earth coordinates from which latitude and longitude of each pixel can be calculated. It is obtained for each image time from the knowledge of some satellite physical parameters (orbit, altitude, etc.) and of coordinates of known reference points on the earth.

4. Procedure

Hourly images are scanned in boxes of 24 x 24 pixels (approx. 15 miles resolution) to derive hourly insolution, each box being tested for cloudiness. When a box is clear, a clear air model of the atmosphere, which includes Rayleigh scattering, water vapor absorption (derived from climatological dew point temperatures) ozone absorption and sun geometry information is applied to calculate the insolation for that specific box. When a box is cloudy, its brightness is used to derive cloud absorption and cloud albedo necessary to estimate surface insolation.

The daily insolation is obtained by integrating the hourly estimates over 6-12 daylight hours depending on length of day. Our integration scheme follows the trapezoidal integration method, i.e.,

$$SW{\downarrow}_{daily} = \sum_{k=1}^{n} \tfrac{1}{2}(t_{k+1} - t_{k-1})\,SW{\downarrow}(t_k) \qquad (2)$$

where $SW\downarrow(t_k)$ is the calculated insolation for a 24 x 24 pixel box at time t_k, and t_0 and t_{n+1} are sunrise and sunset, respectively. We assume that $SW\downarrow(t_0) = SW\downarrow(t_{n+1}) = 0$. The exact time of sunrise and sunset are obtained as a function of latitude, longitude and day of year.

5. Physical Models

a. Clear-air model

The upwelling radiant energy the satellite receives is a function of the incident energy at the top of the atmosphere and of the planetary albedo (earth-atmosphere) which represents both atmospheric and surface processes.

In order to calculate the insolation at the surface we must estimate the addition or depletion of energy, due to the atmosphere and the surface, to the energy detected at the satellite.

The upwelling shortwave radiant flux measured by the satellite sensor under clear conditions is composed of 1) backscattered radiation from the impinging downward solar beam at the top of the atmosphere; and 2) incident shortwave radiation reflected from the surface and passing back upward through the atmosphere.

These terms, comprising the upwelling radiant flux to the satellite, may be written

$$\begin{aligned} SW\uparrow = {} & F_0(1-oz1/V)(1-oz2/V)\,\alpha(\lambda) \\ & + F_0(1-oz1/V)(1-oz2/V) \\ & \times [1-\alpha(\lambda)][1-\alpha_1(\lambda)]A, \end{aligned} \tag{3}$$

where

$SW\uparrow$ upward shortwave radiant flux in VISSR channel (W m^{-2})

F_0 instantaneous shortwave solar radiant flux at the top of the atmosphere in the VISSR channel (W m^{-2})

oz1	absorption coefficient for ozone of direct total solar flux by visible absorption band (dimensionless)
oz2	absorption coefficient for ozone of diffuse total solar flux by visible absorption band (dimensionless)
V	ratio solar flux in VISSR channel/total solar flux (dimensionless)
$\alpha(\lambda)$	scattering coefficient for beam radiation in VISSR channel (dimensionless)
$\alpha_1(\lambda)$	scattering coefficient for diffuse radiation in VISSR channel (dimensionless)
A	surface albedo (dimensionless)

Solving for the surface albedo we obtain

$$A = \frac{SW\uparrow - F_0\alpha(\lambda)(1-oz1/V)(1-oz2/V)}{F_0[1-\alpha(\lambda)](1-oz1/V)(1-oz2/V)[1-\alpha_1(\lambda)]}, \qquad (4)$$

For the case of known clear conditions SW↑ can be derived directly from the satellite measurement and all the other variables on the right side of the equation are prescribed via our representations. The only unknown is the surface albedo which we can then calculate. Then with the albedo determined, the insolation at the surface is

$$SW\downarrow = F_0(1-\alpha)(1-oz1)(1-oz3) \times [1-a(u_1)](1+A\alpha_1), \qquad (5)$$

where

F_0	total solar radiant flux at the top of the atmosphere (W m^{-2})
SW↓	surface insolation (W m^{-2})
α	scattering coefficient for direct total solar flux (dimensionless)
α_1	scattering coefficient for diffuse total solar flux (dimensionless)
$a(u_1)$	absorption coefficient for slant path of water vapor u_1 for sun angle θ (dimensionless)

oz3 absorption coefficient for ozone of direct total solar flux by ultraviolet absorption band (dimensionless).

b. Cloudy atmosphere model

The calculation of the incident radiation in a cloudy atmosphere is more difficult than in clear-air conditions for which the cosine of the solar zenith angle is the dominating factor. The scattering and absorption processes outlined for the clear atmosphere can take place both above and below cloud level. Additionally, clouds scatter, absorb and reflect radiation in ways that even complex models have difficulty describing. Observation and theory still slightly disagree inducing us to choose a simple treatment. In the case of cirrus clouds, transfer calculations cannot even be carried out due to the lack of knowledge on scattering properties of nonspherical ice crystals.

The information we have from the data is brightness which indicates what is coming out of the top of the atmosphere due to all processes. The brightness indicates the presence (or absence) of cloud and provides a qualitative information about its thickness.

Stratiform low and middle clouds are the ones which attenuate the incident solar radiation the most over space and time. Our cloud representation is designed to best describe these situations, as discussed below.

To describe insolation at the ground under cloudy conditions we assigned fractions of precipitable water, and thus the water vapor absorption, above and below cloud height for both the downwelling and upwelling paths. For low and midlevel clouds we estimated an average of 30% of atmospheric water vapor above cloud level, assuming that most of the water vapor is under cloud base (Paltridge, 1973). This is an average value and seasonal variations could be introduced but our results would not be appreciably modified. Cloud absorption, which has been measured to be as much as 10-20% of the incident flux is estimated here on the basis of cloud brightness, an indicator of cloud type and thickness. The mechanisms responsible for this large absorption are still unclear. Because of these uncertainties we chose a simple linear relationship between cloud absorption and brightness, ranging from zero for no cloud to a maximum of .07 for very deep clouds. This implicitly takes into account the effect of zenith angle variation on absorption. Although using visible brightness as an indicator of absorption might be questioned, the effects on our results are minimal since cloud reflection is the most important mechanism in reducing the insolation. Scattering processes are assigned above cloud level where the bulk of the atmospheric mass lies for low and mid-level clouds. With these approximations, under cloudy conditions the energy to the satellite in the VISSR channel is written

$$\begin{aligned} SW\uparrow = {} & F_0(1-oz1/V)\alpha(\lambda)(1-oz2/V) \\ & + F_0(1-oz1/V)[1-\alpha(\lambda)]A[1-\alpha_1(\lambda)] \\ & \times (1-oz2/V) + F_0(1-oz1/V)[1-\alpha(\lambda)] \\ & \times Ac^2\alpha_1(\lambda)[1-oz2/V] + F_0(1-oz1/V) \\ & \times [1-\alpha(\lambda)](1-Ac)^2 A[1-\alpha_1(\lambda)] \times (1-oz2/V), \end{aligned} \tag{6}$$

where Ac is the cloud albedo (dimensionless). Eq. 6 represents 1) energy scattered from the atmosphere to the satellite; 2) energy reflected from the cloud to the satellite; and 3) energy passing through the cloud, reflected from the ground back through the cloud to the satellite. Over low-albedo surfaces, the third term is usually negligible except for very thin clouds. It may be significant for somewhat thicker clouds over a high-albedo surface.

From the energy measured at the satellite, the surface albedo [calculated from (4) in the way described in the previous section] and the atmospheric representations just described, we can solve (6) for the cloud albedo Ac.

The incident shortwave at the surface is then written

$$SW\downarrow = F_0(1-oz1)(1-oz3)(1-\alpha)[1-a(u_1)_a] \times (1-Ac-abs)[1-a(u_1)_b]. \qquad (7)$$

Here $a(u_1)_a$ is the absorption coefficient for water vapor of the total solar flux above cloud (dimensionless), $a(u_1)_b$ the absorption coefficient for water vapor of the total solar flux below cloud (dimensionless), and abs cloud absorption coefficient for the total solar flux (dimensionless).

6. Parameterizations of Absorption and Scattering Processes

The solar constant is taken at 1373 W m^{-2}. The bulk scattering coefficients α, as a function of the solar zenith angle and α_1 for diffuse shortwave radiation, have been taken from Coulson (1959). To estimate the effect of Rayleigh scattering of the direct solar beam in the VISSR channel, a single-scattering approximation to the Rayleigh scattered intensity at the VISSR peak sensitivity wavelength (0.6μm) (Coulson, 1959) is used. The magnitude is a function of the Rayleigh scattering optical depth of the atmosphere at that wavelength and the satellite, sun and relative angles. Backscattering of diffuse flux in the VISSR channel is estimated at this optical depth from the tables of Coulson (1959).

In case of cloud, all scattering processes are assigned above cloud top (which we fix at ~700 mb). The magnitude of the scattering is adjusted by lowering the Rayleigh scattering optical depth to represent the fraction of atmospheric mass above cloud tops.

In the VISSR bandpass, water vapor has only a weak absorption band at 0.7 μm and the sensor sensitivity is low at this wavelength. Thus, water vapor absorption is neglected in calculating surface albedo and cloud albedo. Bulk solar parameterizations of water vapor absorption are retained in the calculations of insolation (Eqs. 5,7) since outside of the VISSR channel water vapor absorption has an appreciable effect. Paltridge (1973) has derived analytical expressions for theoretical water vapor absorptions as a function of atmospheric precipitable water (u) and is parameterized via an empirical function of the surface dew-point temperature. Numerous such formulations exist. The relationship we have chosen to use is from Smith (1966) and contains an empirical constant (λ) adjusted to the season and the latitude.

While the effect of ozone absorption on the total solar flux is small (2%), the effect of the visible absorption band on the flux in the VISSR channel is important. Ozone absorption was modeled in the manner of Lacis and Hansen (1974), considering the ozone layer as an absorbing medium overlying a reflecting layer (the earth-atmosphere system). The empirical formula in Lacis and Hansen for ozone absorption in the visible region is used to estimate the absorption in the VISSR channel for the calculation of surface albedo and cloud albedo. This formula plus a counterpart for ozone absorption in the ultraviolet, together describe the effects of ozone on the total solar flux for calculation of insolation.

7. Accuracy of Results

Testing of our methodologies has involved comparisons of daily insolation values with pyranometer site measurements for approximately 300 site-days over conditions ranging from the continental U.S. and Canada to the tropical Atlantic and Pacific oceans. In these tests the standard error of satellite measurements vs pyranometer is 9.5 percent of the mean in satellite estimated vs. pyranometer measured daily insolation.

LIST OF FIGURES

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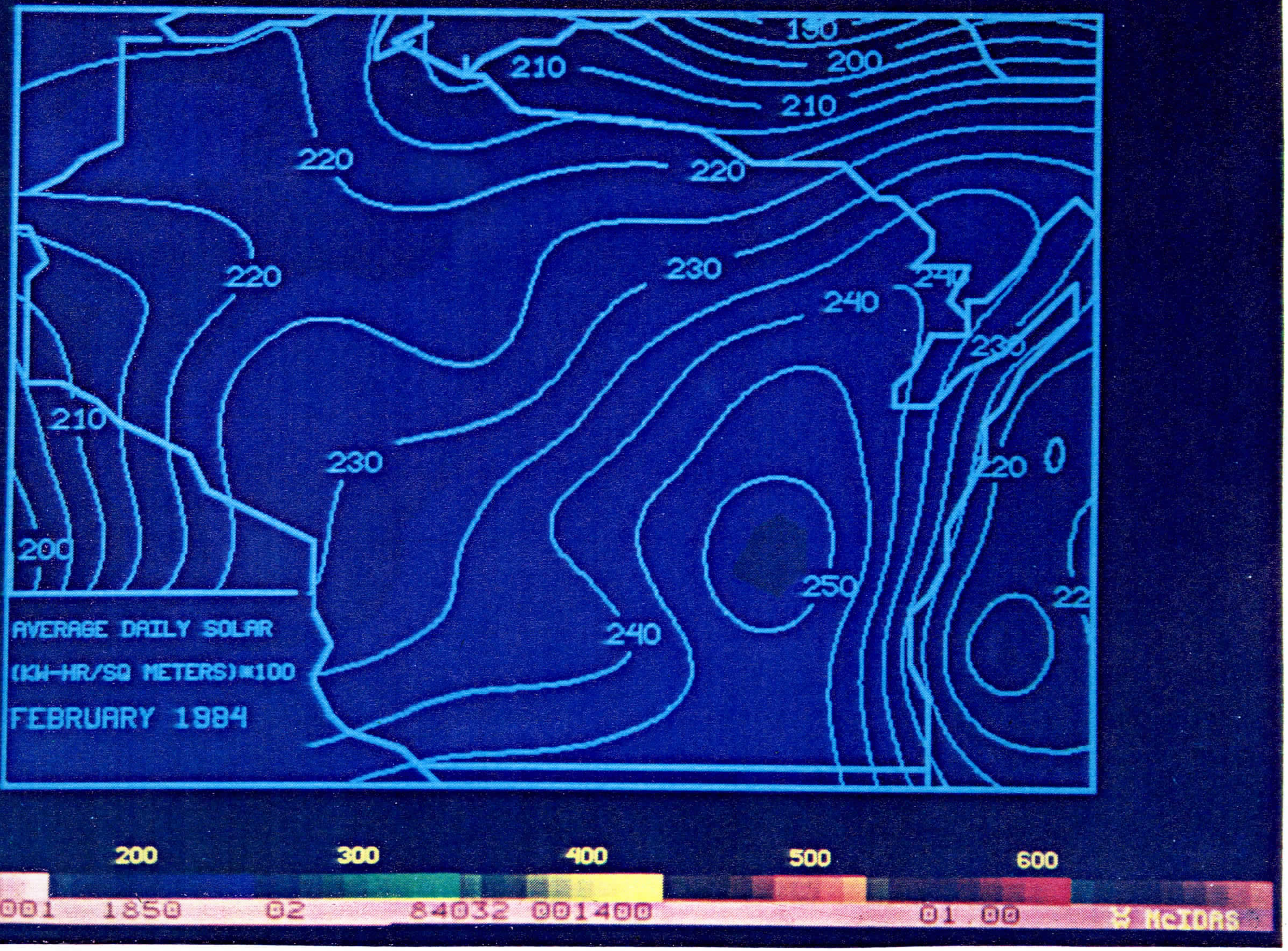
FIG 1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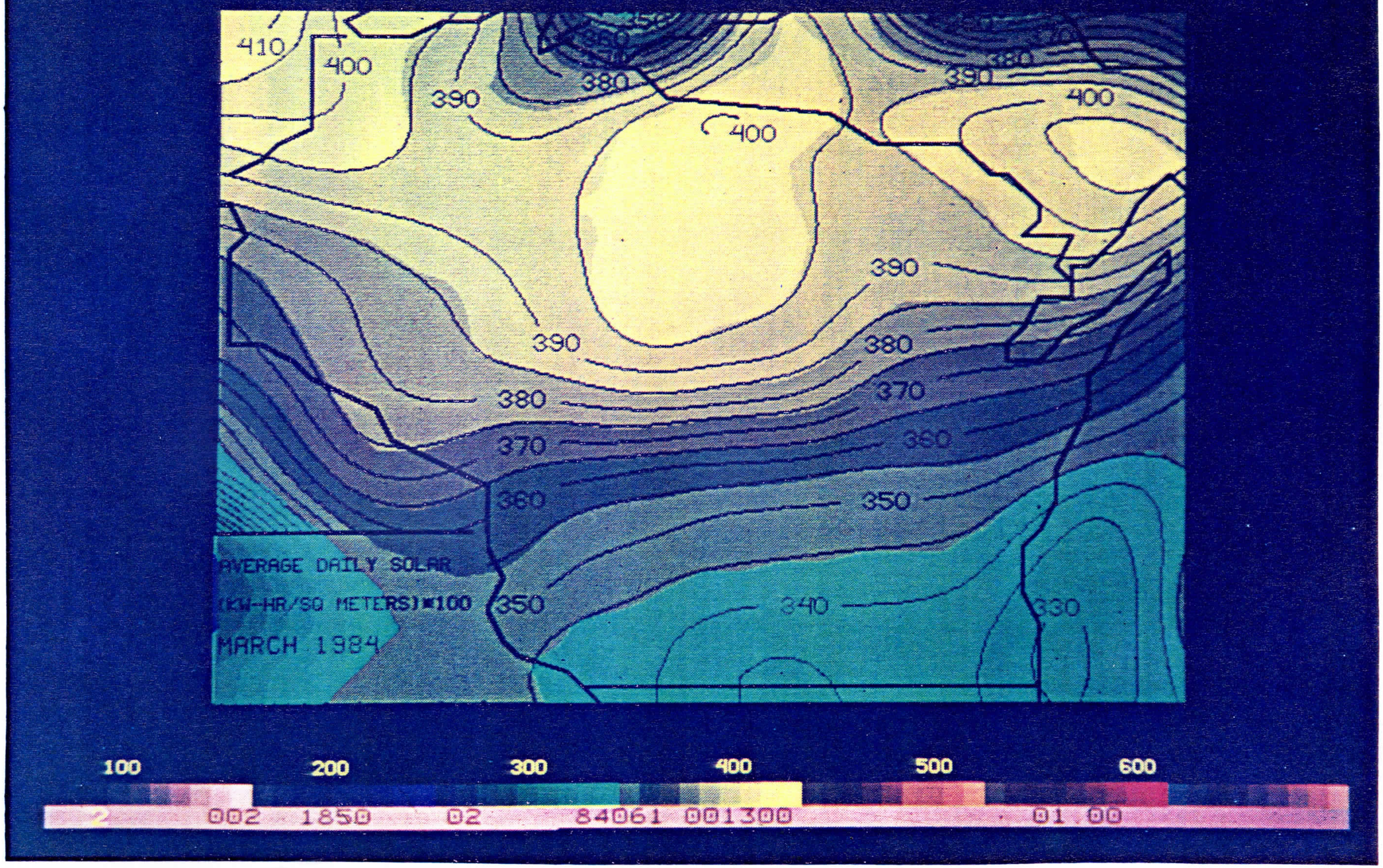
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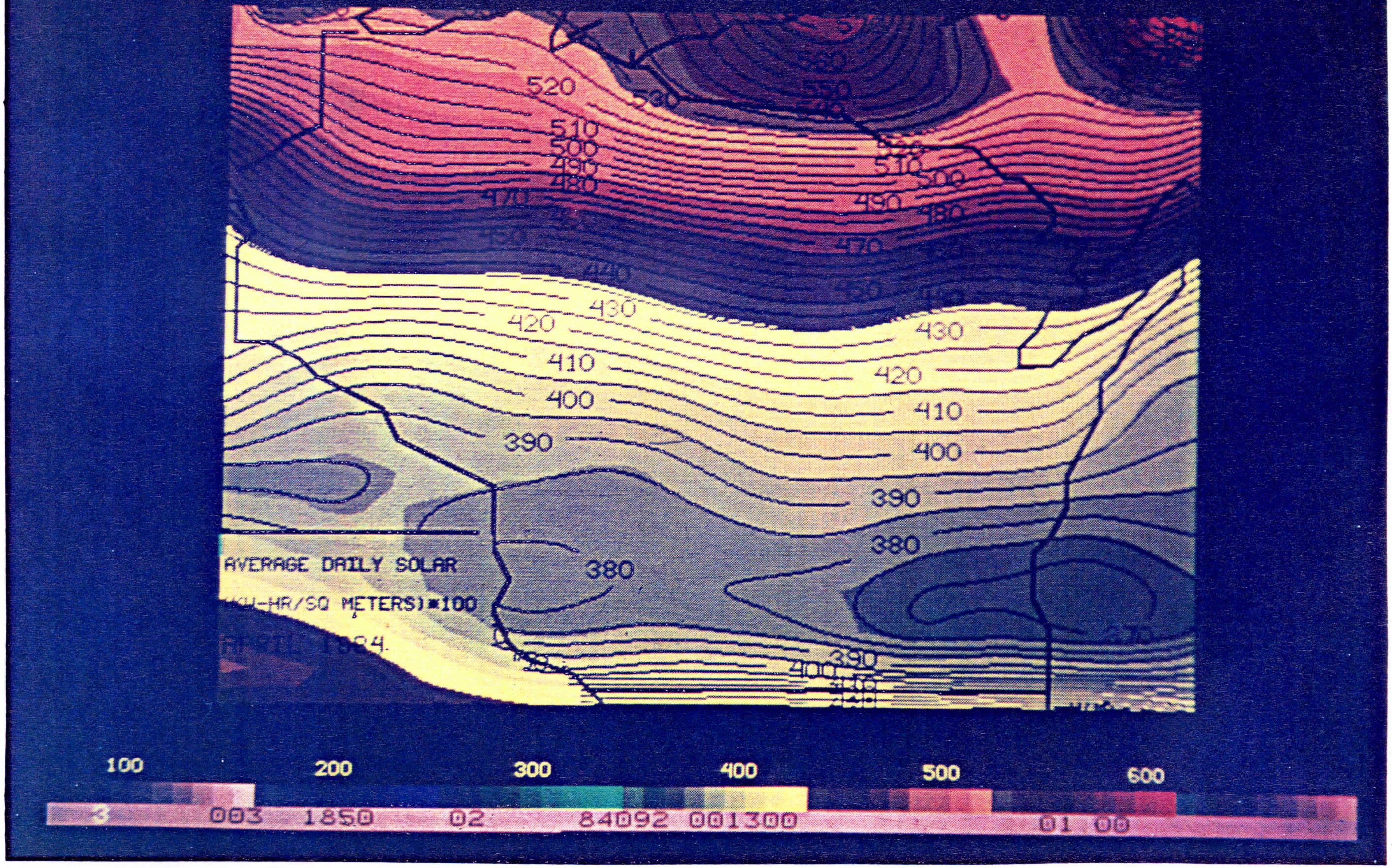
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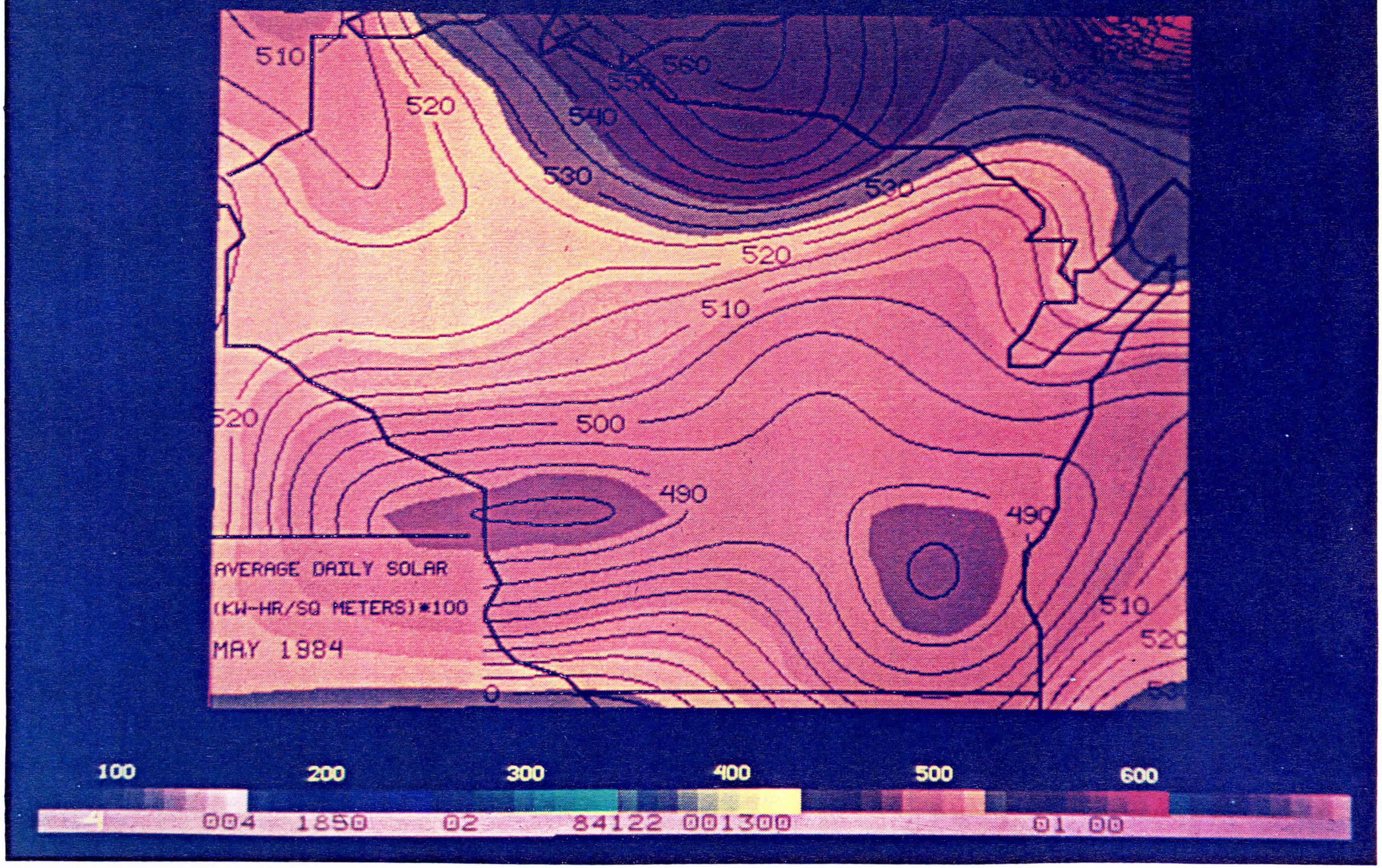
FIG 4



AVERAGE DAILY SOLAR
(KW-HR/SQ METERS)*100
MAY 1984

FIG 5

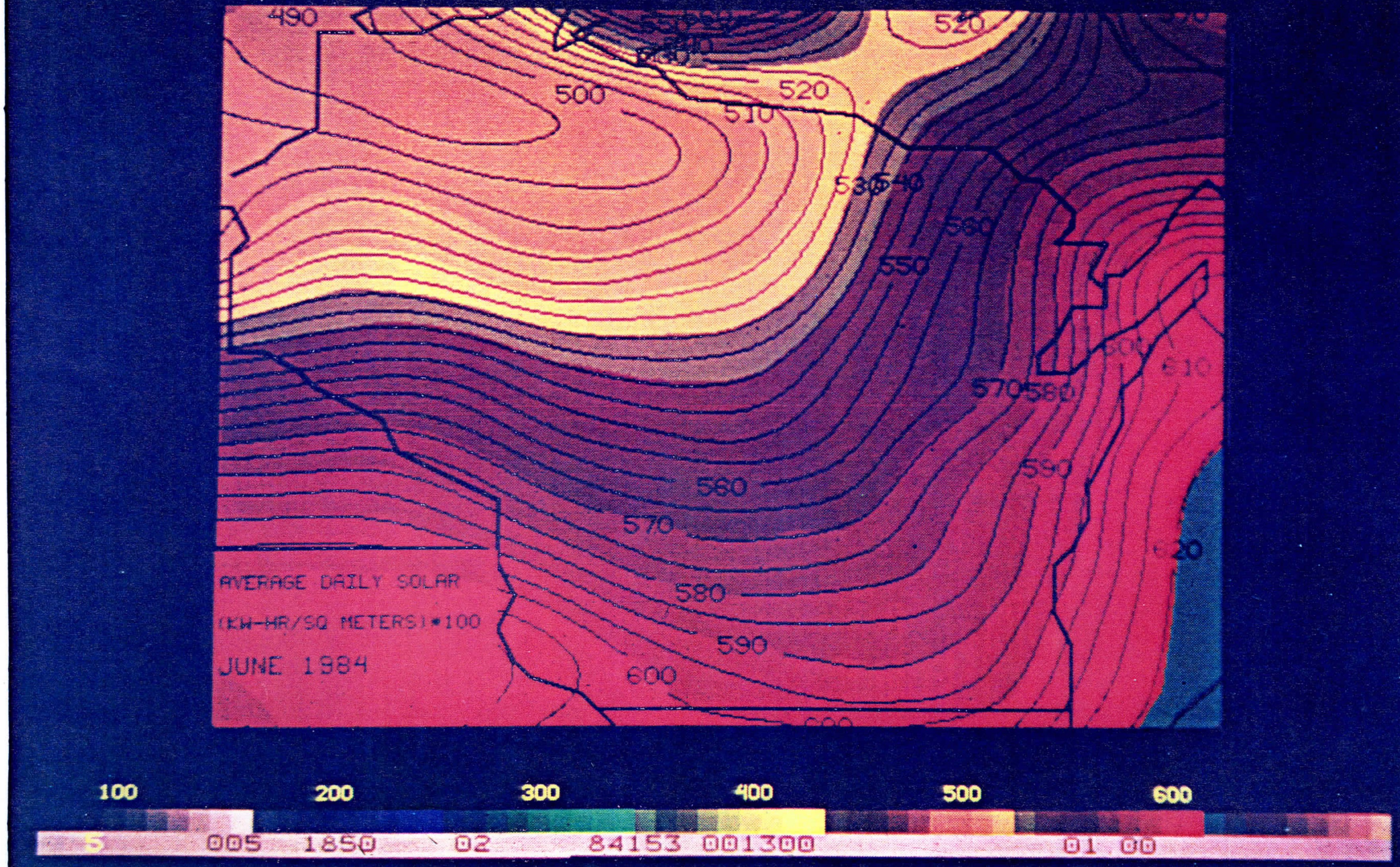

AVERAGE DAILY SOLAR
(KW-HR/SQ METERS)*100
JUNE 1984
490
500
510
520
530
540
550
560
570
580
590
600
610
620
100
200
300
400
500
600
5
005 1850 02 84153 001300 01 00

FIG 6

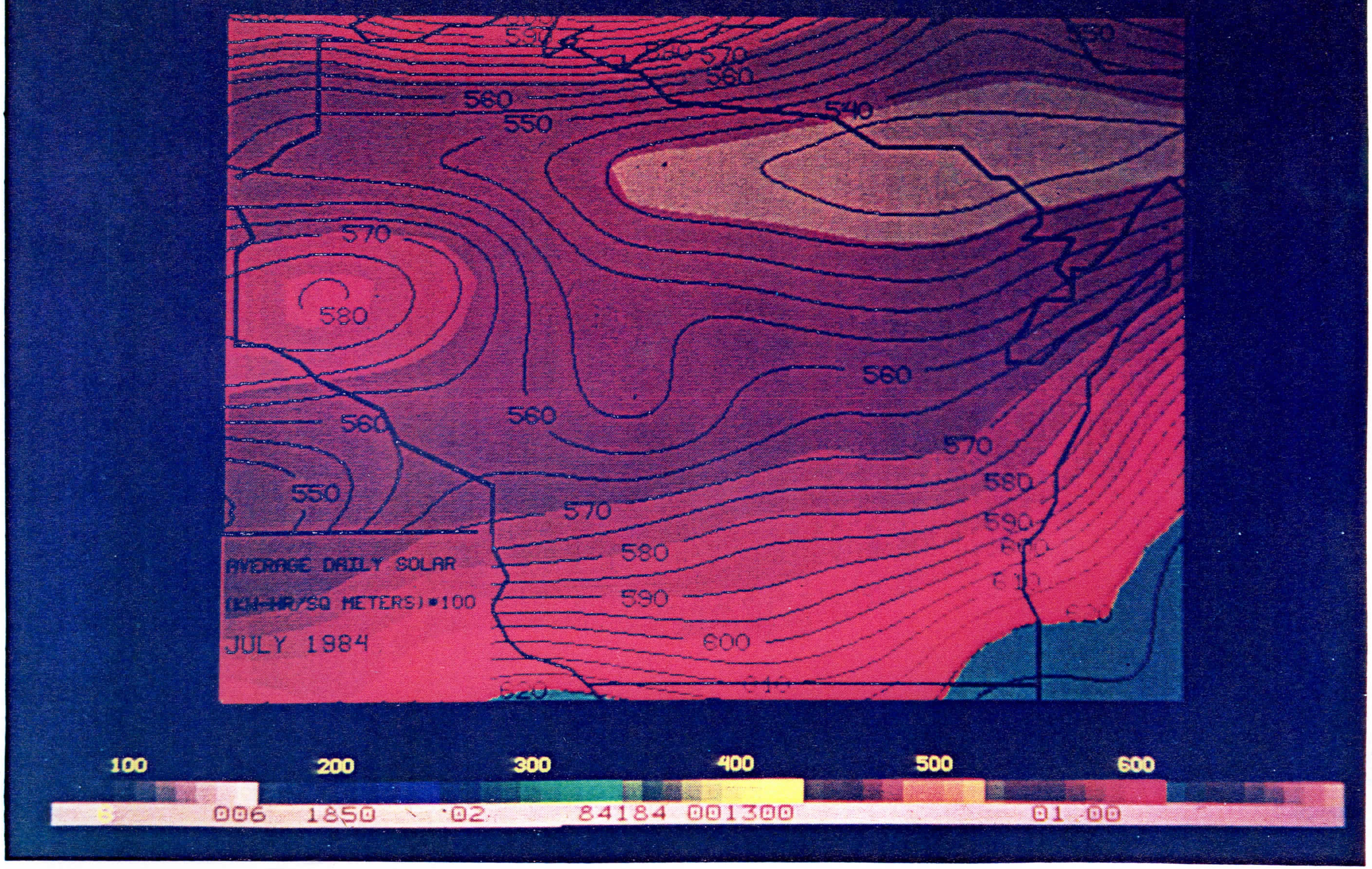

AVERAGE DAILY SOLAR
(KW-HR/SQ METERS)*100
JULY 1984
540
550
560
570
580
590
600
610
620
100
200
300
400
500
600
006 1850 .02 84184 001300 01.00

FIG 7

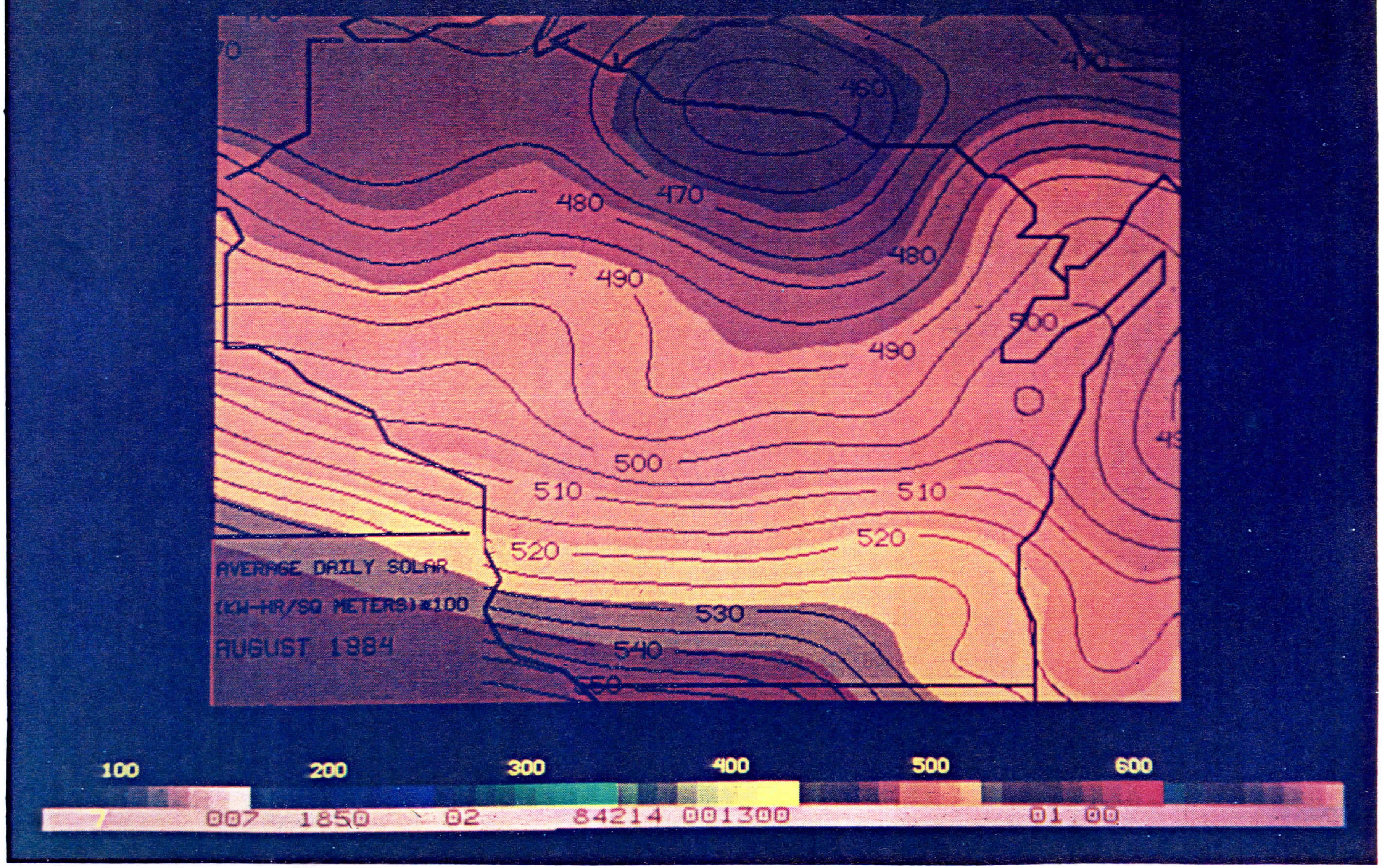
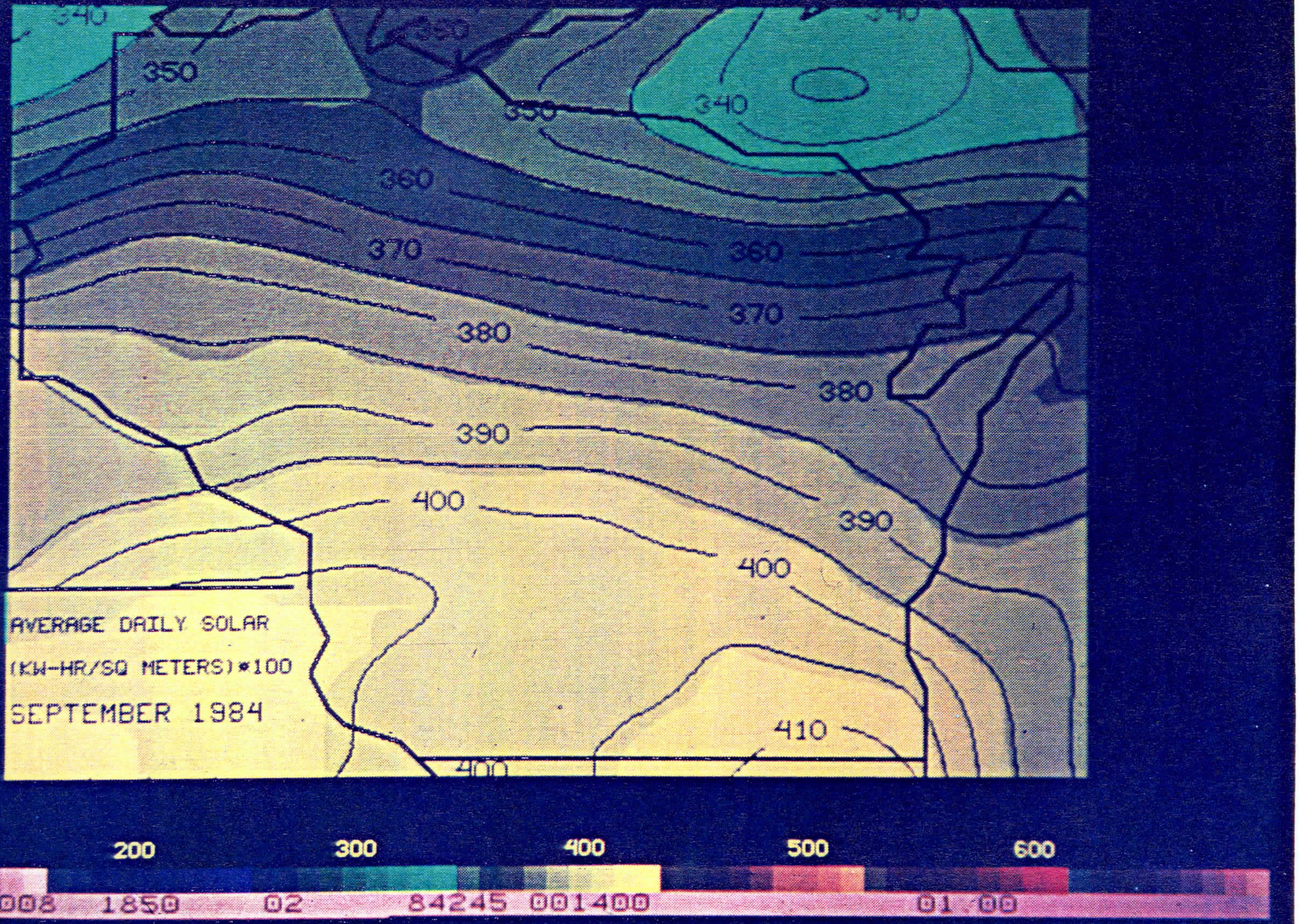
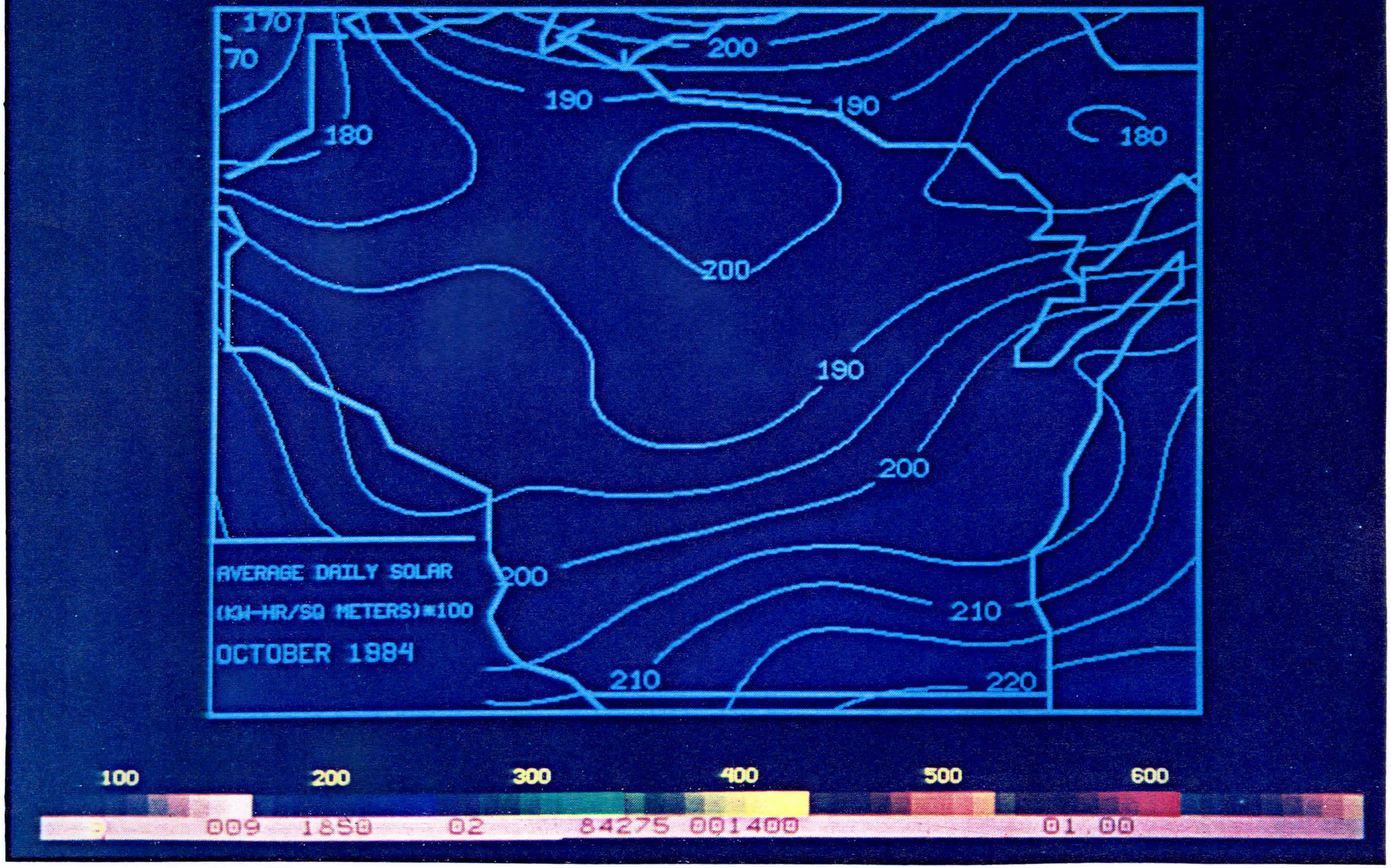

AVERAGE DAILY SOLAR
(KW-HR/SQ METERS)*100
AUGUST 1984
460
470
480
480
480
490
490
500
500
510
510
520
520
530
540
100
200
300
400
500
600
007 1850 02 84214 001300 01.00

FIG 8



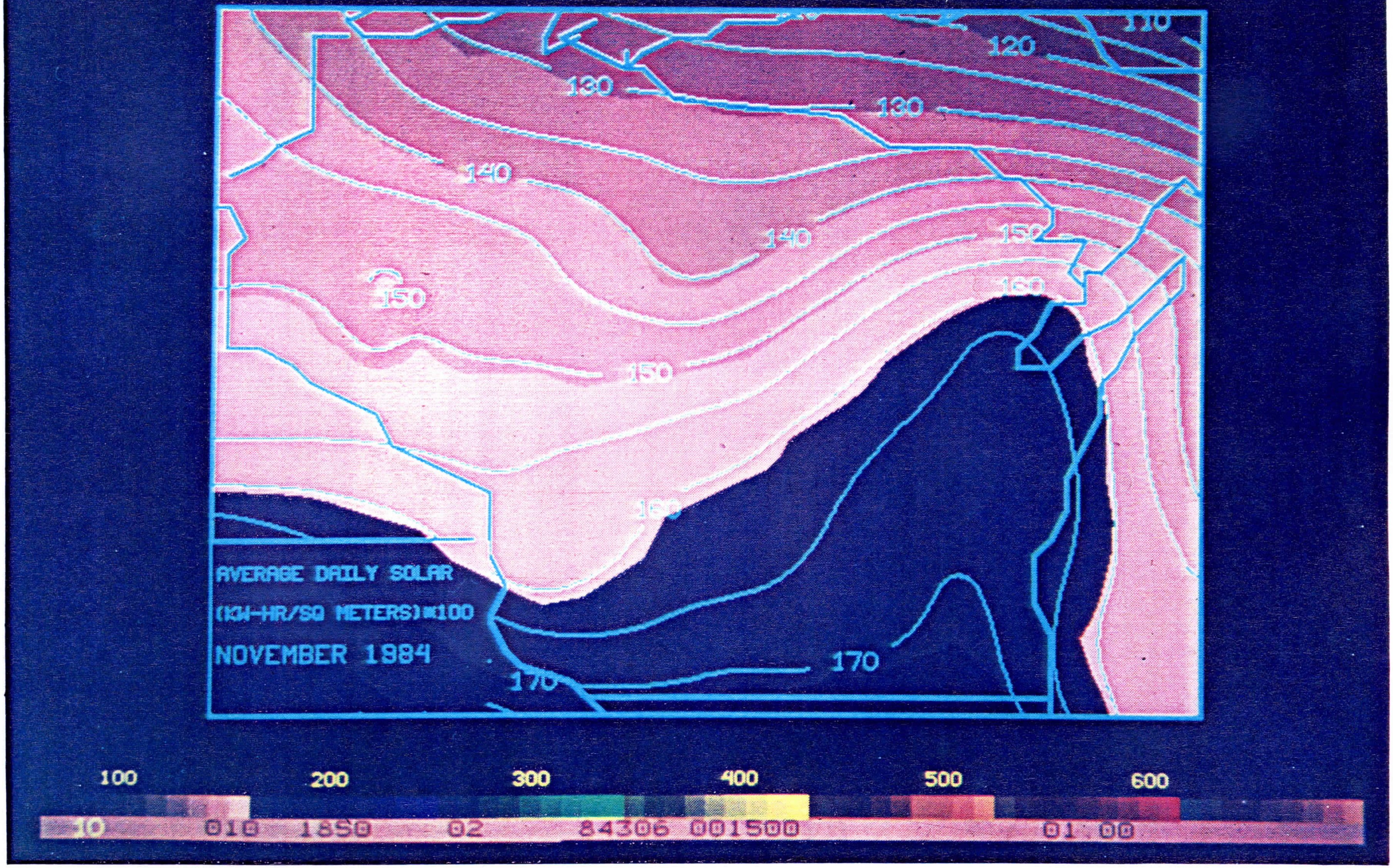
AVERAGE DAILY SOLAR
(KW-HR/SQ METERS)*100
SEPTEMBER 1984

FIG 9



AVERAGE DAILY SOLAR
(KW-HR/SQ METERS)*100
OCTOBER 1984

FIG 10



AVERAGE DAILY SOLAR

(KW-HR/SQ METERS)*100

NOVEMBER 1984

FIG 11

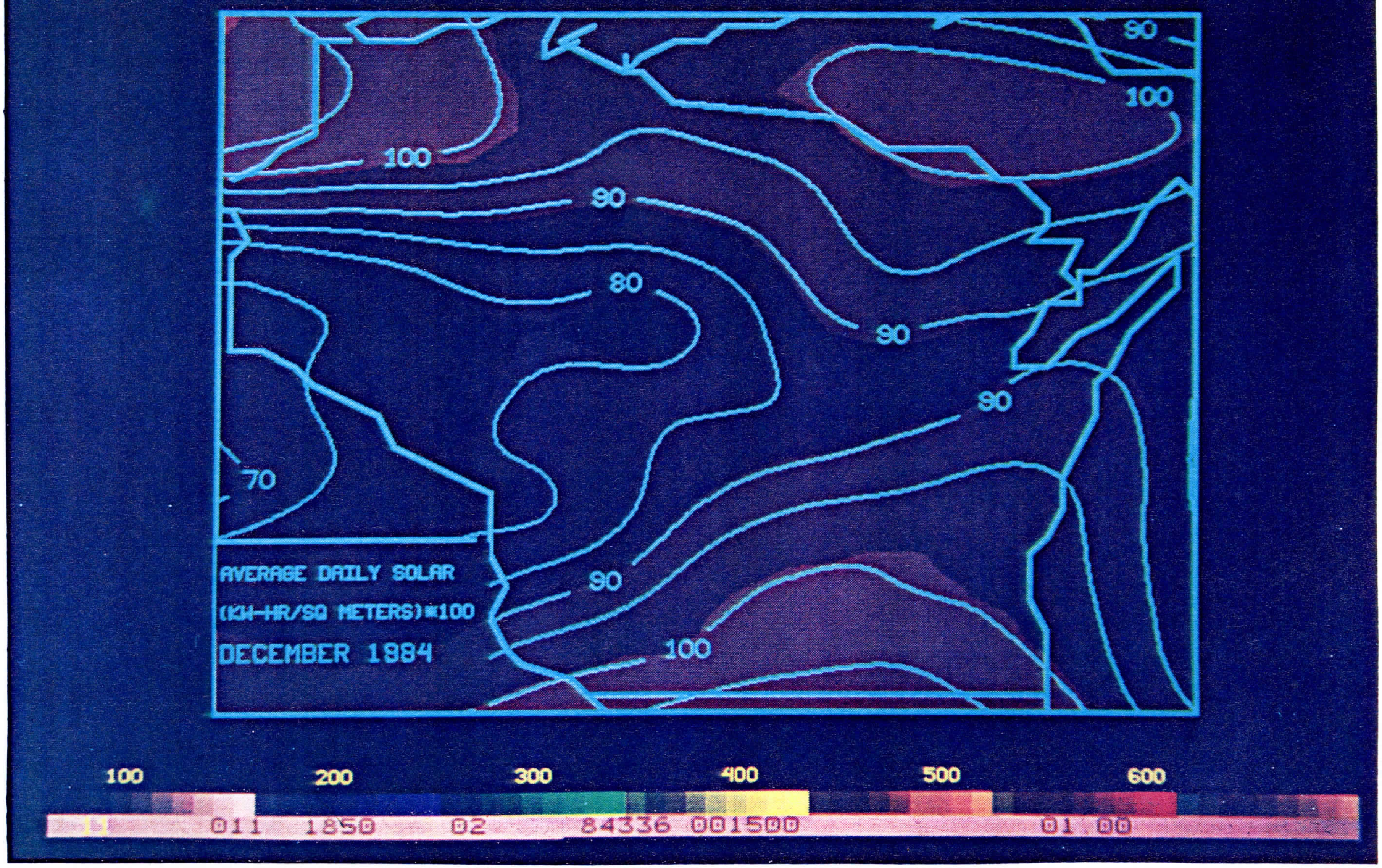

90
100
100
90
80
90
90
70
90
100
AVERAGE DAILY SOLAR
(KW-HR/SQ METERS)*100
DECEMBER 1884
100
200
300
400
500
600
11 011 1850 02 84336 001500 01 00

FIG 12

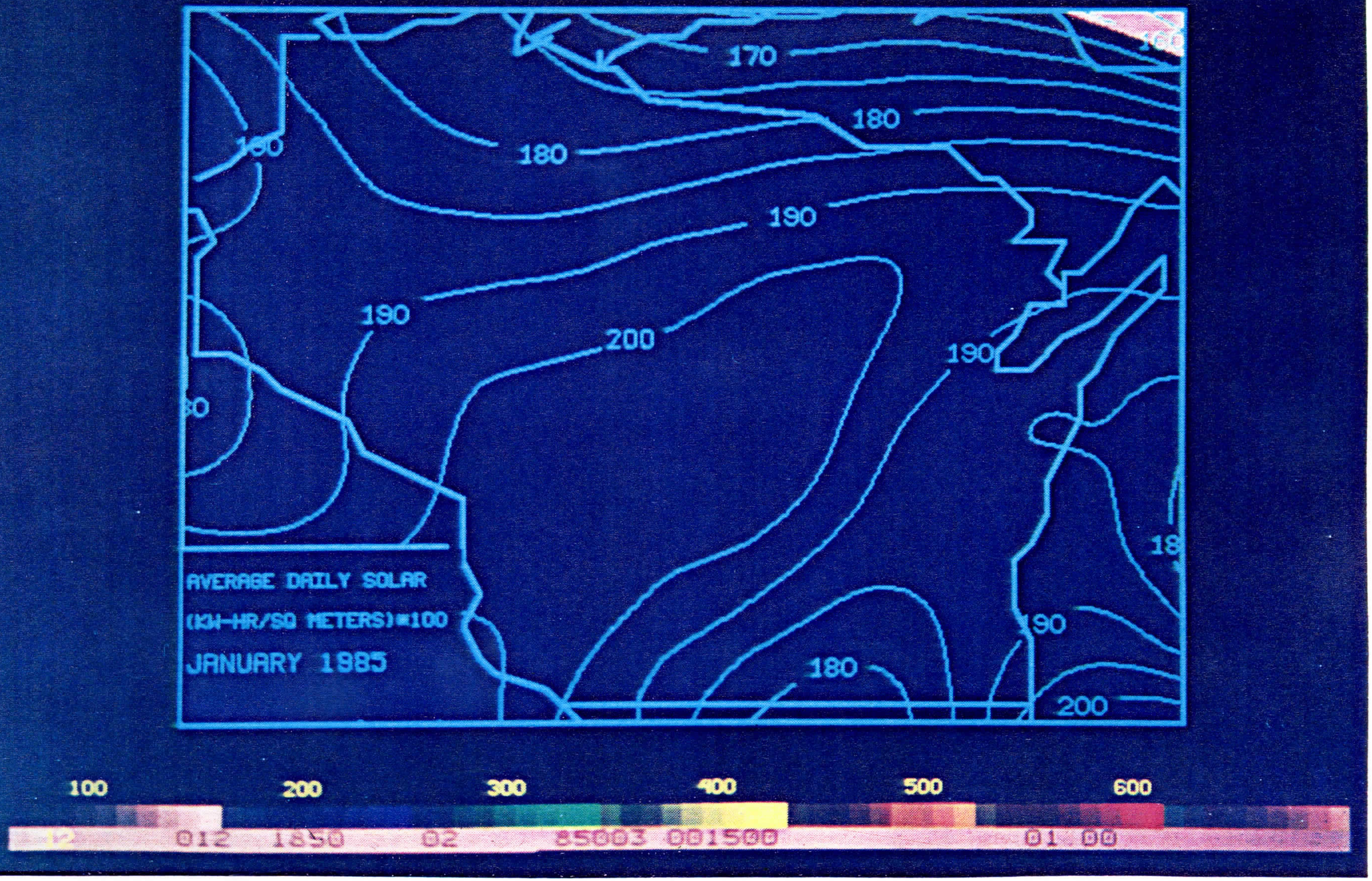

AVERAGE DAILY SOLAR
(KW-HR/SQ METERS)*100
JANUARY 1985
170
180
180
190
190
200
190
180
190
200
18
160
100
200
300
400
500
600
12 012 1850 02 85003 001500 01 00

FIG 13

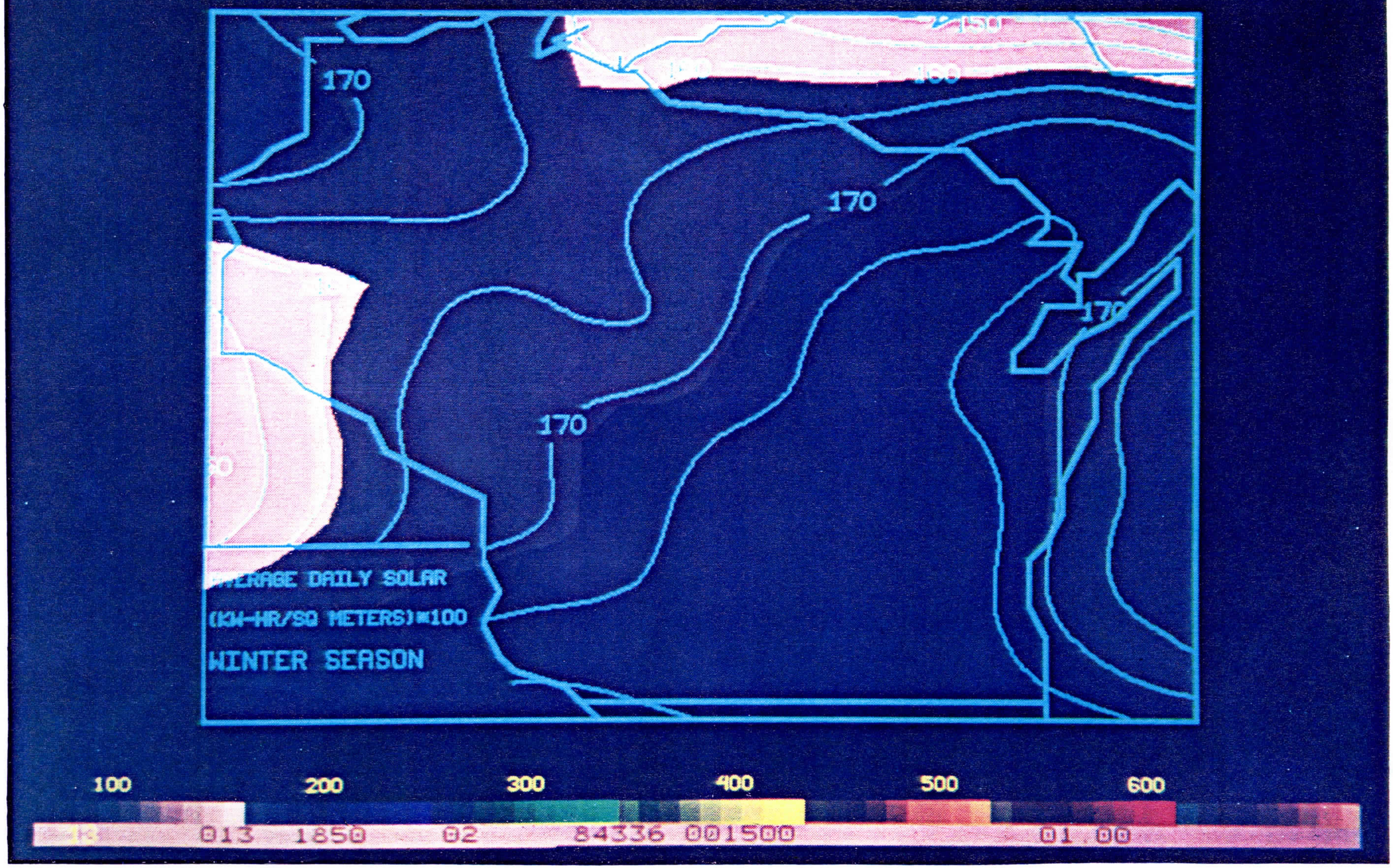

170
150
160
170
170
170
50
ERAGE DAILY SOLAR
(KW-HR/SQ METERS)*100
WINTER SEASON
100
200
300
400
500
600
013 1850 02 84336 001500 01.00

FIG 14

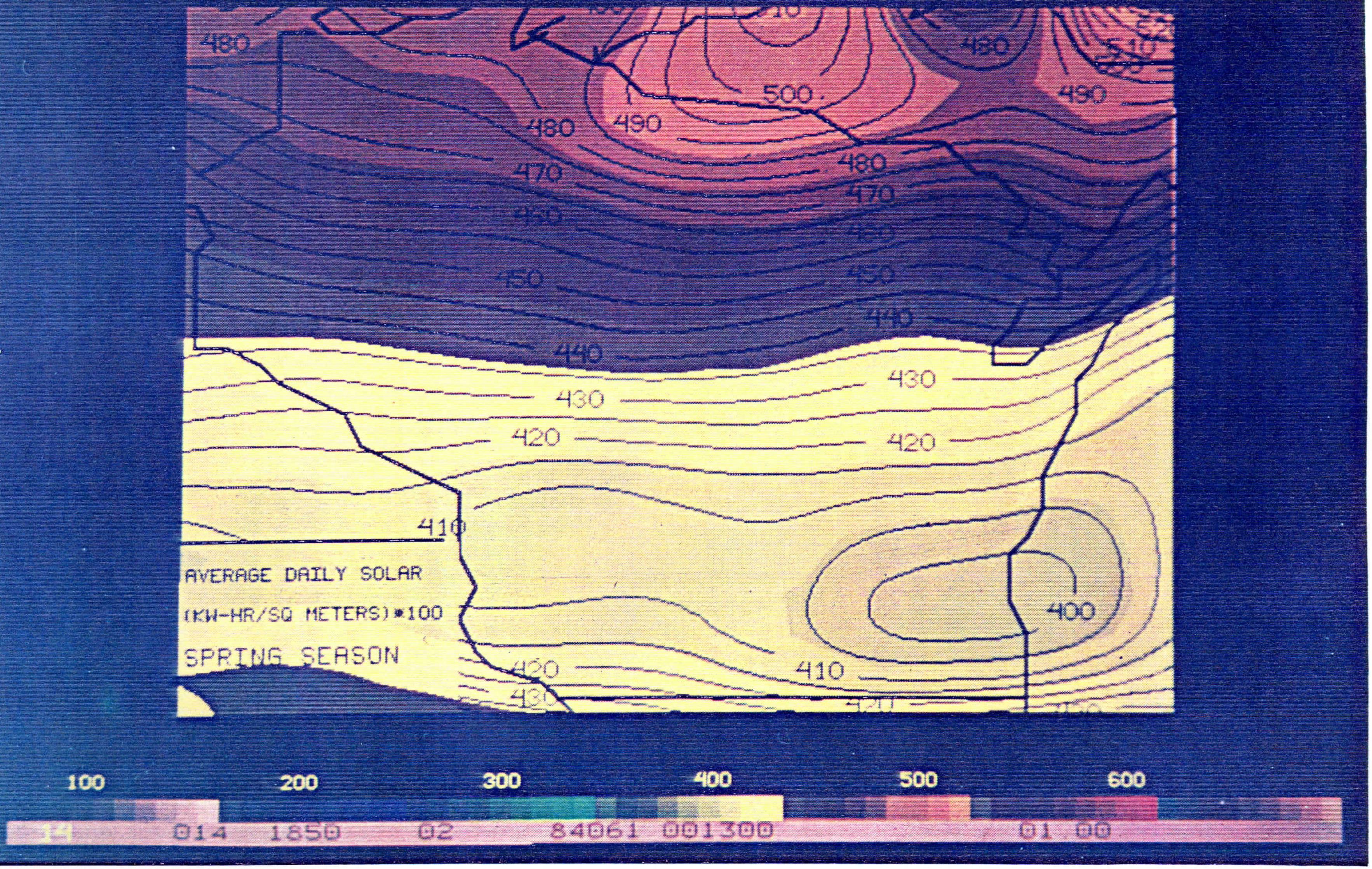

480
480
490
500.
480
490
480
470
460
450
480
470
460
450
440
440
430
420
430
420
410
AVERAGE DAILY SOLAR
(KW-HR/SQ METERS)*100
SPRING SEASON
420
430
410
400
100
200
300
400
500
600
14
014 1850
02
84061 001300
01.00

FIG 15

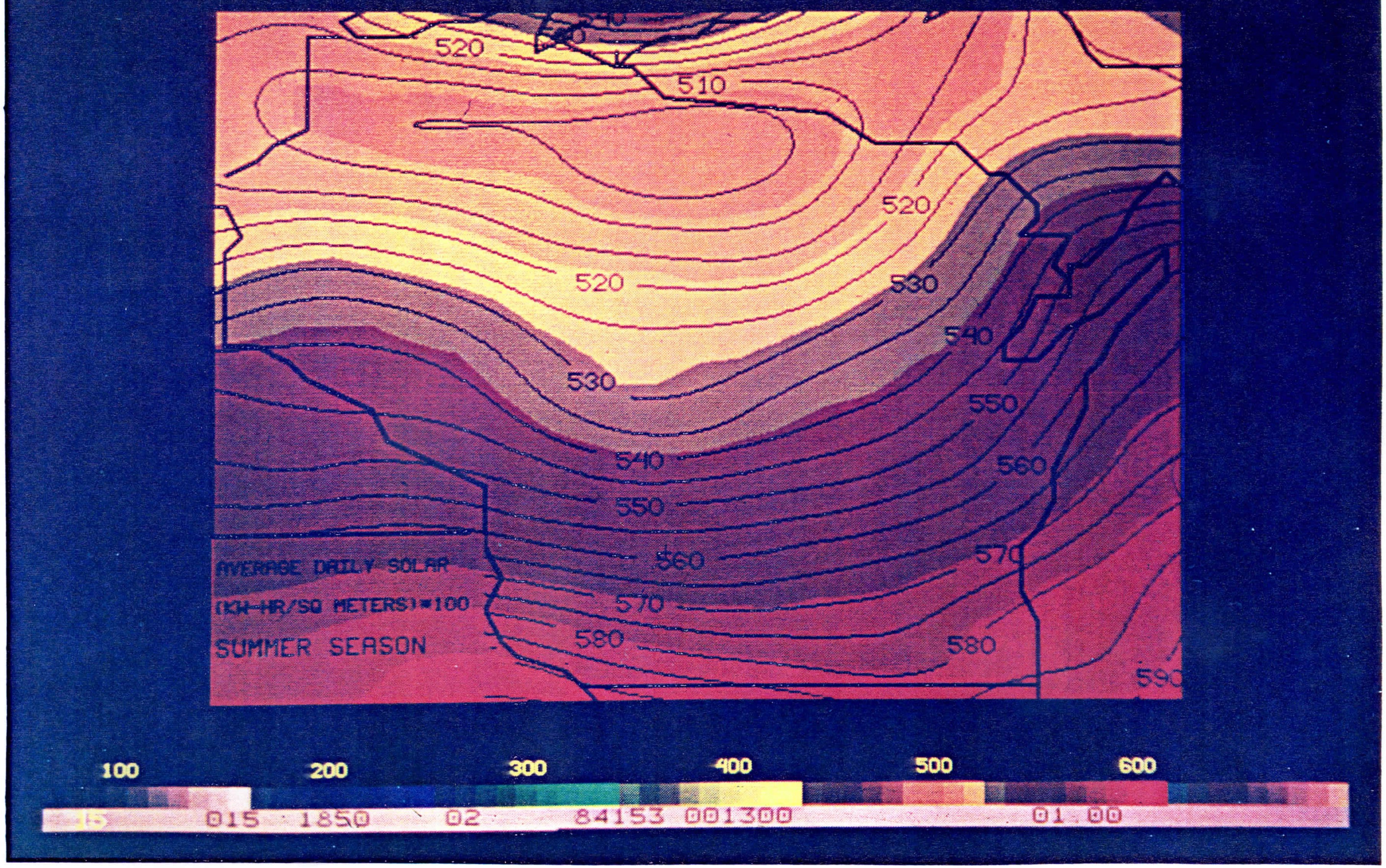

520
510
520
520
530
530
540
540
550
550
560
560
570
570
580
580
590
AVERAGE DAILY SOLAR
(KW-HR/SQ METERS)*100
SUMMER SEASON
100
200
300
400
500
600
15 015 1850 02 84153 001300 01.00

FIG 16

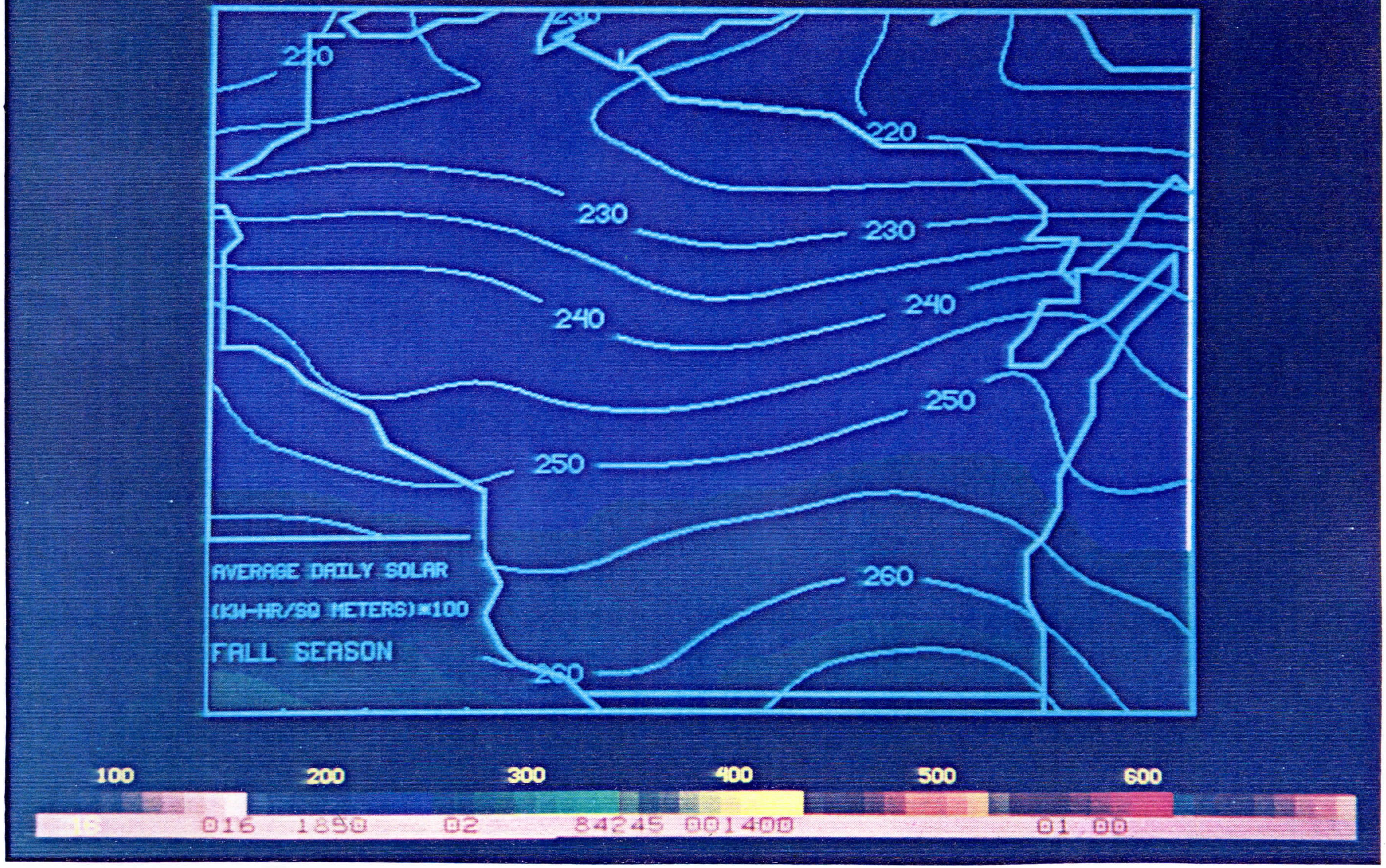
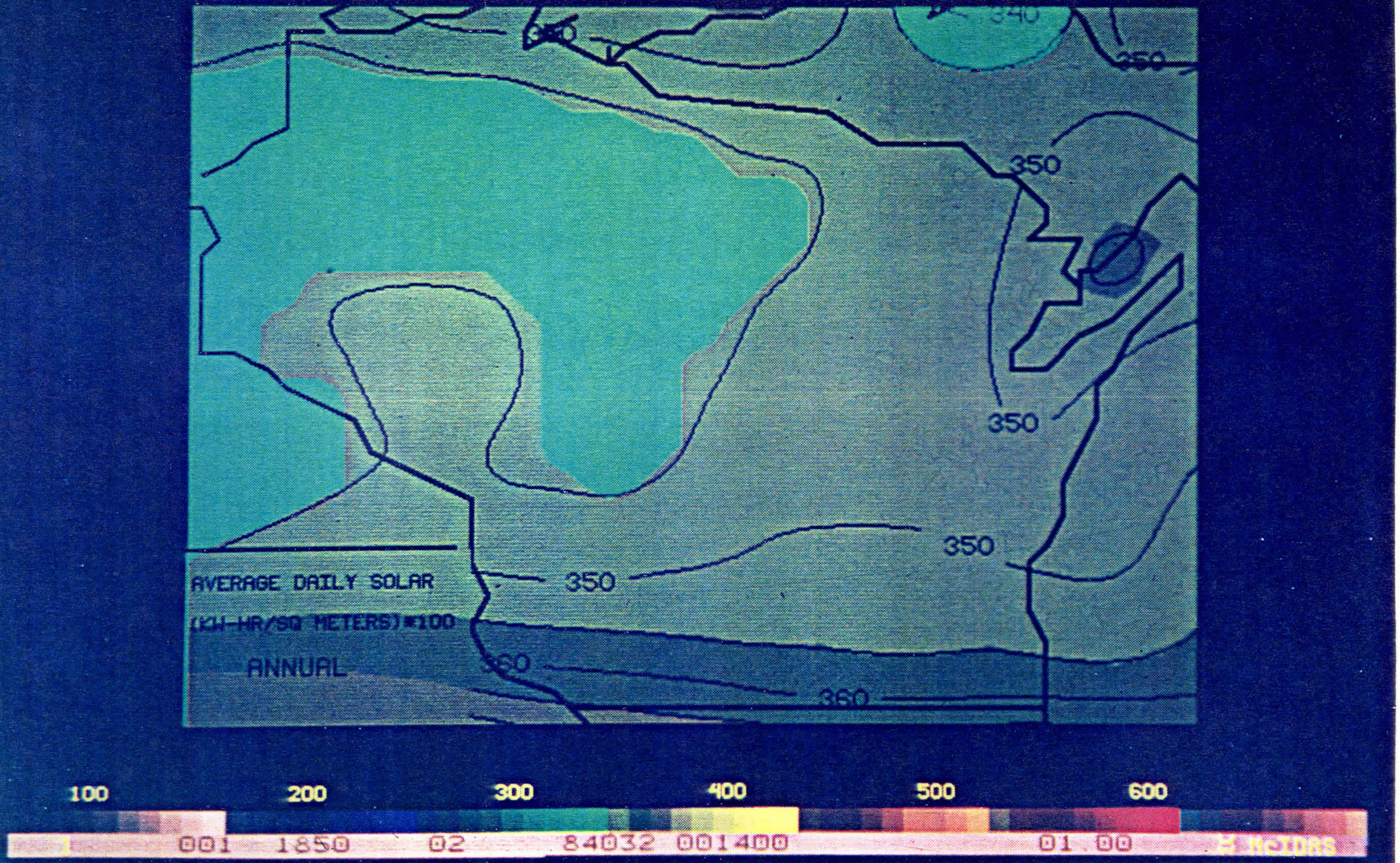

230
220
220
230
230
240
240
250
250
260
260
AVERAGE DAILY SOLAR
(KW-HR/SQ METERS)*100
FALL SEASON
100
200
300
400
500
600
16 016 1850 02 84245 001400 01 00

FIG 17


AVERAGE DAILY SOLAR
(KW-HR/SQ METERS)*100
ANNUAL
340
350
350
350
350
350
350
360
360
360
100
200
300
400
500
600
001 1850 02 84032 001400 01.00
McIDAS

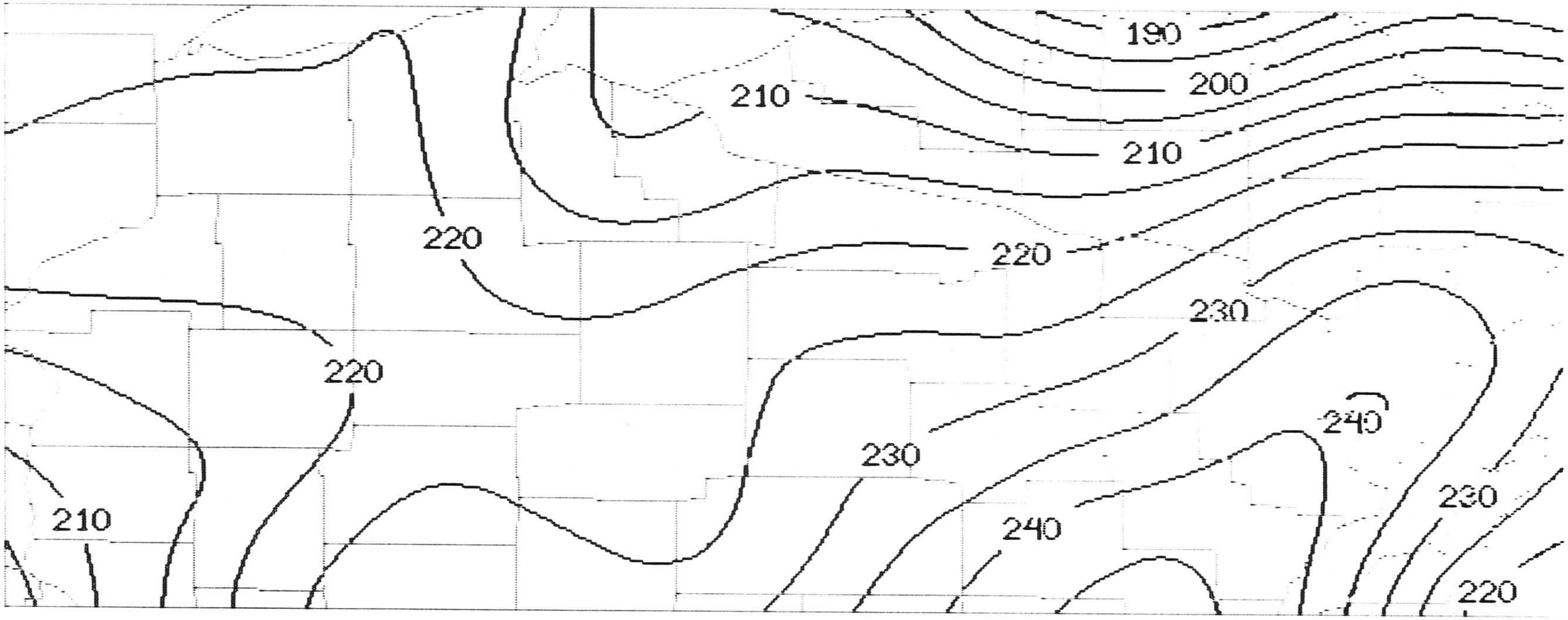


FIG 18A

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
FEBRUARY' 1984

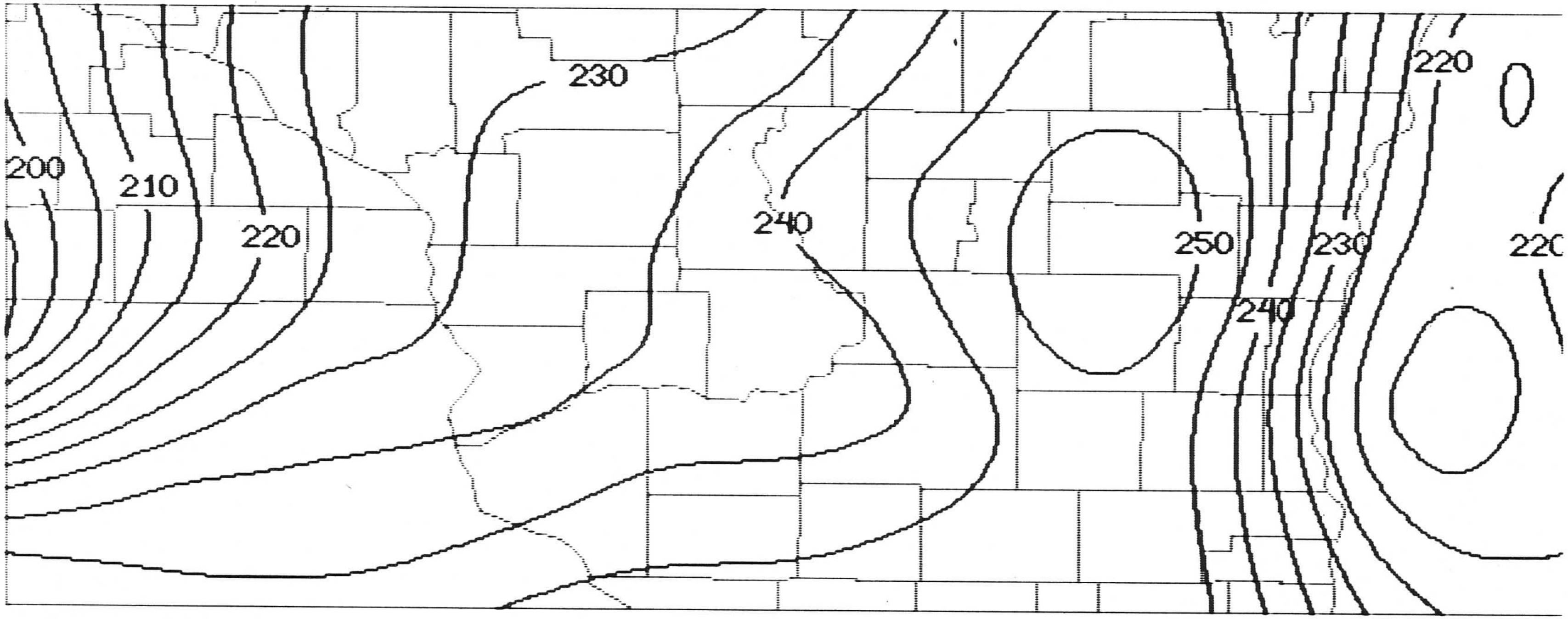


FIG 18B

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
FEBRUARY' 1984

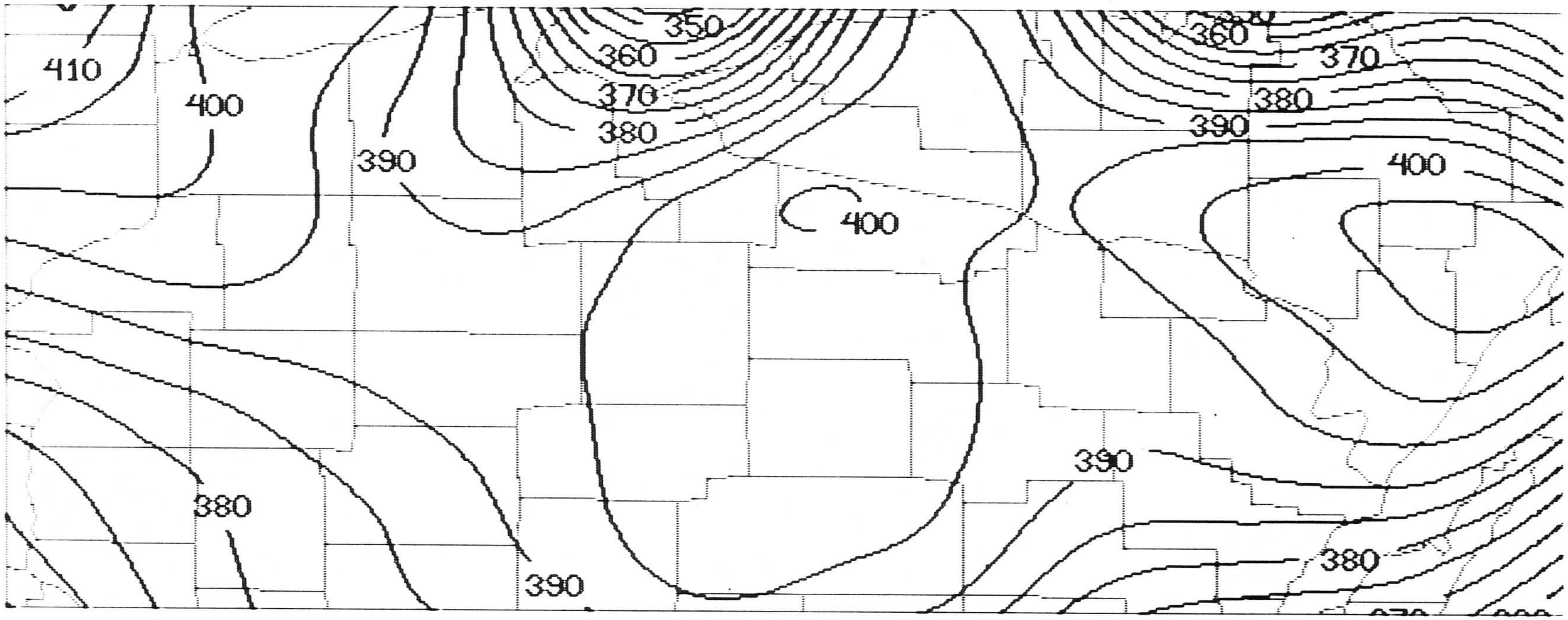


FIG 19A

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
MARCH 1984

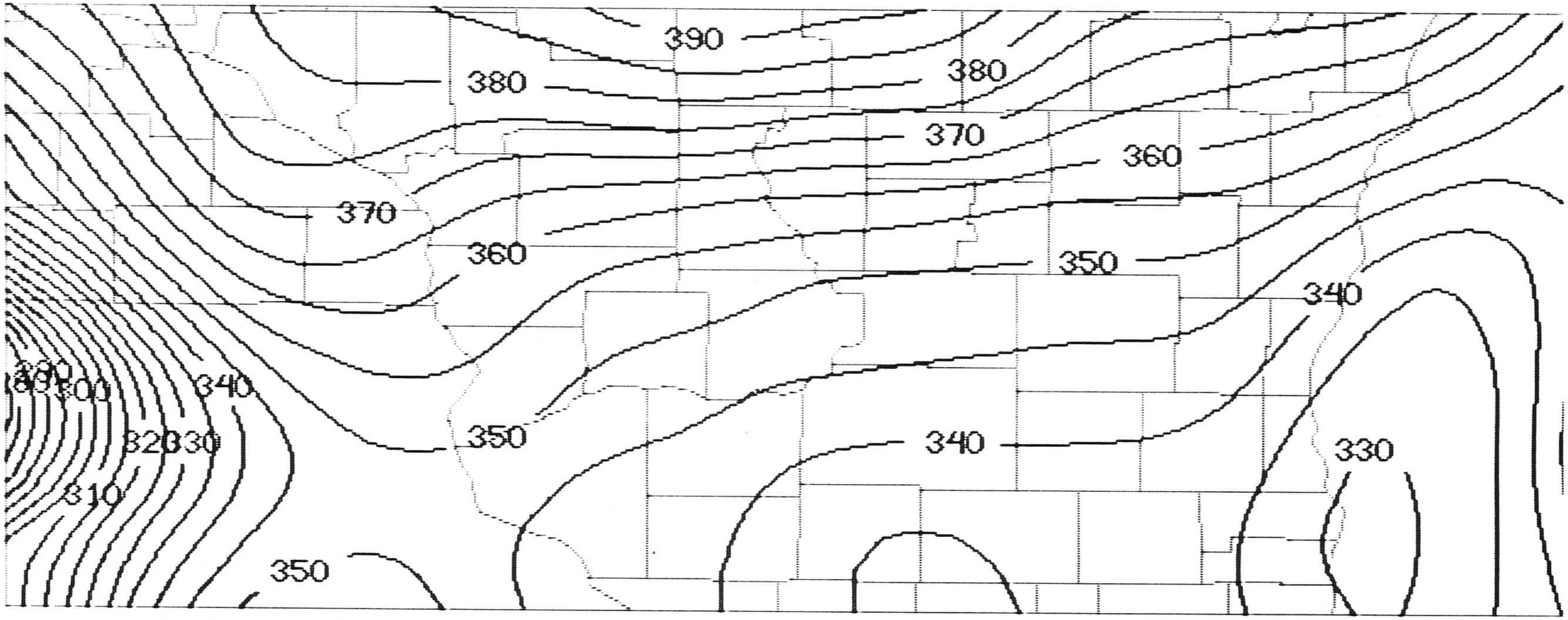


FIG 19B

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
MARCH 1984

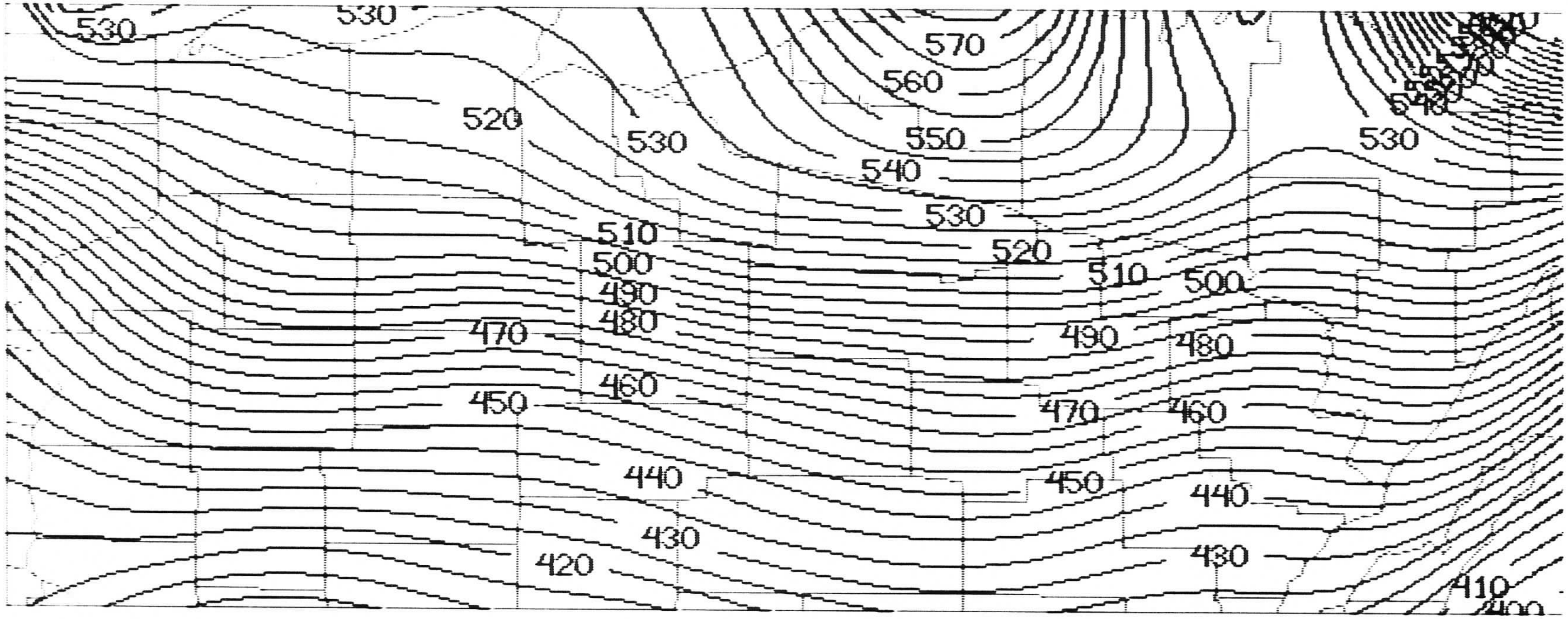


FIG 20A

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
APRIL 1984

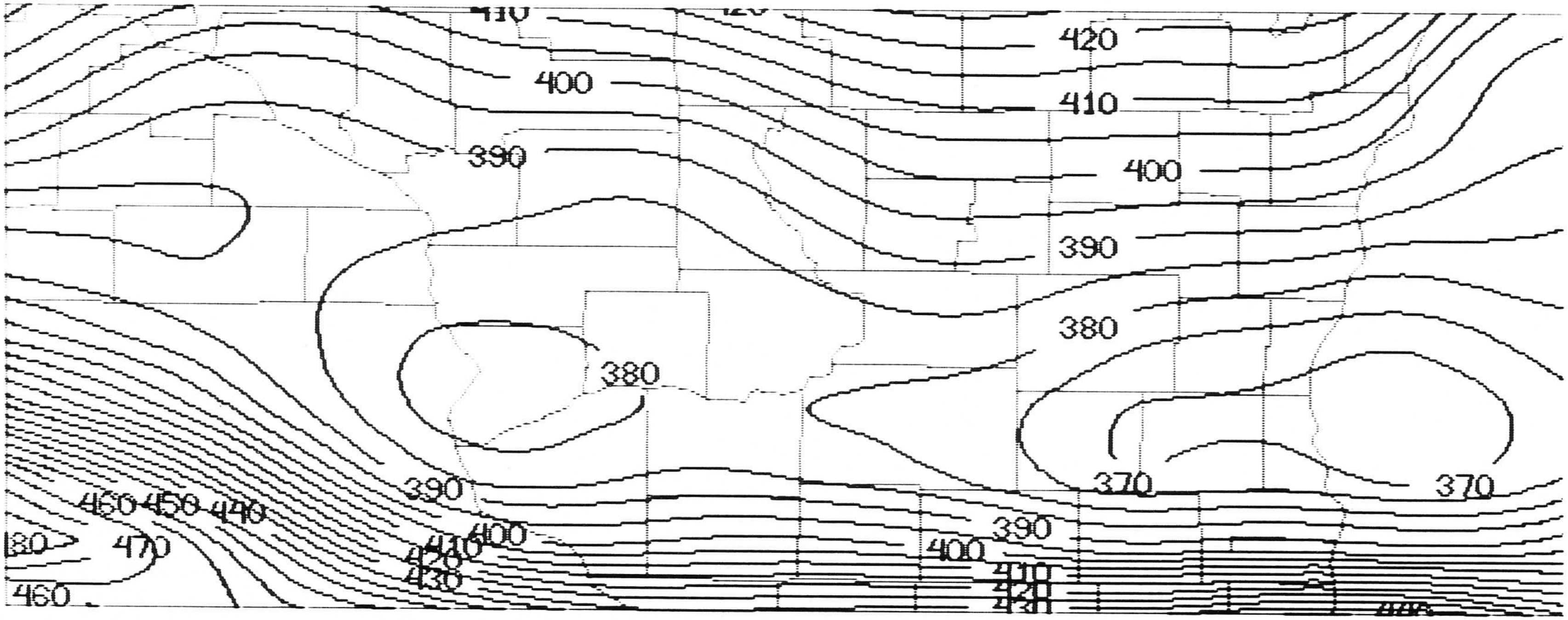


FIG 20B

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
APRIL 1984

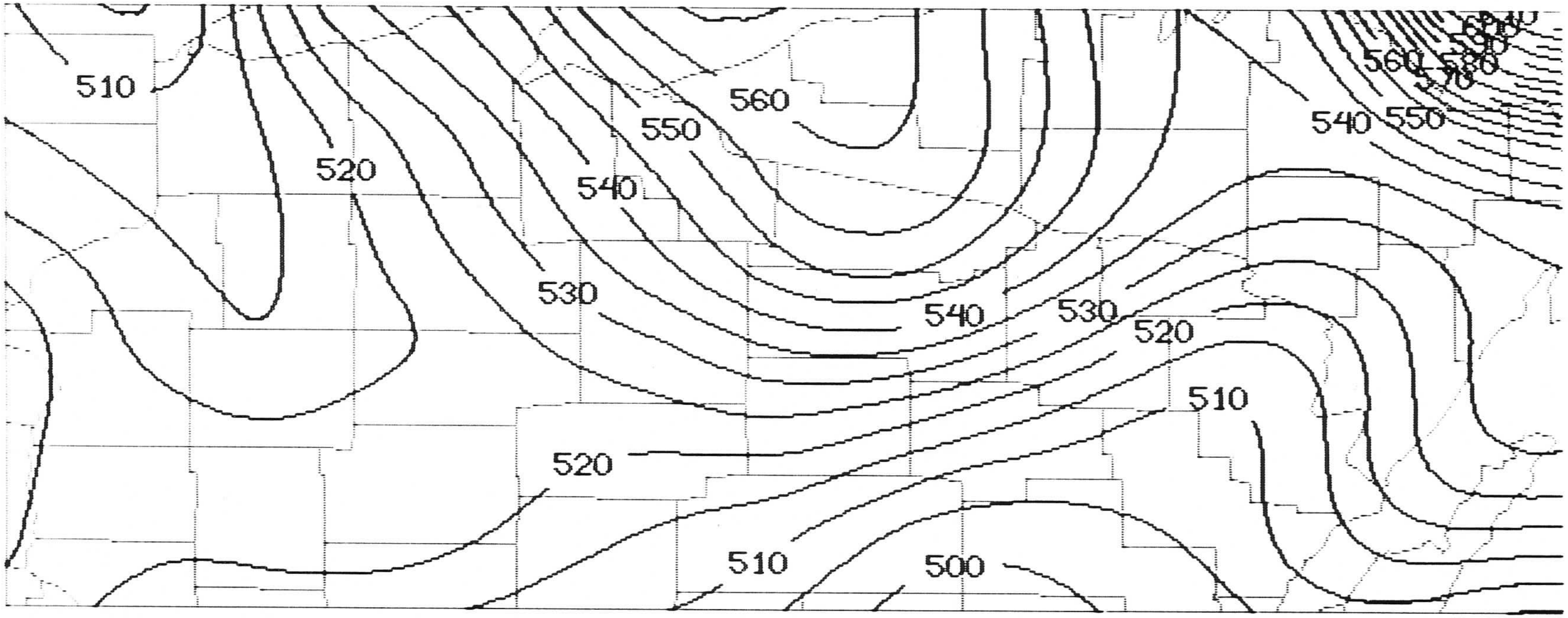


FIG 21A

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
MAY 1984

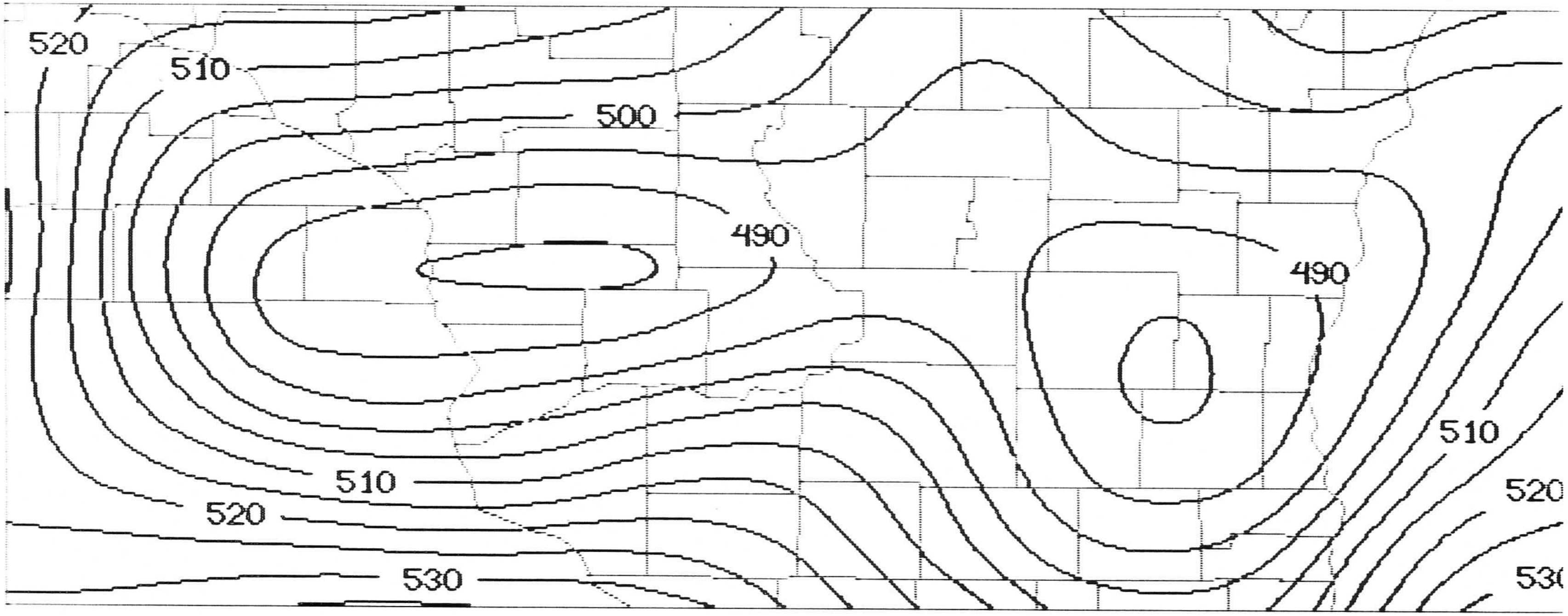


FIG 21B

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
MAY 1984

McIDAS

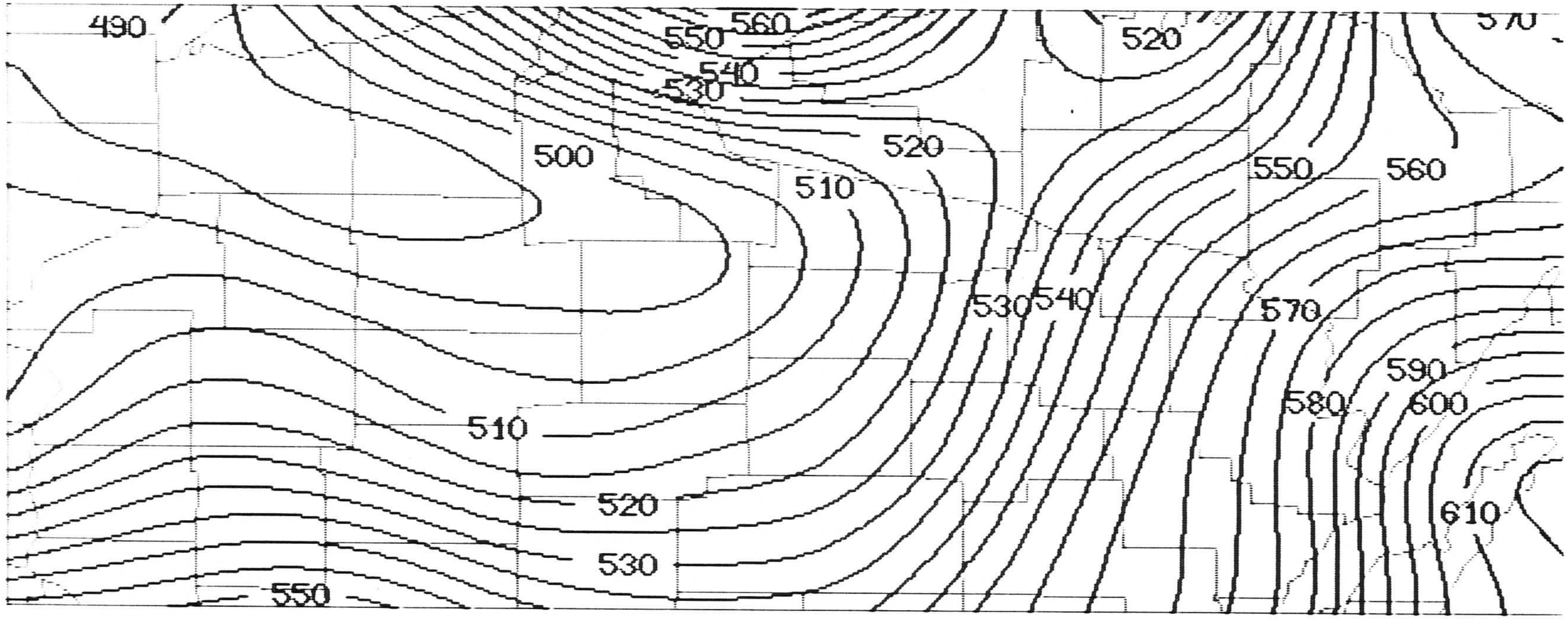


FIG 22A

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
JUNE 1984

McIDAS

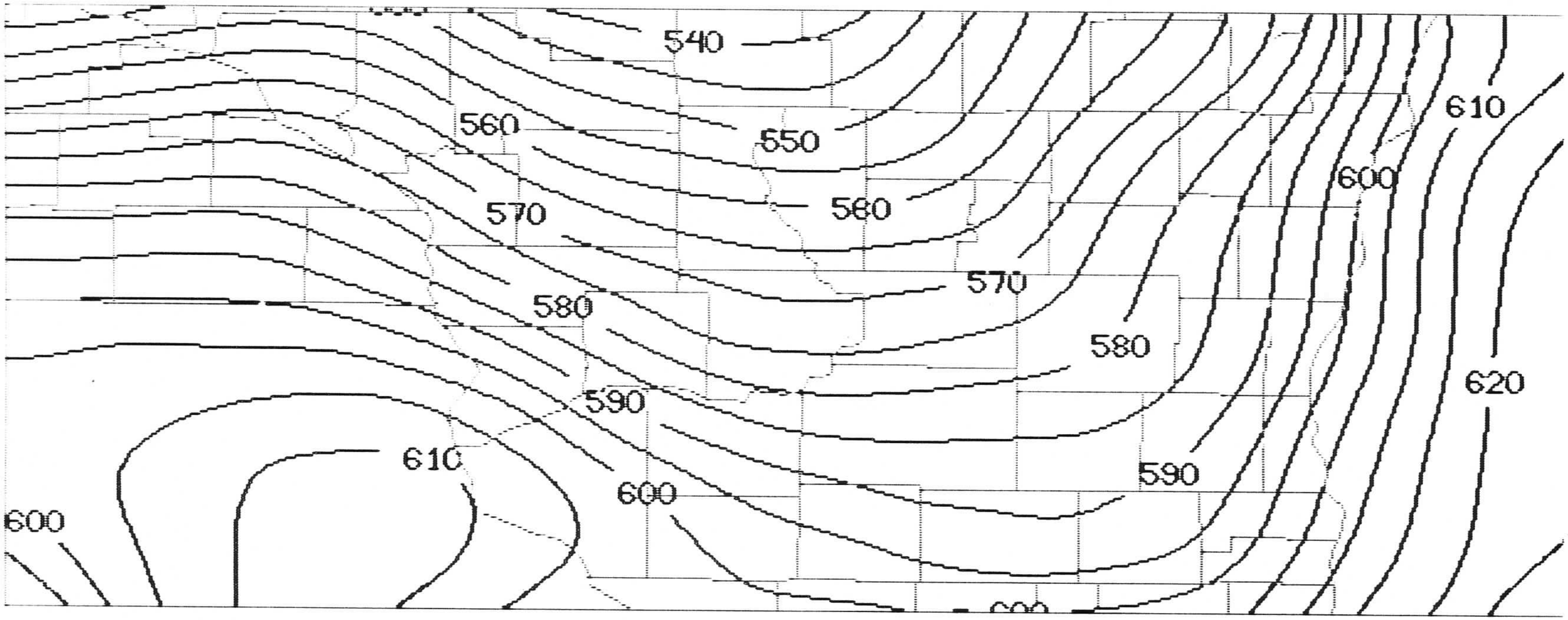


FIG 22B

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
JUNE 1984

McIDAS

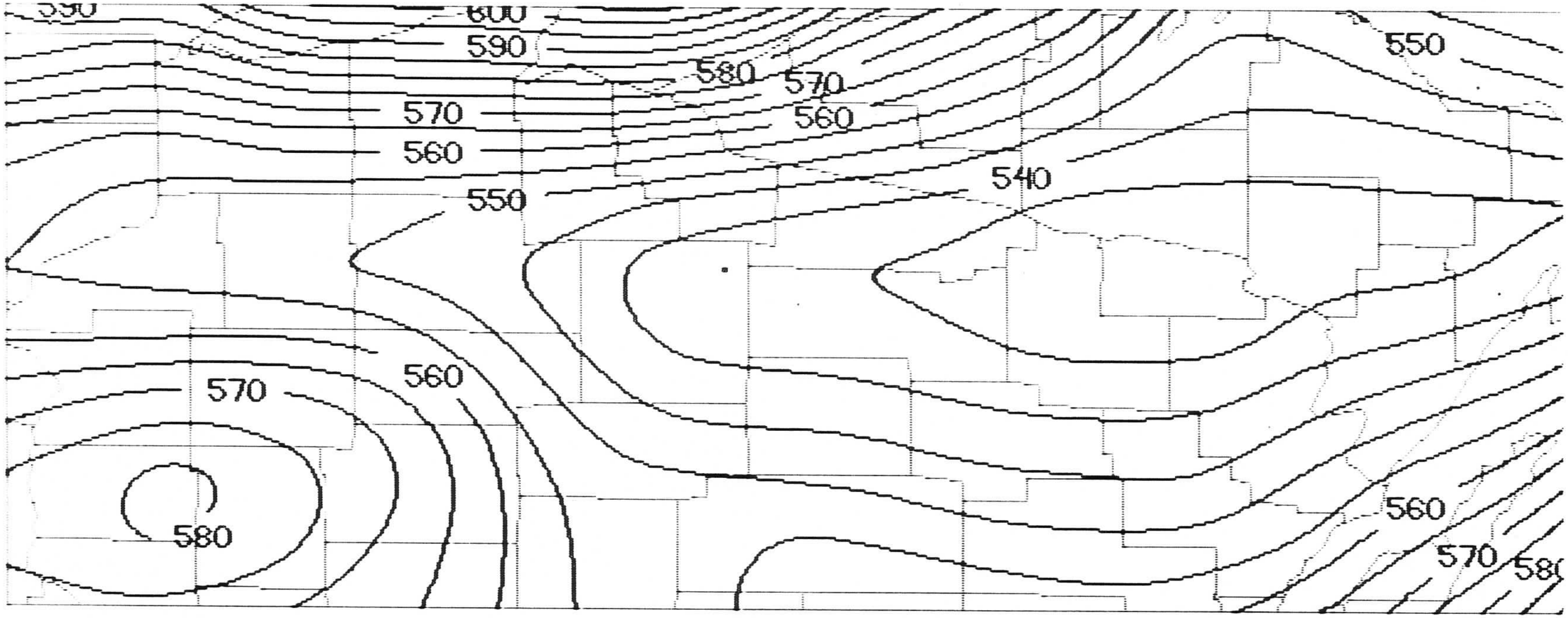


FIG 23A

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
JULY 1984

McIDAS

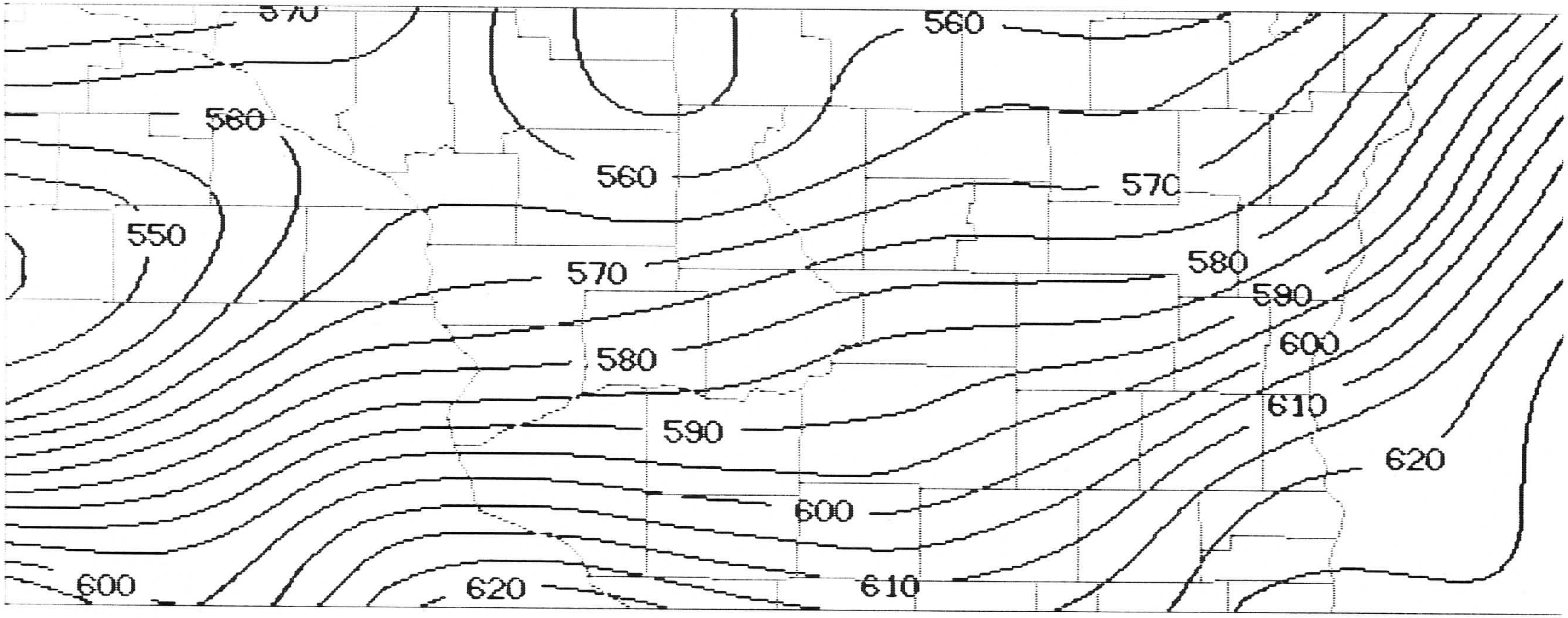


FIG 23B

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
JULY 1984

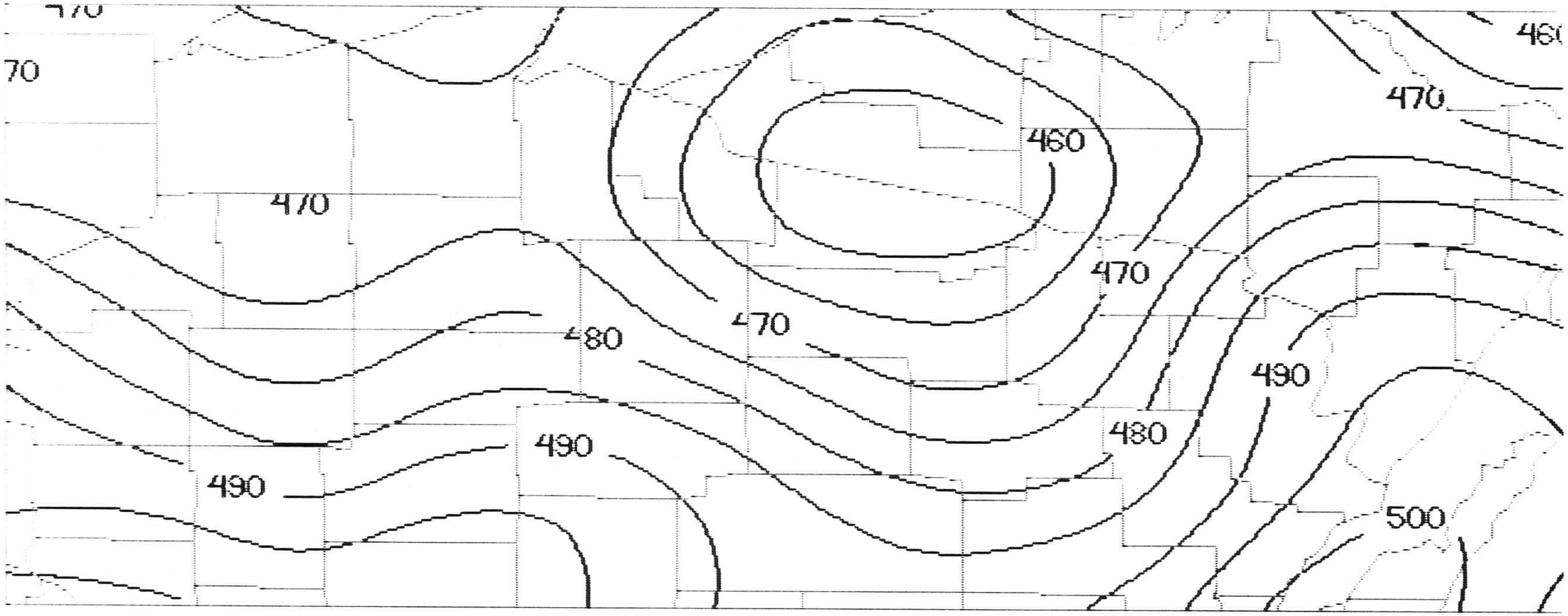


FIG 24A

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
AUGUST 1984

McIDAS

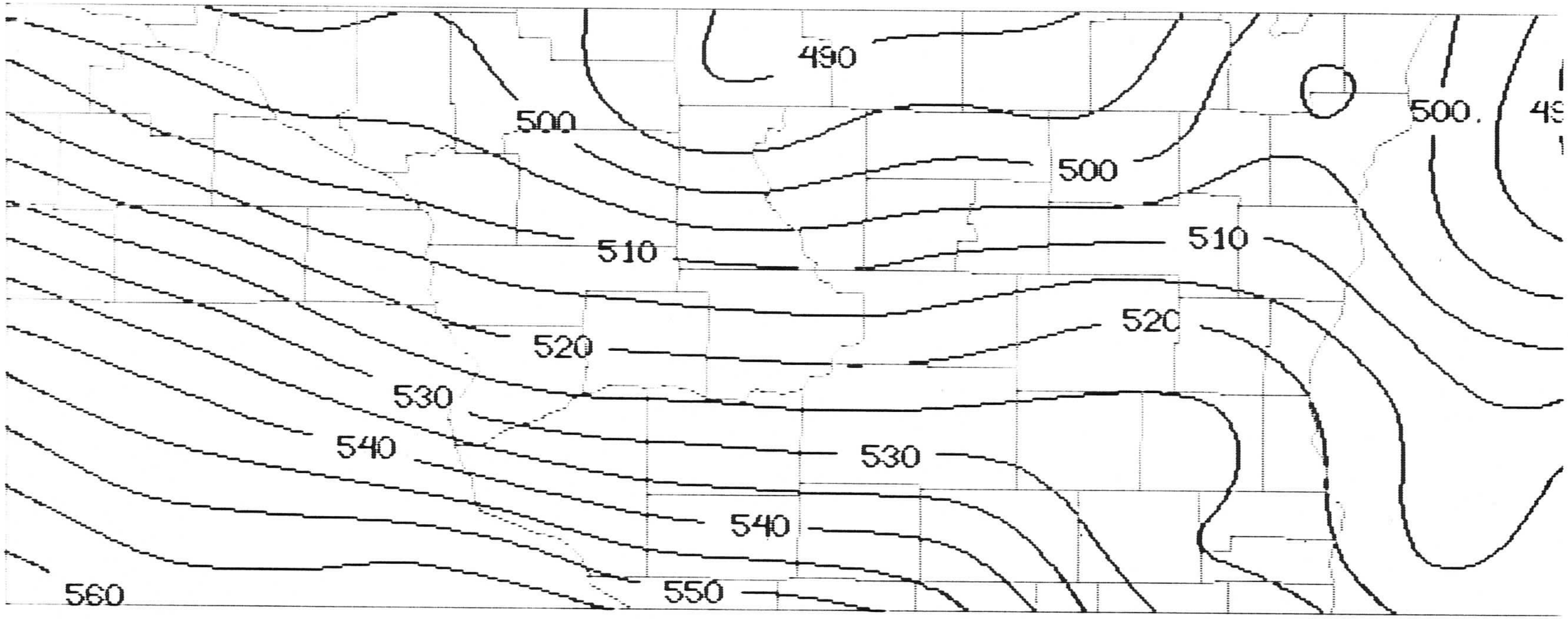


FIG 24B

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
AUGUST 1984

McIDAS

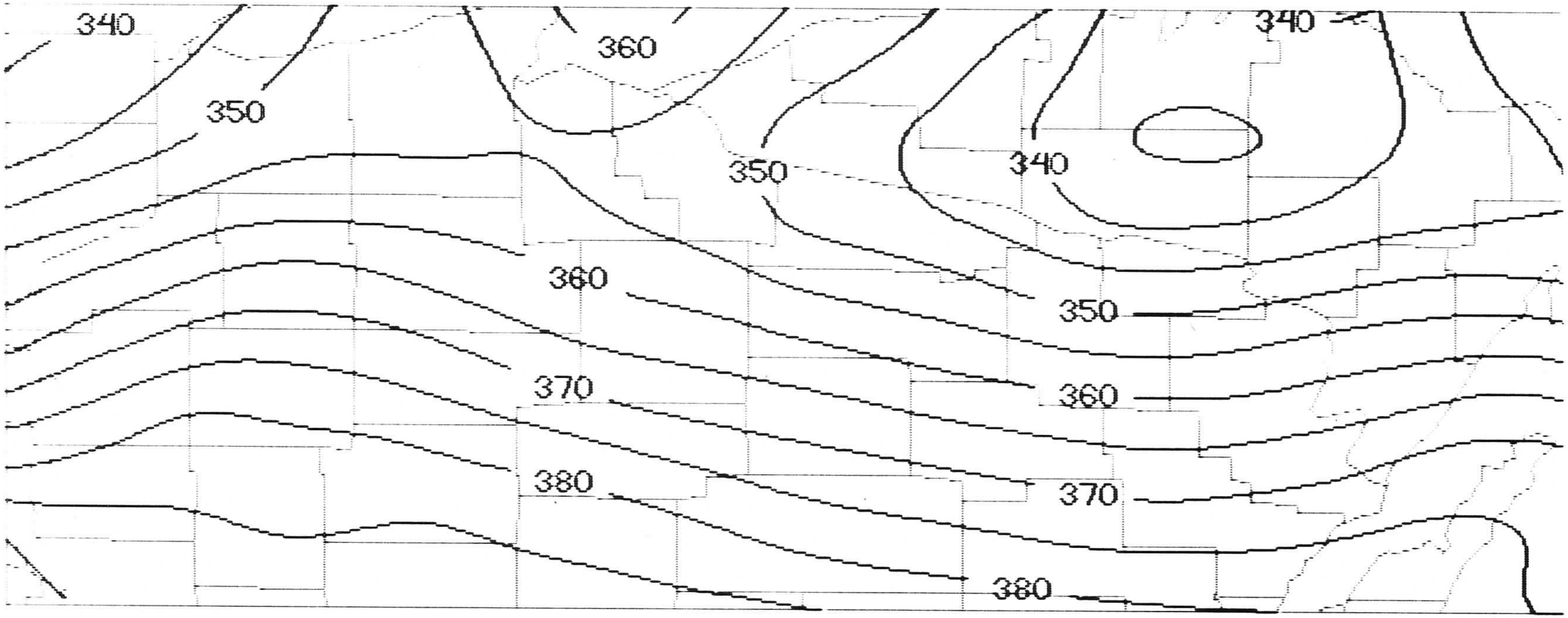


FIG 25A

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
SEPTEMBER 1984

McIDAS

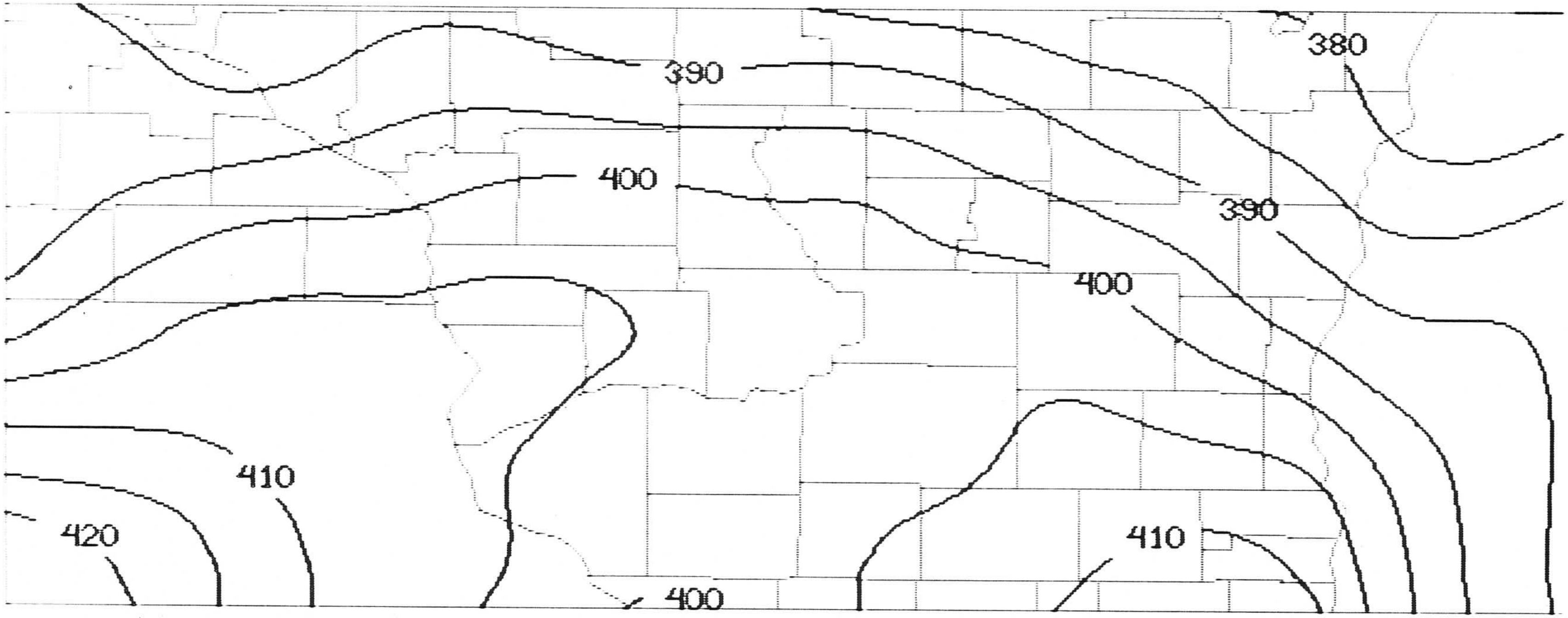


FIG 25B

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
SEPTEMBER 1984

McIDAS

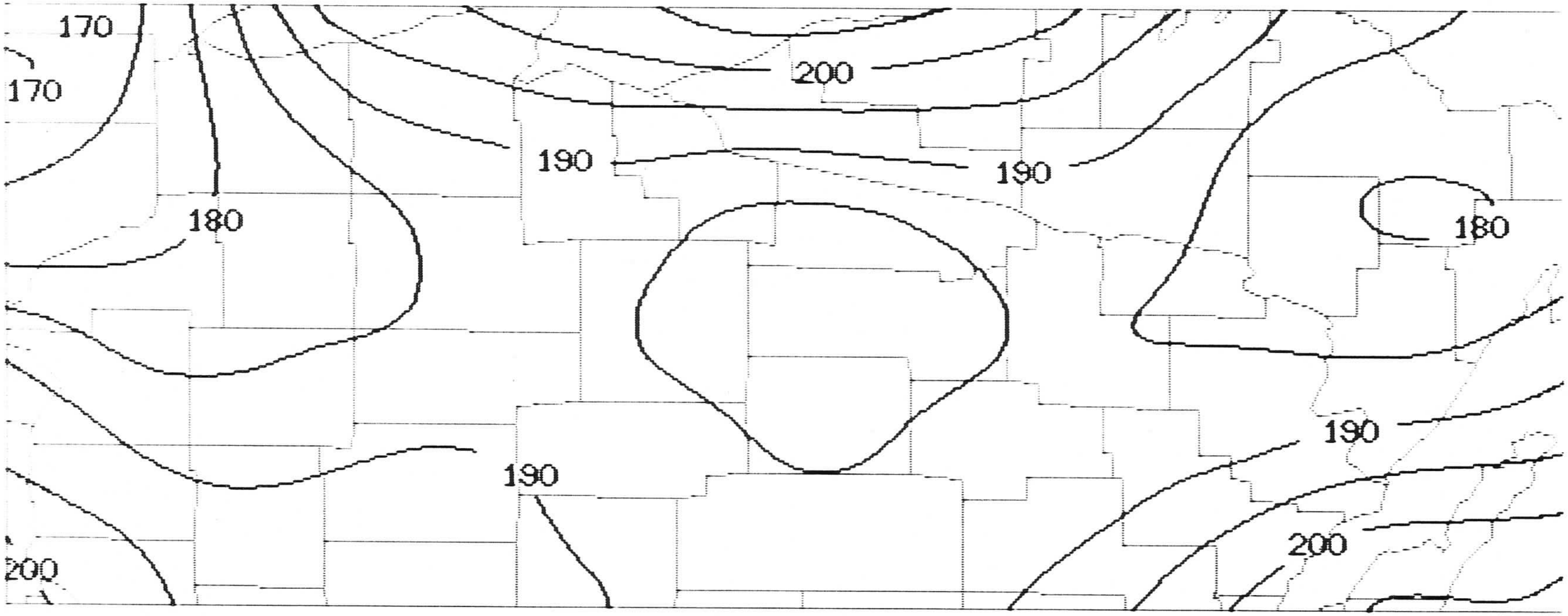


FIG 26A

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
OCTOBER 1984

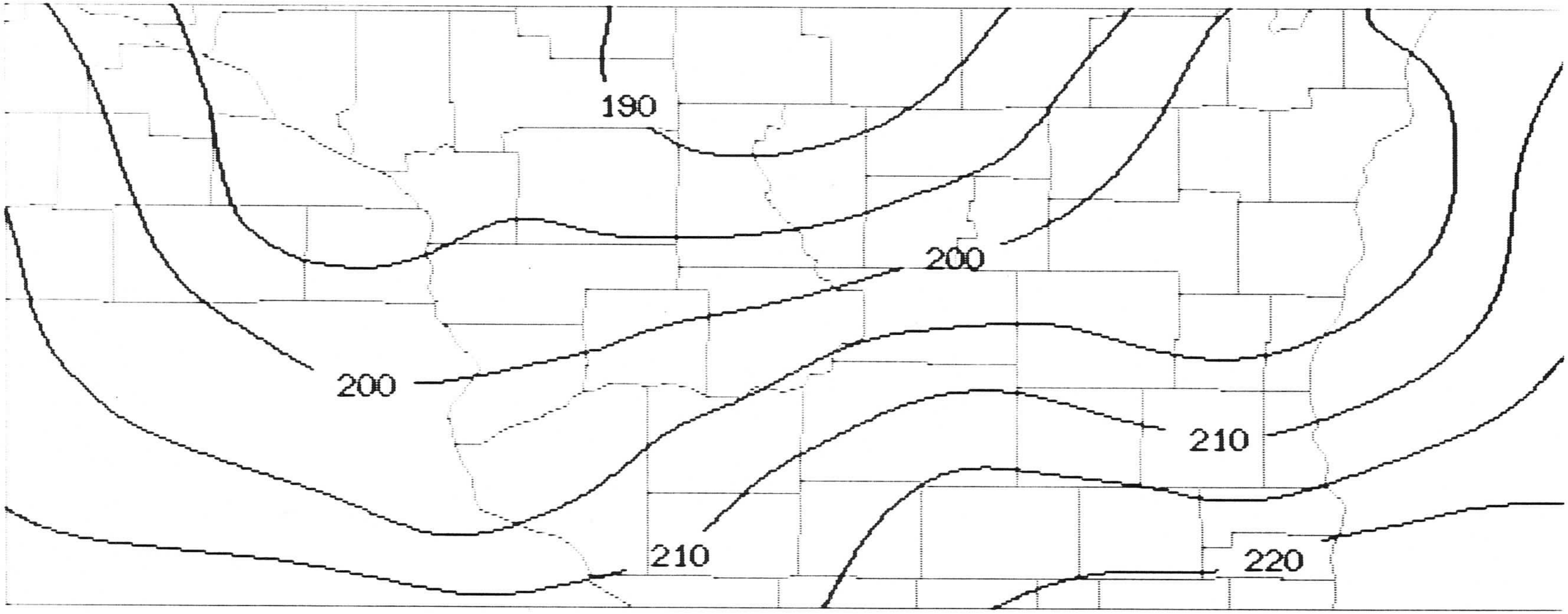


FIG 26B

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
OCTOBER 1984

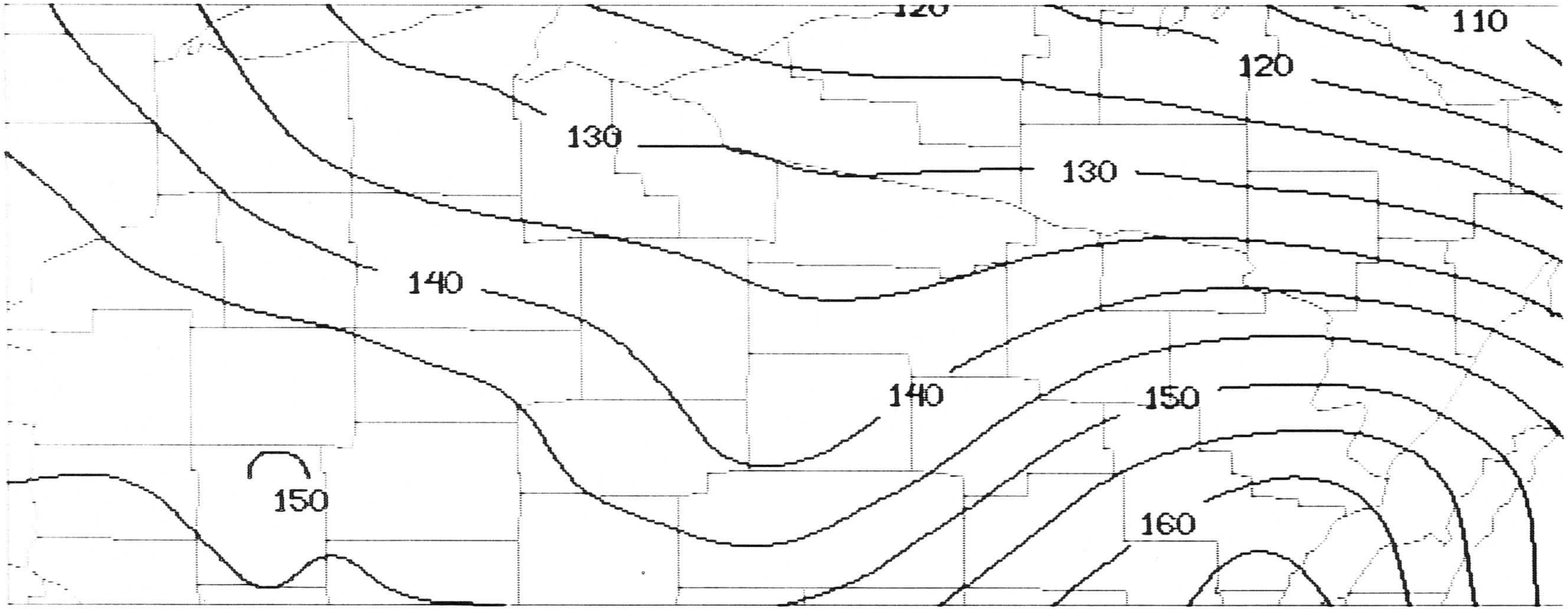
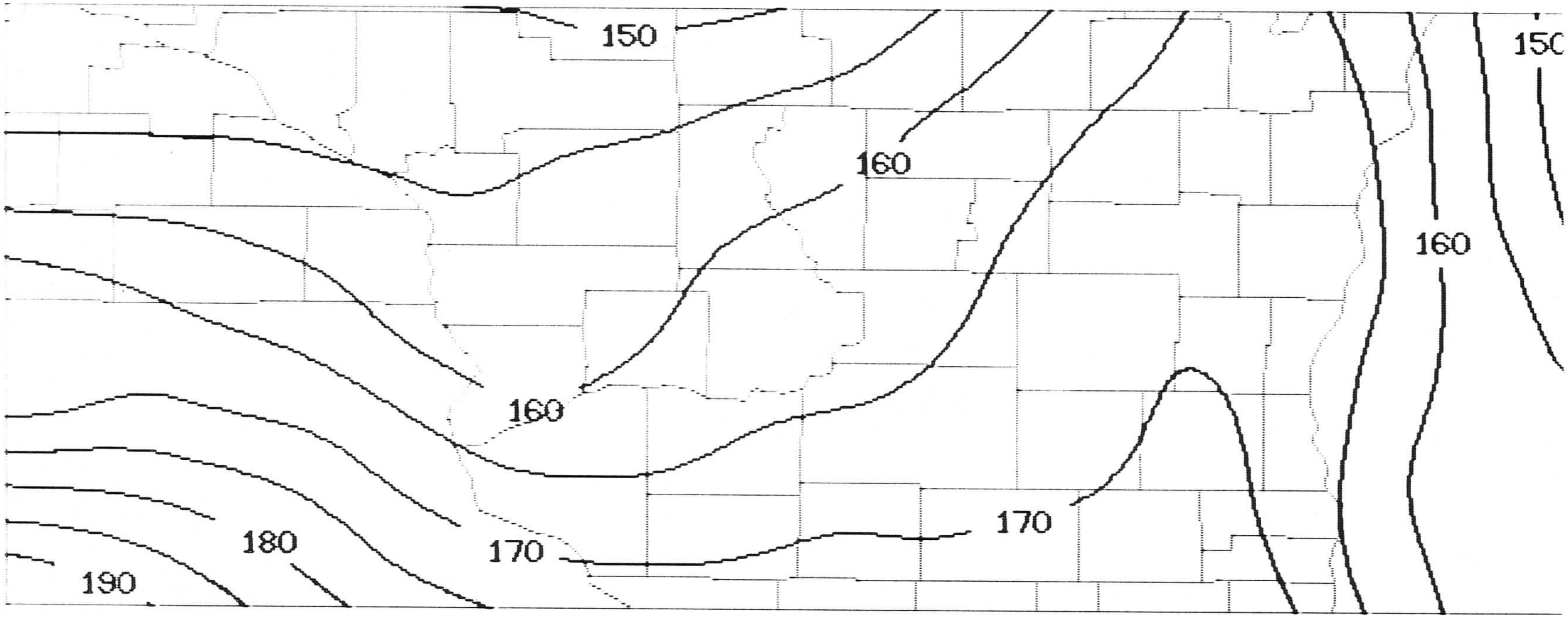


FIG 27A

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
NOVEMBER 1984



FIB 27B

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
NOVEMBER 1984

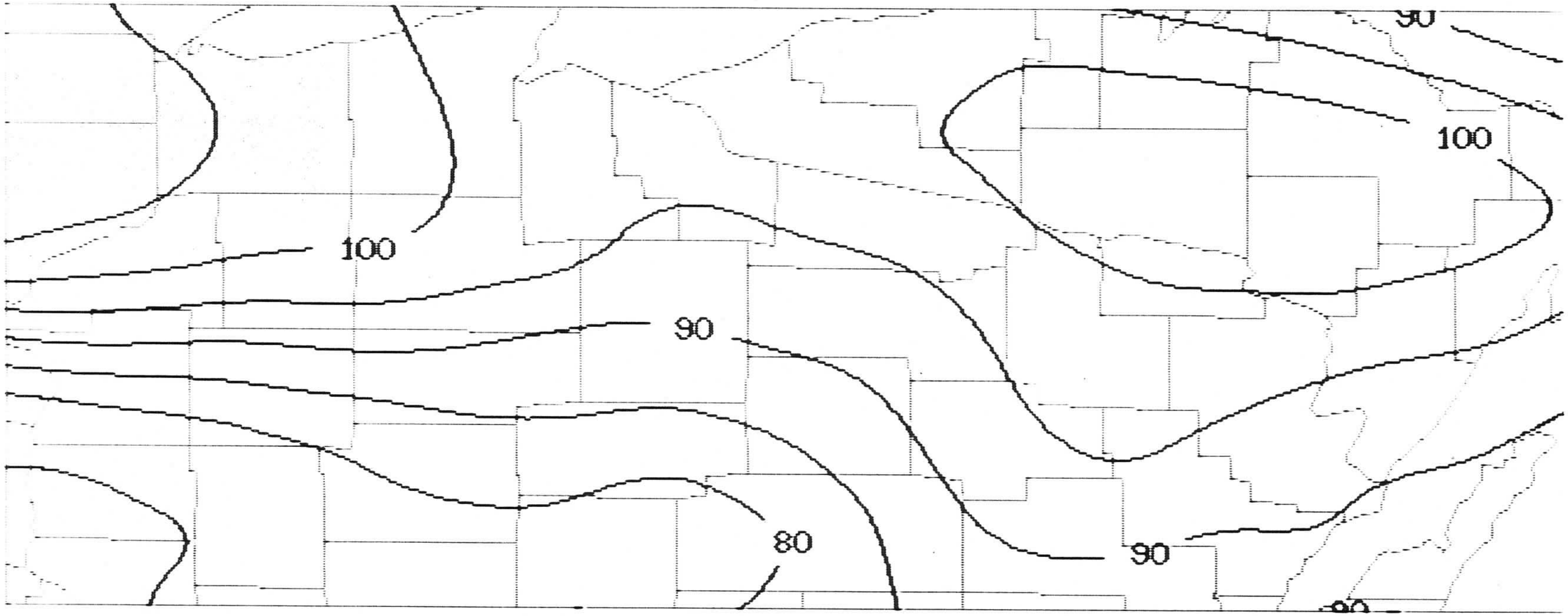


FIG 28A

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
DECEMBER 1984

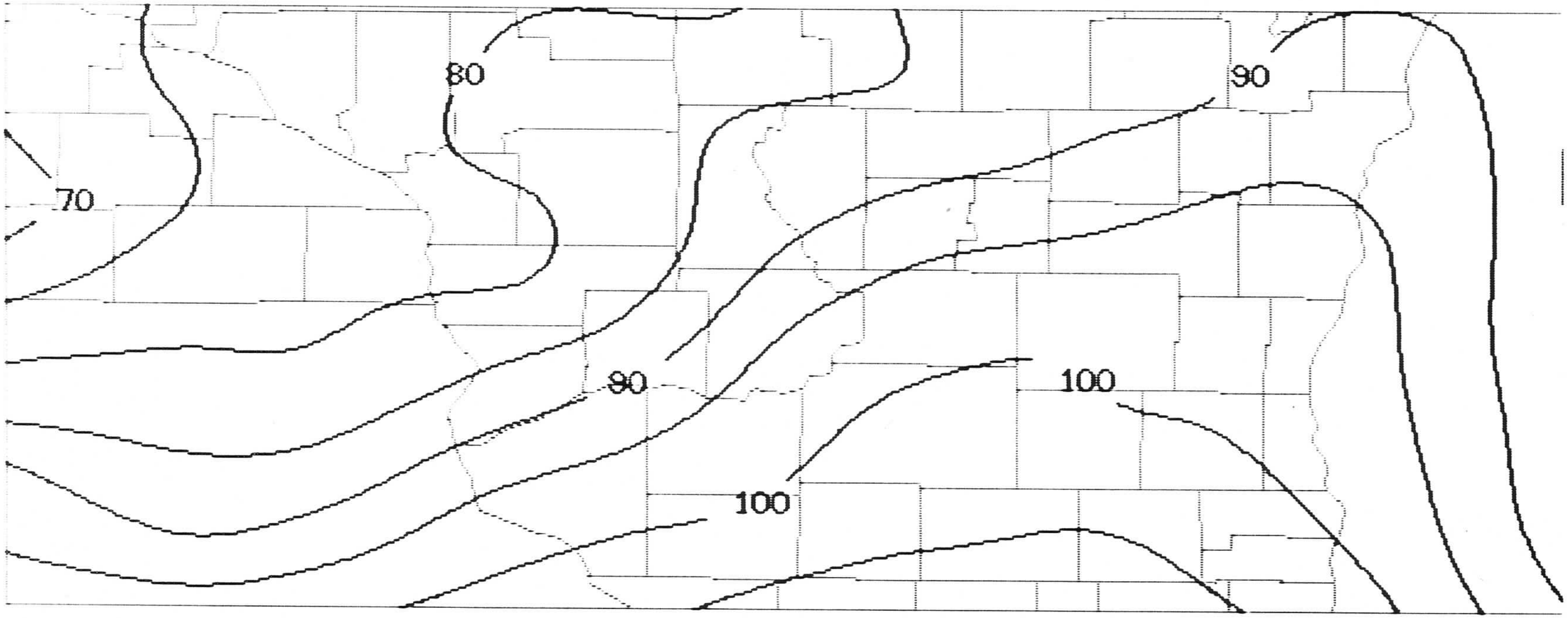


FIG 28B

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
DECEMBER 1984

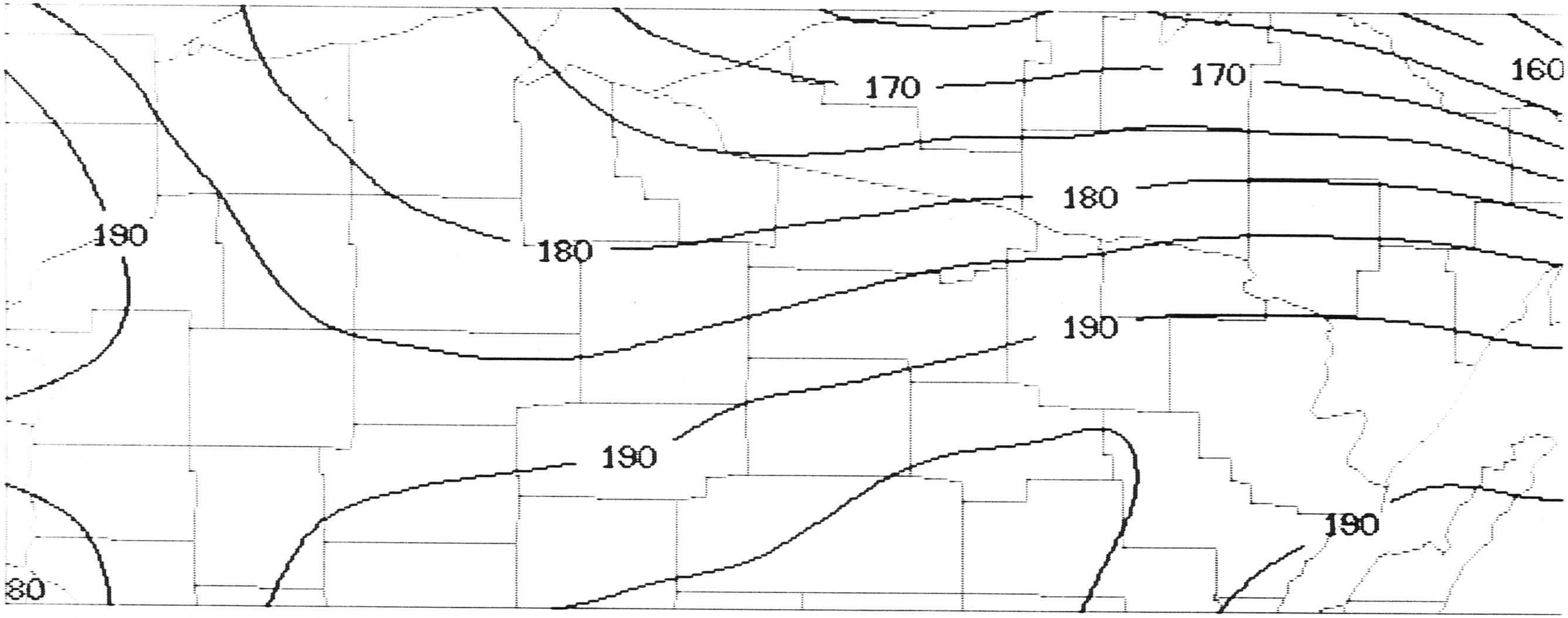


FIG 29A

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
JANUARY 1985

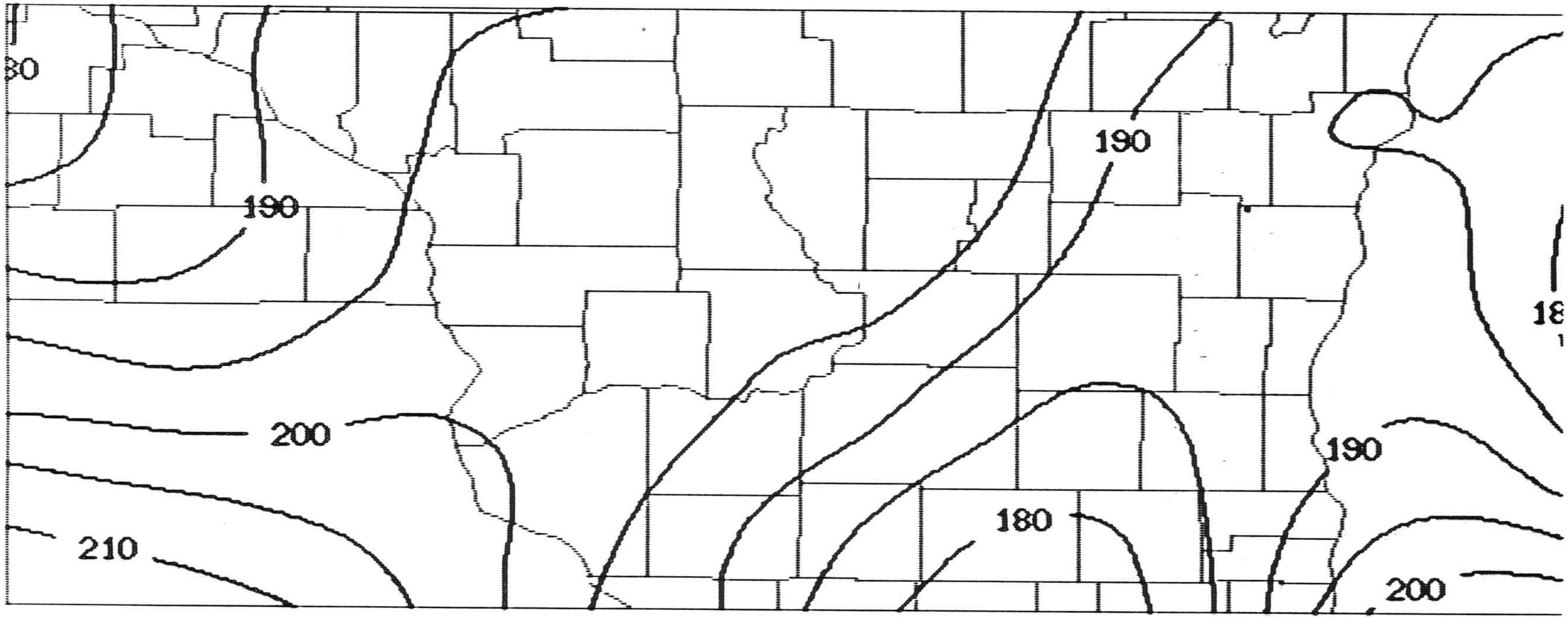


FIG 29B

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
JANUARY 1985

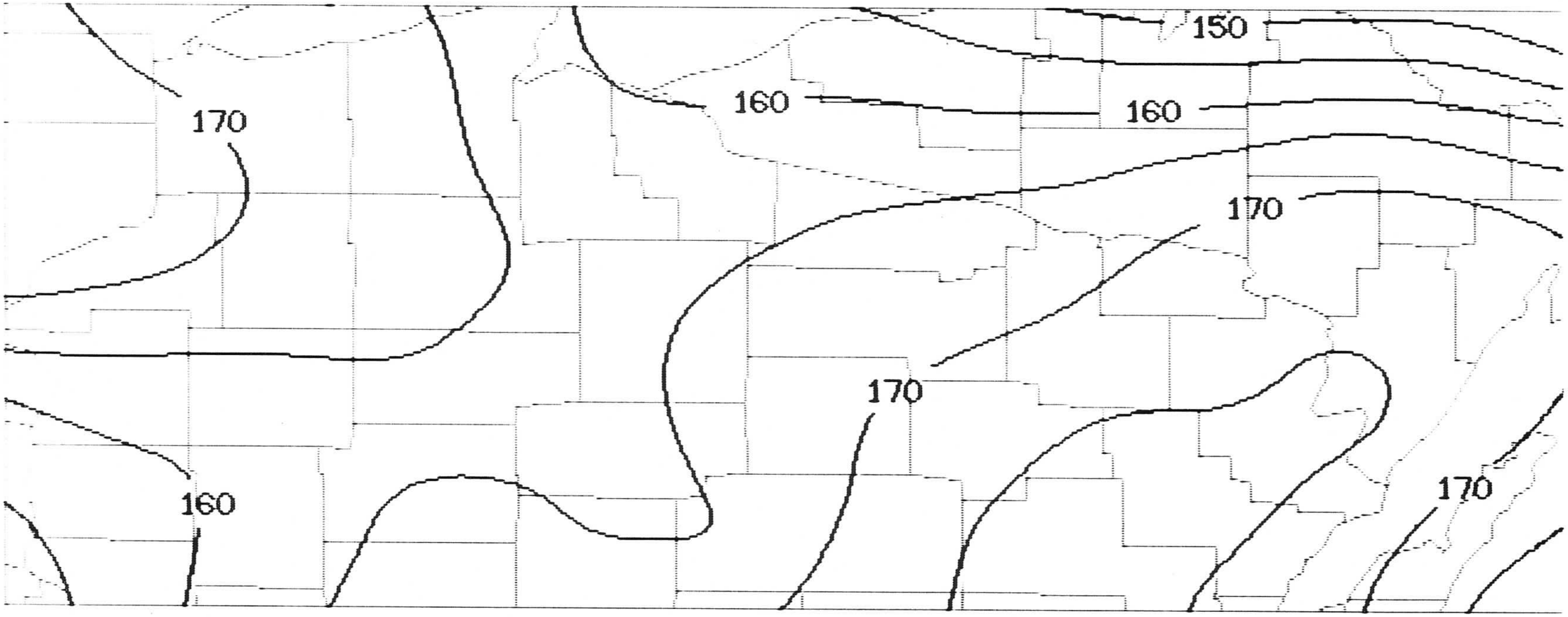


FIG 30A

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
WINTER SEASON

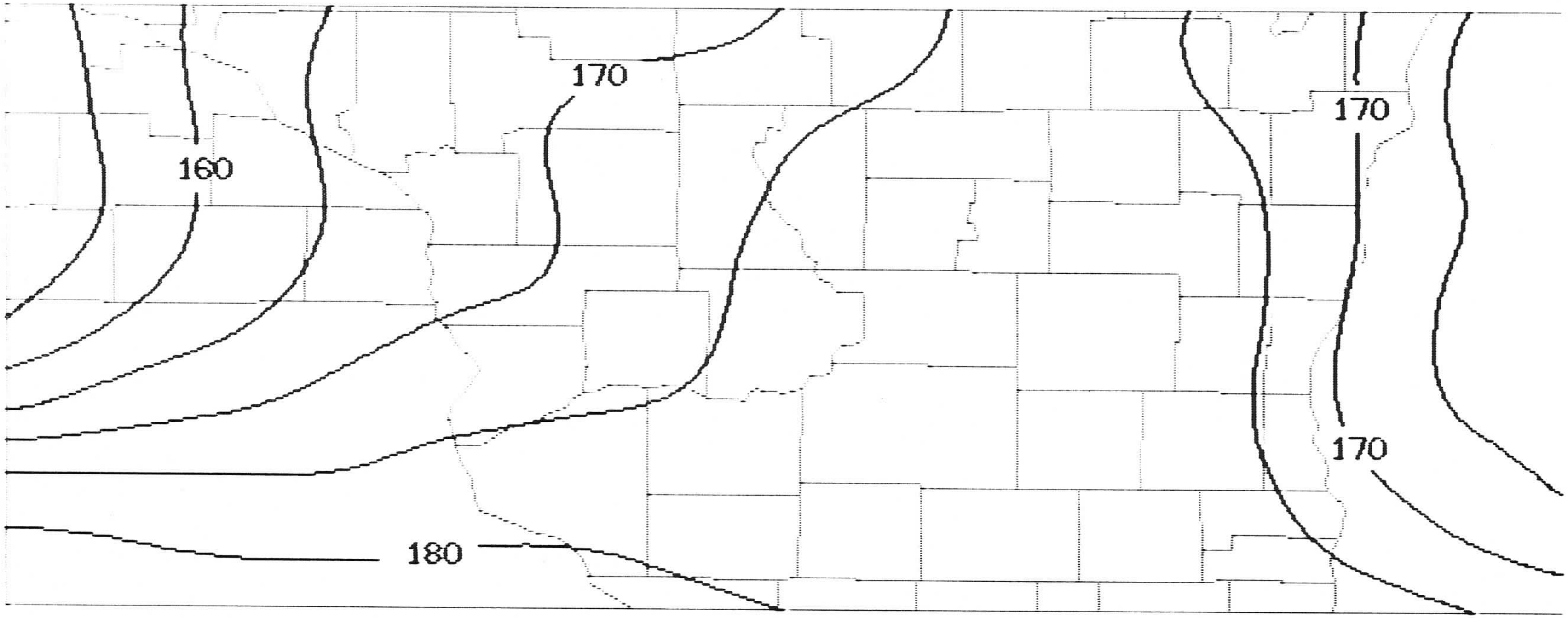


FIG 30B

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
WINTER SEASON

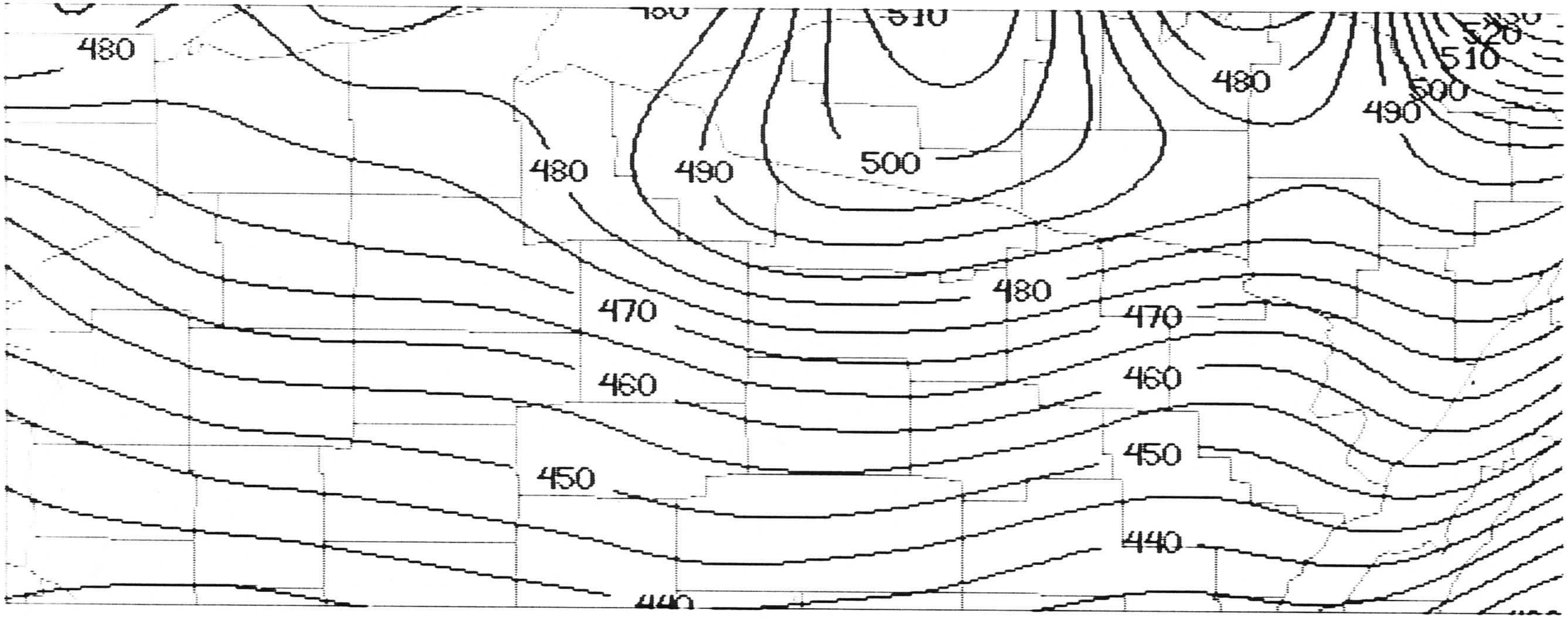


FIG 31A

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
SPRING SEASON

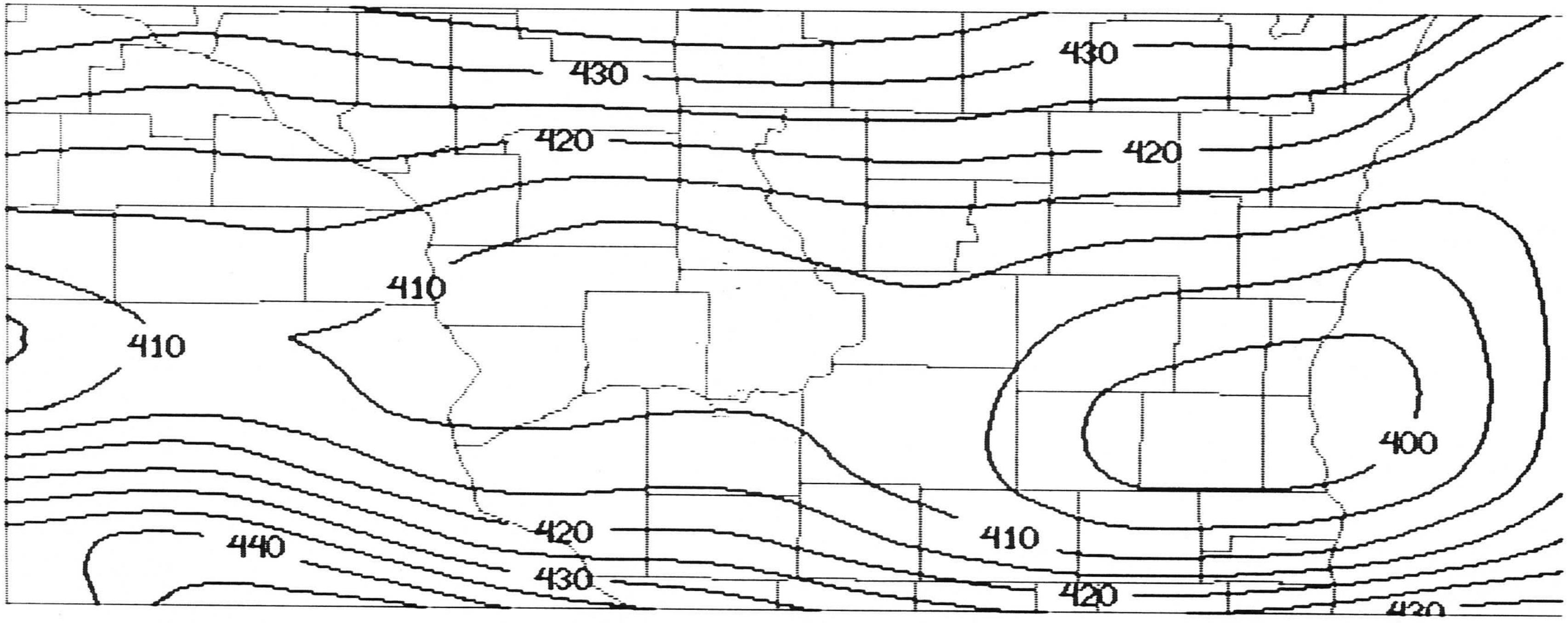


FIG 31B

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
SPRING SEASON

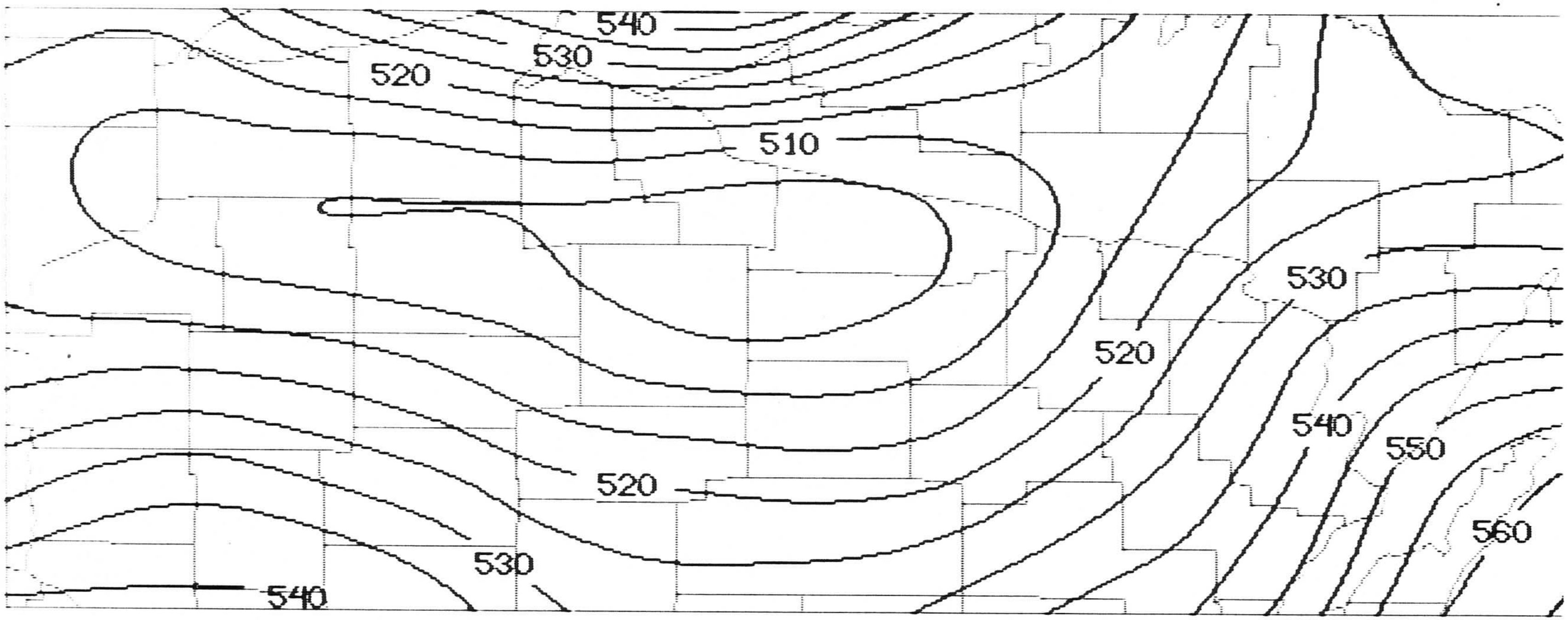


FIG 32A

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
SUMMER SEASON

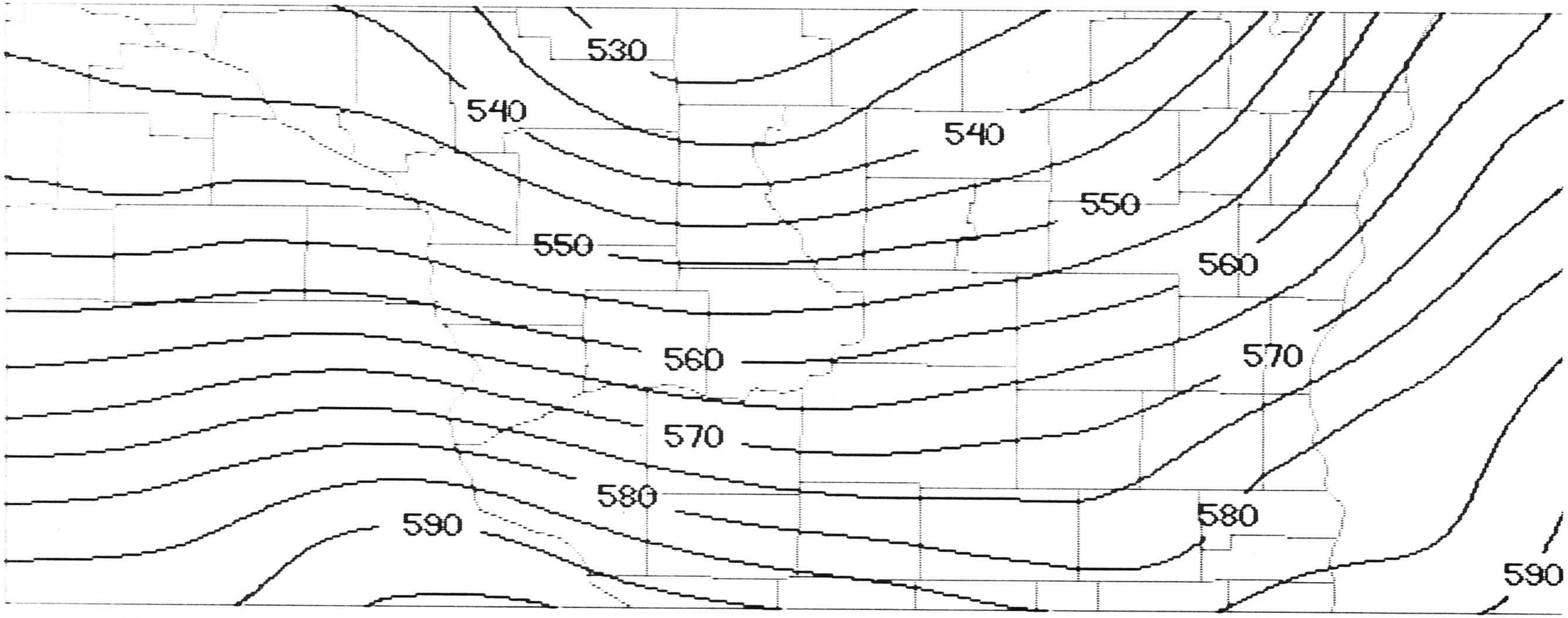


FIG 32B

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
SUMMER SEASON

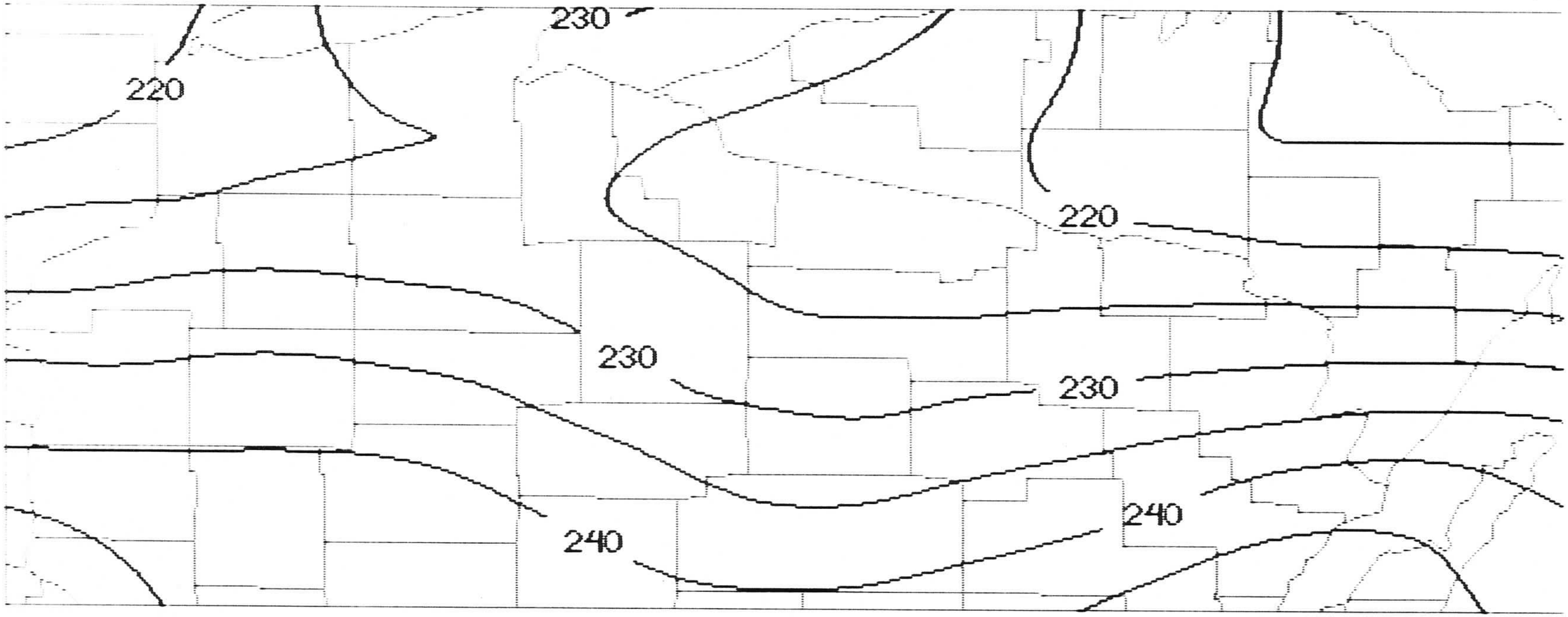


FIG 33A

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
FALL SEASON

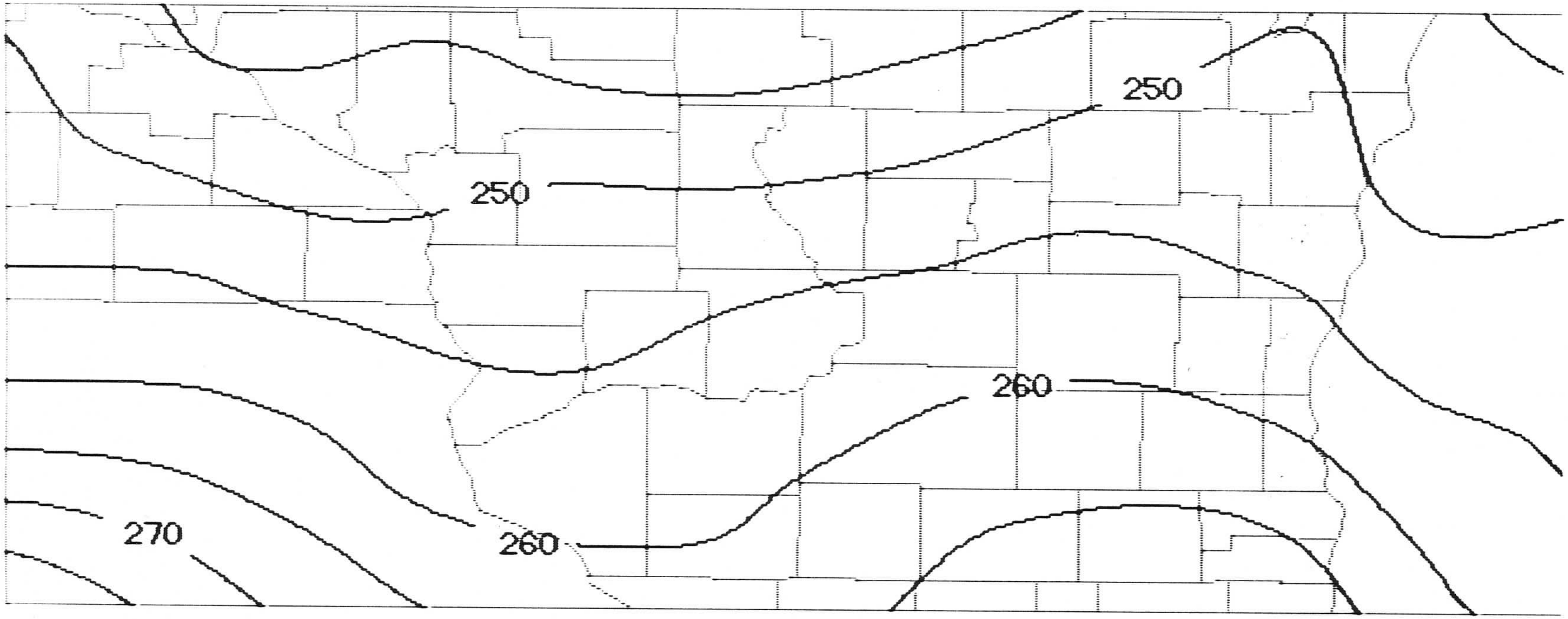


FIG 33B

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
FALL SEASON

Ж McIDAS

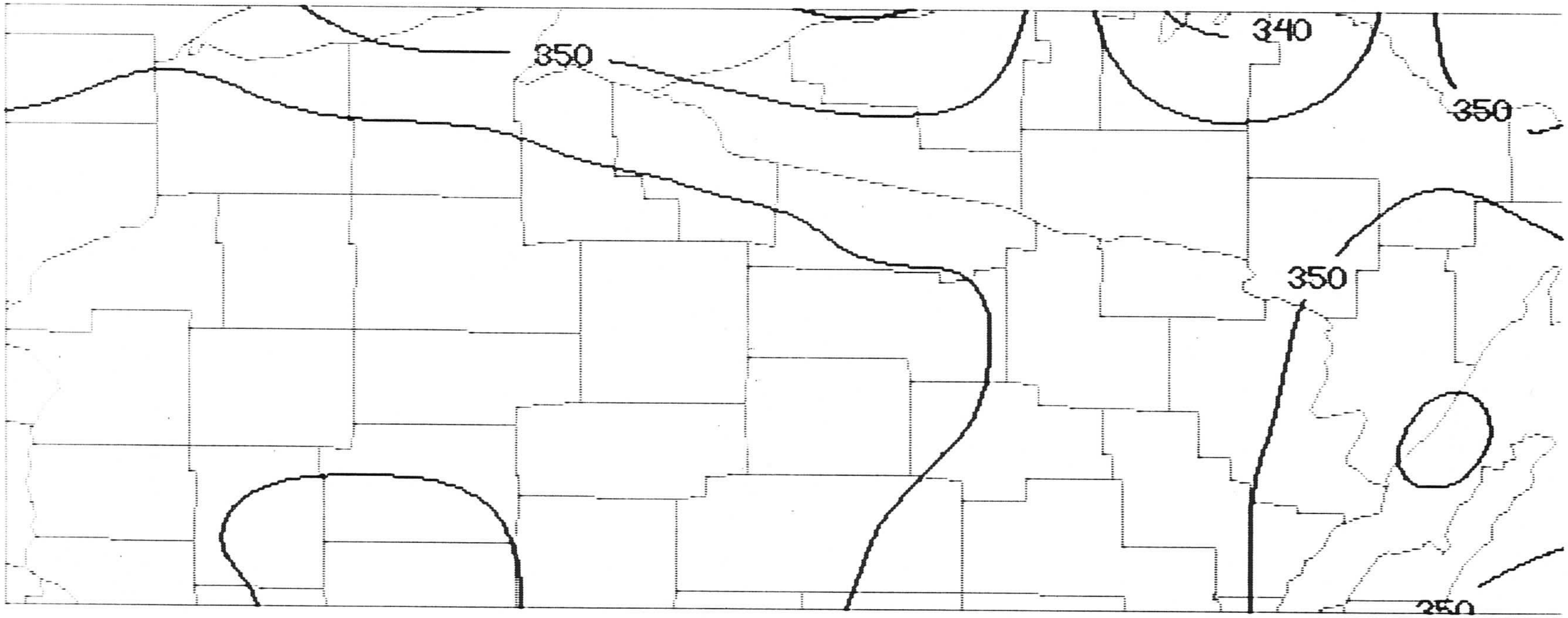


FIG 34A

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
FEBRAURY 1984-JANUARY 1985

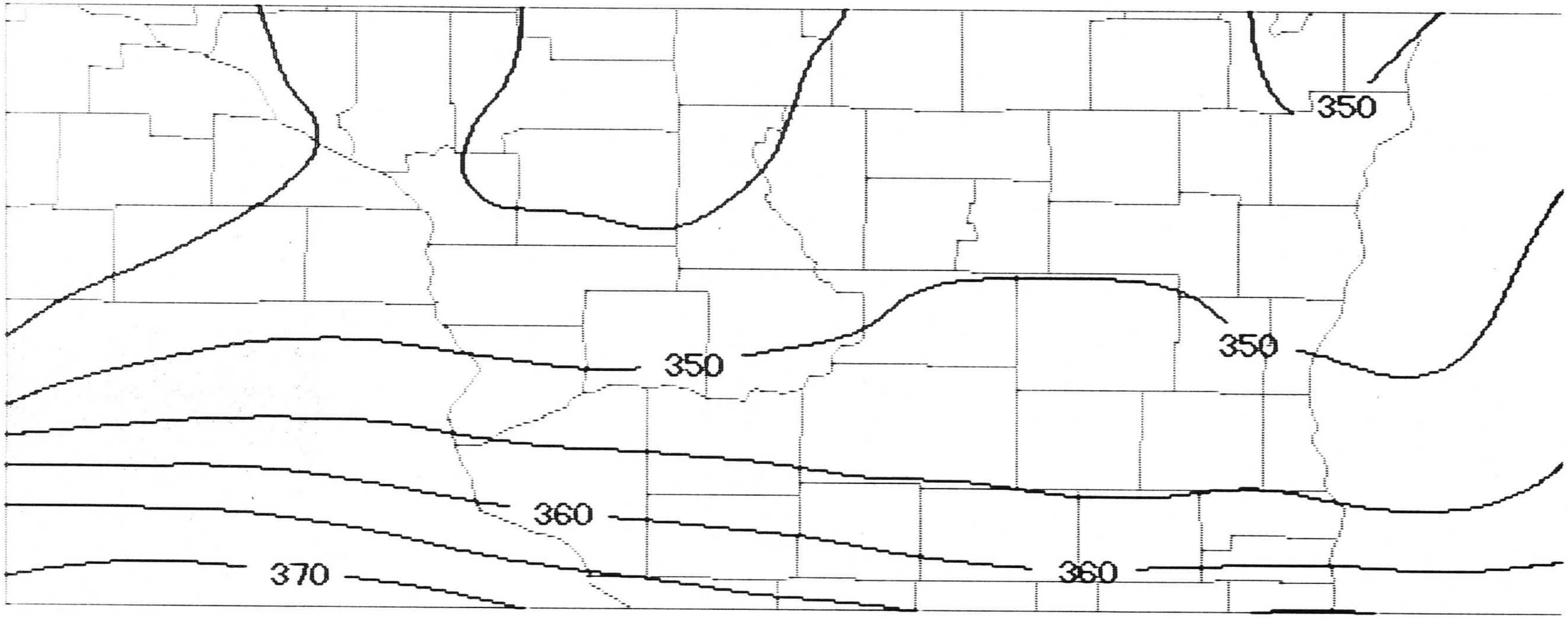


FIG 34B

AVERAGE DAILY SOLAR
(KW-HRS/SQ METERS)*100
FEBRUARY 1984-JANUARY 1985

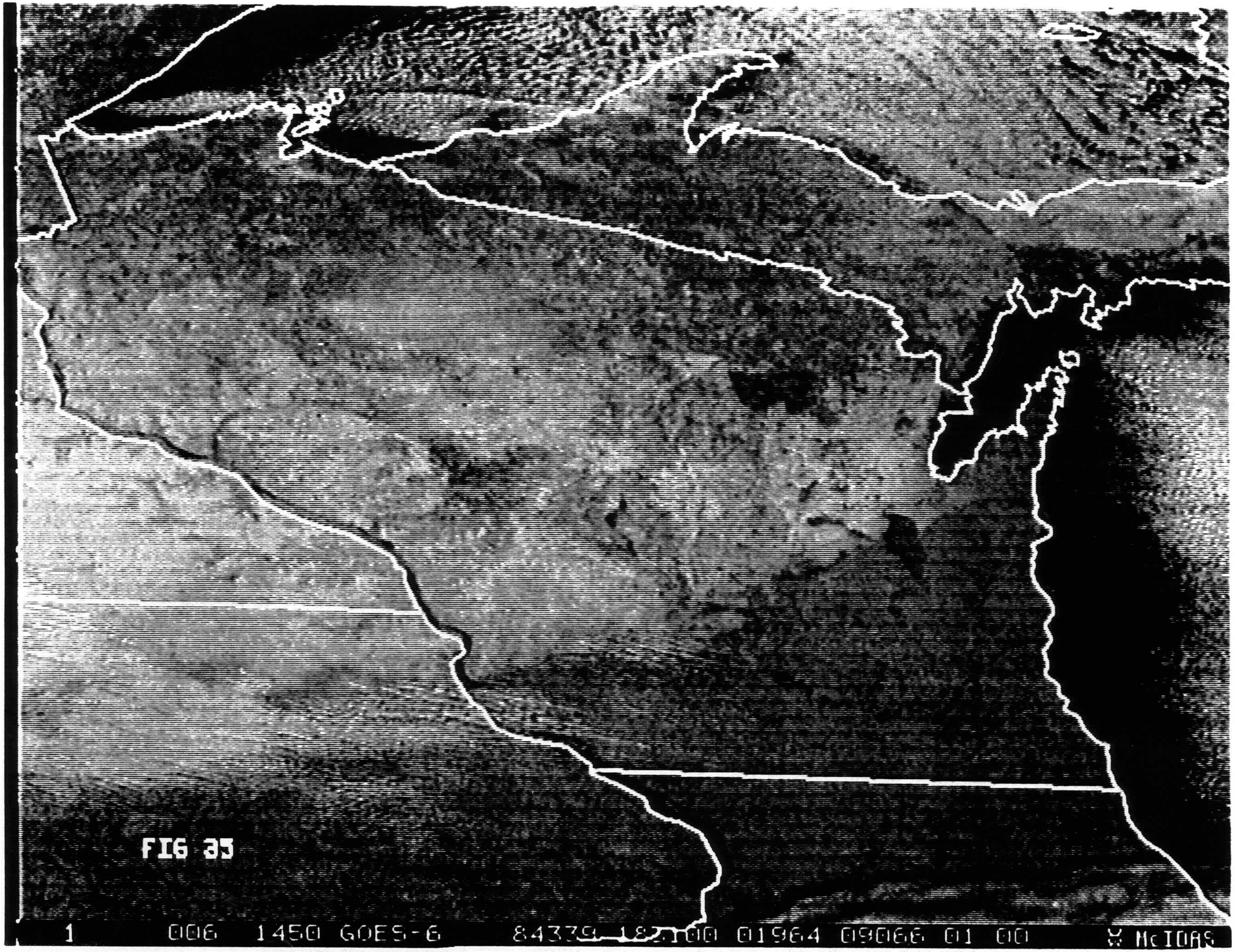


FIG 35

1 006 1450 GOES-6 84339 18[illegible]100 01964 09066 01 00 McIDAS

TABLE 1A

Location	February 1984		March 1984		April 1984		May 1984		June 1984		July 1984	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Madison	240	108	342	168	378	219	502	209	582	182	590	161
Milwaukee	229	104	331	166	372	206	495	222	604	189	621	151
La Crosse	230	111	366	157	386	189	489	203	573	185	565	169
Green Bay	244	93	366	145	414	176	502	199	575	183	567	177
Eau Claire	227	107	385	141	419	162	523	178	536	205	569	200
Sheboygan	236	99	349	151	394	188	492	199	594	196	580	172
Portage	245	102	350	165	389	209	493	196	569	197	579	157
Beaver Dam	249	86	345	166	374	201	484	210	583	211	590	163
Wautoma	244	111	370	143	405	181	493	198	553	203	565	165
Fond du Lac	252	83	354	161	394	197	492	213	581	211	572	166
Lake Geneva	247	101	338	174	392	210	494	226	594	178	618	159
Mineral Point	241	107	342	175	386	210	515	199	594	170	596	158
Monroe	245	105	335	183	402	218	515	210	596	166	604	172
Tomah	234	108	361	158	384	196	488	193	562	189	562	171
Cassville	231	107	357	164	383	192	484	201	577	185	569	168
Wausau	232	112	396	134	438	158	506	182	531	210	555	203
Wis. Rapids	241	113	382	136	415	167	496	194	549	211	563	183
Superior	220	109	400	111	518	144	510	206	492	203	575	191
Soldiers Grove	232	109	354	165	379	196	489	208	588	184	576	169
Janesville	246	108	335	182	398	217	508	221	592	162	607	165

Units are (KW-Hr/Sq. Meter) * 100

TABLE 1B

	August 1984		September 1984		October 1984		November 1984		December 1984		January 1985	
Location	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Madison	525	127	403	150	211	130	166	95	101	68	189	57
Milwaukee	521	101	406	144	214	137	167	88	99	68	190	68
La Crosse	509	110	401	147	194	119	155	93	79	48	197	60
Green Bay	503	88	383	151	203	125	168	85	90	59	187	54
Eau Claire	496	104	386	152	193	116	149	87	78	40	192	56
Sheboygan	508	92	387	152	203	125	168	85	96	62	186	57
Portage	512	111	401	139	201	128	164	93	96	63	196	55
Beaver Dam	523	107	400	149	204	129	170	90	99	66	186	52
Wautoma	498	99	395	141	191	122	161	89	88	52	199	56
Fond du Lac	506	100	392	151	202	123	168	86	95	61	186	53
Lake Geneva	525	129	411	142	218	132	172	89	104	72	183	52
Mineral Point	534	115	403	154	209	132	166	96	98	70	193	63
Monroe	542	127	405	156	215	132	171	95	104	70	184	59
Tomah	503	118	402	136	193	121	158	90	83	47	199	63
Cassville	513	116	405	143	196	118	156	91	79	47	198	57
Wausau	486	106	378	147	186	125	147	73	83	49	197	55
Wis. Rapids	493	101	390	148	189	121	158	85	85	47	200	56
Superior	473	118	346	153	180	107	137	74	105	50	183	59
Soldiers Grove	520	121	406	148	199	123	157	94	84	52	199	60
Janesville	539	134	408	154	218	133	171	94	105	72	179	65

Units are (KW-Hr/Sq. Meter) * 100

TABLE 2

	Winter	Spring	Summer	Fall	Annual
Madison	177	407	566	260	352
Milwaukee	172	399	582	262	354
La Crosse	169	414	549	250	345
Green Bay	174	427	548	251	350
Eau Claire	166	442	534	243	346
Sheboygan	173	412	561	253	350
Portage	179	411	553	255	350
Beaver Dam	178	401	565	258	350
Wautoma	177	423	539	249	347
Fond du Lac	178	413	553	254	350
Lake Geneva	178	408	579	267	358
Mineral Point	177	414	575	259	356
Monroe	178	417	581	264	360
Tomah	172	411	542	251	344
Cassville	169	408	553	252	346
Wausau	171	447	524	237	345
Wisconsin Rapids	175	431	535	246	347
Superior	169	476	513	221	345
Soldiers Grove	172	407	561	254	348
Janesville	177	412	579	266	358

TABLE 3
FEBRUARY 1984

Location	10:00 AM Mean	11:00 AM Mean	12 NOON Mean	1:00 PM Mean	2:00 PM Mean	3:00 PM Mean
Madison	25	33	39	39	33	27
Milwaukee	22	32	37	38	30	22
La Crosse	26	32	37	33	32	26
Green Bay	28	35	40	37	32	22
Eau Claire	25	29	34	33	33	27
Sheboygan	26	35	39	37	29	20
Portage	28	36	38	37	32	27
Beaver Dam	26	34	42	40	33	24
Wautoma	27	35	39	37	31	24
Fond du Lac	25	35	42	40	33	26
Lake Geneva	25	35	40	40	32	25
Mineral Point	25	33	38	38	33	29
Monroe	26	35	37	38	32	27
Tomah	25	33	37	36	31	25
Cassville	25	32	36	36	30	24
Wausau	26	31	37	36	31	22
Wisconsin Rapids	26	34	39	38	32	23
Superior	22	28	32	33	30	25
Soldiers Grove	24	33	37	35	30	24
Janesville	25	37	40	37	33	25

Units are (KW-Hr/Sq. Meter) * 100

TABLE 4
MARCH 1984

	10:00 AM	11:00 AM	12 NOON	1:00 PM	2:00 PM	3:00 PM
Location	Mean	Mean	Mean	Mean	Mean	Mean
Madison	43	57	60	56	52	43
Milwaukee	43	48	51	47	49	41
La Crosse	44	55	58	57	51	44
Green Bay	45	56	59	54	54	43
Eau Claire	44	53	60	58	55	47
Sheboygan	45	53	56	51	50	42
Portage	45	55	58	53	51	42
Beaver Dam	44	54	59	53	53	43
Wautoma	45	56	60	54	52	42
Fond du Lac	45	56	58	54	51	43
Lake Geneva	44	53	56	54	53	43
Mineral Point	45	54	60	55	51	43
Monroe	44	53	59	56	51	44
Tomah	44	54	57	55	52	43
Cassville	42	52	57	56	51	44
Wausau	45	59	62	59	56	46
Wisconsin Rapids	46	57	63	57	56	46
Superior	44	51	53	61	58	51
Soldiers Grove	43	52	59	56	51	45
Janesville	44	55	59	56	51	44

Units are (KW-Hr/Sq. Meter) * 100

TABLE 5
APRIL 1984

Location	10:00 AM Mean	11:00 AM Mean	12 NOON Mean	1:00 PM Mean	2:00 PM Mean	3:00 PM Mean
Madison	46	53	50	47	44	41
Milwaukee	47	52	50	47	50	42
La Crosse	48	56	57	52	54	40
Green Bay	48	52	55	57	53	41
Eau Claire	46	53	59	57	58	45
Sheboygan	44	52	54	54	48	39
Portage	49	54	53	47	46	39
Beaver Dam	47	51	53	48	45	38
Wautoma	49	57	58	53	49	43
Fond du Lac	49	55	53	50	49	41
Lake Geneva	47	53	48	49	47	41
Mineral Point	49	51	53	48	49	41
Monroe	44	51	52	49	47	38
Tomah	48	56	56	51	49	40
Cassville	48	54	55	54	53	40
Wausau	53	60	61	57	54	45
Wisconsin Rapids	50	57	58	54	52	45
Superior	60	64	69	63	66	55
Soldiers Grove	48	53	53	53	53	40
Janesville	45	51	51	48	46	41

Units are (KW-Hr/Sq. Meter) * 100

TABLE 6
MAY 1984

Location	9:00 AM Mean	10:00 AM Mean	11:00 AM Mean	12 NOON Mean	1:00 PM Mean	2:00 PM Mean	3:00 PM Mean	4:00 PM Mean
Madison	44	58	61	64	64	59	51	39
Milwaukee	41	56	60	62	61	53	46	39
La Crosse	43	51	57	63	56	57	50	41
Green Bay	43	55	60	63	64	57	51	38
Eau Claire	45	54	60	67	65	64	53	44
Sheboygan	43	56	55	63	65	58	54	37
Portage	42	53	60	65	67	57	50	38
Beaver Dam	38	55	57	58	63	55	50	38
Wautoma	44	53	56	61	61	56	52	38
Fond du Lac	41	52	56	65	68	60	51	39
Lake Geneva	40	57	60	63	59	52	48	41
Mineral Point	43	57	62	65	64	61	53	39
Monroe	45	59	62	62	62	60	53	41
Tomah	44	54	58	59	57	53	49	38
Cassville	45	55	57	58	53	57	49	39
Wausau	45	55	60	65	61	56	49	41
Wisconsin Rapids	45	55	59	58	60	55	50	38
Superior	42	49	58	61	63	60	49	39
Soldiers Grove	45	54	58	58	55	58	53	39
Janesville	42	58	61	60	58	56	51	40

Units are (KW-Hr/Sq. Meter) * 100

TABLE 7
JUNE 1984

Location	9:00 AM Mean	10:00 AM Mean	11:00 AM Mean	12 NOON Mean	1:00 PM Mean	2:00 PM Mean	3:00 PM Mean	4:00 PM Mean
Madison	47	56	65	74	72	71	69	50
Milwaukee	50	61	70	73	80	69	65	50
La Crosse	47	59	63	75	76	73	64	48
Green Bay	52	56	61	72	78	65	62	47
Eau Claire	44	53	62	69	72	70	61	48
Sheboygan	53	59	64	71	76	68	66	49
Portage	49	55	64	72	75	74	67	47
Beaver Dam	49	53	61	71	75	66	65	51
Wautoma	47	53	65	70	72	68	61	48
Fond du Lac	50	57	65	72	76	71	69	49
Lake Geneva	52	56	67	71	73	63	63	47
Mineral Point	48	60	65	74	72	72	66	50
Monroe	50	58	68	74	73	67	66	51
Tomah	48	58	65	72	77	71	61	49
Cassville	46	58	63	71	73	69	64	50
Wausau	45	53	61	70	73	64	62	48
Wisconsin Rapids	46	54	63	71	75	66	61	49
Superior	43	49	59	66	67	58	54	40
Soldiers Grove	48	56	64	73	79	71	64	53
Janesville	50	61	69	68	76	65	65	51

Units are (KW-Hr/Sq. Meter) * 100

TABLE 8
JULY 1984

Location	9:00 AM Mean	10:00 AM Mean	11:00 AM Mean	12 NOON Mean	1:00 PM Mean	2:00 PM Mean	3:00 PM Mean	4:00 PM Mean
Madison	48	62	71	79	79	73	55	45
Milwaukee	54	67	78	83	83	73	62	53
La Crosse	42	58	70	74	74	72	60	51
Green Bay	50	64	72	75	75	63	52	47
Eau Claire	48	56	67	75	74	71	63	52
Sheboygan	52	62	73	75	75	67	56	49
Portage	50	62	71	74	77	66	61	50
Beaver Dam	51	66	77	76	76	67	58	49
Wautoma	47	63	73	75	73	64	56	50
Fond du Lac	49	64	71	72	77	64	57	50
Lake Geneva	51	64	76	84	81	71	62	52
Mineral Point	49	60	71	80	80	73	57	50
Monroe	52	62	75	81	80	69	58	47
Tomah	46	60	70	78	73	73	60	54
Cassville	44	59	73	77	76	73	60	53
Wausau	48	60	73	75	71	59	53	50
Wisconsin Rapids	48	62	73	77	72	62	54	51
Superior	48	57	68	71	72	65	61	50
Soldiers Grove	45	60	71	76	77	73	56	53
Janesville	50	62	74	81	79	71	62	50

Units are (KW-Hr/Sq. Meter) * 100

TABLE 9
AUGUST 1984

Location	9:00 AM Mean	10:00 AM Mean	11:00 AM Mean	12 NOON Mean	1:00 PM Mean	2:00 PM Mean	3:00 PM Mean	4:00 PM Mean
Madison	42	57	65	70	71	60	49	39
Milwaukee	47	60	68	68	69	64	53	40
La Crosse	32	48	59	56	69	63	52	40
Green Bay	40	55	65	65	68	60	47	37
Eau Claire	30	47	59	60	64	60	51	43
Sheboygan	44	58	65	62	67	61	48	36
Portage	39	53	63	65	69	60	48	39
Beaver Dam	45	60	65	67	70	62	50	39
Wautoma	38	52	62	54	70	61	46	38
Fond du Lac	42	55	62	66	69	62	49	35
Lake Geneva	45	61	67	64	69	61	49	38
Mineral Point	42	61	66	65	70	62	54	41
Monroe	44	62	67	74	71	62	55	42
Tomah	36	51	60	54	70	61	52	40
Cassville	37	51	59	59	70	62	51	42
Wausau	32	48	56	48	66	59	45	35
Wisconsin Rapids	36	51	60	50	68	61	46	38
Superior	36	49	54	55	62	59	46	37
Soldiers Grove	39	54	61	55	71	62	53	42
Janesville	45	60	68	73	70	63	52	41

Units are (KW-Hr/Sq. Meter) * 100

TABLE 10
SEPTEMBER 1984

Location	9:00 AM Mean	10:00 AM Mean	11:00 AM Mean	12 NOON Mean	1:00 PM Mean	2:00 PM Mean	3:00 PM Mean	4:00 PM Mean
Madison	30	43	53	57	59	49	41	31
Milwaukee	34	45	55	58	59	51	45	32
La Crosse	30	42	51	62	57	52	44	32
Green Bay	32	44	49	56	55	47	41	33
Eau Claire	28	40	51	61	54	48	41	35
Sheboygan	31	44	51	55	51	48	42	32
Portage	31	43	52	59	55	50	44	33
Beaver Dam	32	41	52	58	55	50	42	34
Wautoma	30	43	51	57	56	51	44	31
Fond du Lac	31	43	52	55	55	51	45	32
Lake Geneva	33	44	55	59	57	50	44	32
Mineral Point	31	42	54	59	57	49	43	34
Monroe	31	41	53	61	57	50	43	33
Tomah	31	43	51	60	59	52	45	34
Cassville	32	43	53	62	59	52	44	34
Wausau	30	42	49	54	52	44	39	30
Wisconsin Rapids	30	43	52	56	53	50	42	31
Superior	27	38	49	50	46	41	33	29
Soldiers Grove	31	43	53	60	58	52	43	34
Janesville	32	40	55	61	56	51	43	32

Units are (KW-Hr/Sq. Meter) * 100

TABLE 11
OCTOBER 1984

Location	9:00 AM Mean	10:00 AM Mean	11:00 AM Mean	12 NOON Mean	1:00 PM Mean	2:00 PM Mean	3:00 PM Mean	4:00 PM Mean
Madison	18	26	31	39	35	31	23	16
Milwaukee	20	27	30	39	38	35	24	16
La Crosse	16	24	28	35	33	28	22	14
Green Bay	18	27	29	37	34	29	23	15
Eau Claire	16	23	27	33	33	30	23	15
Sheboygan	19	27	30	35	33	30	23	15
Portage	17	24	28	35	34	30	22	15
Beaver Dam	19	26	30	36	31	30	23	14
Wautoma	17	24	28	35	32	28	21	14
Fond du Lac	19	26	28	38	34	30	23	15
Lake Geneva	19	26	30	40	36	33	23	16
Mineral Point	18	26	30	38	34	29	24	17
Monroe	19	29	32	39	35	32	23	16
Tomah	16	23	28	34	32	27	21	14
Cassville	17	24	29	35	33	27	22	16
Wausau	16	25	27	32	30	26	20	14
Wisconsin Rapids	17	25	29	35	32	27	21	14
Superior	14	21	25	30	30	27	21	13
Soldiers Grove	17	24	29	36	32	29	23	16
Janesville	19	27	33	40	35	32	23	16

Units are (KW-Hr/Sq. Meter) * 100

TABLE 12
NOVEMBER 1984

Location	10:00 AM Mean	11:00 AM Mean	12 NOON Mean	1:00 PM Mean	2:00 PM Mean	3:00 PM Mean
Madison	21	26	28	29	23	17
Milwaukee	23	27	29	30	25	17
La Crosse	19	24	27	27	22	16
Green Bay	21	27	30	30	25	15
Eau Claire	18	23	25	25	21	15
Sheboygan	22	28	30	30	24	16
Portage	21	26	28	28	24	17
Beaver Dam	23	28	29	29	24	16
Wautoma	21	26	28	29	24	16
Fond du Lac	22	28	29	29	24	15
Lake Geneva	21	29	30	30	25	17
Mineral Point	21	27	29	30	26	19
Monroe	22	28	30	30	25	18
Tomah	19	25	27	29	23	16
Cassville	19	24	26	27	23	16
Wausau	17	23	24	25	21	15
Wisconsin Rapids	20	25	28	28	23	15
Superior	15	22	25	27	22	16
Soldiers Grove	18	23	27	28	25	18
Janesville	22	28	30	30	25	18

Units are (KW-Hr/Sq. Meter) * 100

TABLE 13
DECEMBER 1984

Location	10:00 AM Mean	11:00 AM Mean	12 NOON Mean	1:00 PM Mean	2:00 PM Mean	3:00 PM Mean
Madison	14	19	21	19	16	11
Milwaukee	14	18	22	19	17	12
La Crosse	10	15	18	15	14	9
Green Bay	13	17	20	18	15	9
Eau Claire	11	15	16	14	13	9
Sheboygan	13	19	21	18	16	11
Portage	13	19	20	19	16	11
Beaver Dam	14	20	20	19	16	11
Wautoma	11	16	18	17	14	9
Fond du Lac	13	18	21	18	16	10
Lake Geneva	14	19	23	20	17	12
Mineral Point	13	18	20	19	16	11
Monroe	14	19	21	19	17	11
Tomah	11	14	17	16	14	9
Cassville	10	14	17	15	14	9
Wausau	10	17	19	17	14	10
Wisconsin Rapids	11	16	19	16	13	9
Superior	12	20	23	20	18	12
Soldiers Grove	11	15	18	16	14	10
Janesville	14	19	22	19	17	12

Units are (KW-Hr/Sq. Meter) * 100

TABLE 14
JANUARY 1985

Location	10:00 AM Mean	11:00 AM Mean	12 NOON Mean	1:00 PM Mean	2:00 PM Mean	3:00 PM Mean
Madison	20	31	35	36	31	23
Milwaukee	20	32	36	38	30	21
La Crosse	20	30	35	38	31	23
Green Bay	19	29	33	35	28	21
Eau Claire	20	31	35	38	30	23
Sheboygan	19	30	34	37	27	20
Portage	21	33	38	38	32	23
Beaver Dam	19	30	33	35	27	20
Wautoma	21	32	37	39	32	23
Fond du Lac	19	28	32	34	27	20
Lake Geneva	19	29	32	34	28	21
Mineral Point	20	29	33	35	29	23
Monroe	20	32	32	35	30	23
Tomah	20	30	35	37	30	23
Cassville	20	29	34	38	30	22
Wausau	21	33	37	37	30	23
Wisconsin Rapids	20	32	36	38	31	22
Superior	19	31	33	37	29	22
Soldiers Grove	20	31	35	38	31	24
Janesville	20	30	32	36	29	22

Units are (KW-Hr/Sq. Meter) * 100