

AD-A260 032

2



PL-TR-92-2289

**EFFECTS OF CLOUD COVER ON SATELLITE
POSITIONING**

**Gary E. Gray
James H. Willand
Albert R. Boehm**

DTIC
ELECTE
DEC 11 1992
S c D

**Hughes STX Corporation
109 Massachusetts Avenue
Lexington, MA 02173**

9 November 1992

Scientific Report No. 3

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED



**PHILLIPS LABORATORY
Directorate of Geophysics
AIR FORCE MATERIEL COMMAND
HANSCOM AIR FORCE BASE, MA 01731-5000**

92-31258



92 12 10 016

"This technical report has been reviewed and is approved for publication"



DONALD D. GRANTHAM
Contract Manager
Chief, Atmospheric Structure Branch
Atmospheric Sciences Division



ROBERT A. McCLATCHEY, Director
Atmospheric Sciences Division

This report has been reviewed by the ESC Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS).

Qualified requestors may obtain additional copies from the Defense Technical Information Center. All others should apply to the National Technical Information Service.

If your address has changed, or if you wish to be removed from the mailing list, or if the addressee is no longer employed by your organization, please notify PL/tsi, Hanscom AFB, MA 01731-5000. This will assist us in maintaining a current mailing list.

Do not return copies of this report unless contractual obligations or notices on a specific document requires that it be returned.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE 9 November 1992	3. REPORT TYPE AND DATES COVERED Scientific Report No. 3	
4. TITLE AND SUBTITLE EFFECTS OF CLOUD COVER ON SATELLITE POSITIONING			5. FUNDING NUMBERS F19628-88-C-0089 PE 62101F PR 6670 TA 09 WU AP	
6. AUTHOR(S) Gary E. Gray, James H. Willand, and Albert R. Boehm				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Hughes STX Corporation 109 Massachusetts Avenue Lexington, MA 02173			8. PERFORMING ORGANIZATION REPORT NUMBER STX Scientific Report No. 3	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Phillips Laboratory Hanscom AFB, MA 01731-5000 Contract Manager: Don Grantham/GPAA			10. SPONSORING / MONITORING AGENCY REPORT NUMBER PL-TR-92-2289	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) This report specifies how cloud cover would affect the Landsat-7 satellite at two different equatorial crossing times, 0945 or 1030 Mean Apparent Sun Time (MAST). Changes in the frequency of cloud cover observed in the two orbits are shown in maps and graphs.				
14. SUBJECT TERMS Clouds, Climatology, Landsat-7, Coverage			15. NUMBER OF PAGES 36	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT Unlimited Distribution	

CONTENTS

1. PURPOSE	1
2. DATA	1
2a. DOE/NCAR Data	1
2b. Burger Data	2
2c. NIMBUS-7 Data	2
2d. Data Merging	3
3. DERIVED STATISTICS	3
3a. Mean Maps	3
3b. Fractional Cloud Cover Frequency Maps	4
3c. Graphs	5
4. RESULTS AND ANALYSIS	5
5. ERROR ANALYSIS	6
6. ACKNOWLEDGEMENT	7
7. REFERENCES	7

DTIC QUALITY INSPECTED 4

Accession For	
NTIS GR&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Avail and/or	
Dist	Special
A-1	

EFFECTS OF CLOUD COVER ON SATELLITE POSITIONING

Gary E. Gray, James H. Willand and Albert R. Boehm

1. PURPOSE

The purpose of this report is to specify how cloud cover would affect the Landsat-7 satellite at two different equatorial crossing times, 0945 and 1030 Mean Apparent Sun Time (MAST). This 45 minute difference affects the climatic frequency of cloud cover. Changes in the frequency of cloud cover as observed in the two orbits are detailed in this report.

2. DATA

The data used for this analysis come from three sources DOE/NCAR data, Burger data, and NIMBUS-7 CMatrix data.

2a. DOE/NCAR Data

The "Climatological Data For Clouds Over The Globe From Surface Observations" (Hahn, 1987) contains digital global maps of long-term monthly and/or seasonal total cloud cover, cloud type amounts and frequencies of occurrence, low cloud base heights, harmonic analyses of annual and diurnal trends, and frequencies of cloud type occurrences. Most of the data are mapped on grids. Each grid box represents a 5-degree latitude by 5-degree longitude resolution equatorward of 50 degrees latitude. The boxes increase in longitude dimension poleward of 50 degrees latitude creating nearly equal area boxes. According to Hahn (1987), data from all available stations within a grid box were used to compute the average for that box. The data are archived so that the land observed cloud data are stored separately from the ocean observed data. The period of record for land observations is the 11 years from January 1971

through December 1981. The period of record for ship observations is the 54 years from January 1930 through November 1983. The seasonal sky cover data archived at eight times of day (GMT) were the portion of data used.

2b. Burger Data

The Burger data (Burger, 1985) is a climatology of ground-observed sky cover observations recorded over single-point locations for over 2,000 weather reporting stations around the globe. The data are archived for the four mid-season months of January, April, July, and October where 3 hourly averages of sky cover are centered at the four local standard times of 01, 07, 13, and 19 LST. Sky cover data over land areas were extracted over a 28 year period of record from 1945 through 1973.

The Burger data were originally compiled from the Revised Uniform Summaries of Surface Weather Observations (RUSSWO's), Naval Intelligence Survey (NIS), and NAVATLAS records. Willand (1988) reformatted the Burger data for subsequent use in the development of an automated global climatology. the database was further refined by Willand (1991) in order to replace the parameter "scale distance" (Burger, 1984) with the more robust parameter called "mean correlation" (Boehm, 1992).

2c. NIMBUS-7 Data

According to Hwang, et al. (1988), the primary merits of the NIMBUS-7 Cmatrix Cloud data set are: 1) observed radiances used for this cloud data set were obtained from the same instruments used over six continuous years between 1979-1985, so it represents the most homogeneous satellite derived cloud data set available; 2) the cloud data set is efficiently retrieved and stored, so the analysis of global cloud distribution over climatological time scales is feasible; and 3) daily, as well as monthly averages and variances of cloud data are presented together with a correlation coefficient

surface temperature archive. Because of these merits, this cloud database was acquired and utilized for defining climatological cloud cover statistics of the earth as viewed from space.

2d. Data Merging

Data from the three sets defined above were first fitted by two parameters, the mean sky cover and the mean correlation. The mean correlation is the arithmetic average of correlation between all possible pairs of points in a domain. It is mathematically related to the standard deviation of the coverage distribution and is a function of the correlation structure.

The mean sky cover and mean correlation as well as sample size and interannual variability were analyzed on the globe by a weighted 14 wave number spectral analysis using a weighted regression matrix inversion to allow for unequally spaced data. Time of day is analyzed with a third order Fourier series.

The sky cover distribution was calculated from the coverage algorithm-CUB (Boehm, 1992) using mean sky cover and mean skydome correlation derived from surface observations which include DOE/NCAR data and Burger data. Next a mean cloud cover probability at a point was calculated using the Malick and Allen (1979) algorithm on each tenth of coverage. Finally, CUB was used to calculate fractional coverage based on the point mean correlation for a specific area size interpolated from NIMBUS-7 data and degrees of freedom set at 80 (found empirically). The mean cloud cover and the fractional coverage frequencies are used in three methods of presentation.

3. DERIVED STATISTICS

3a. Mean Maps

First, maps of mean cloud cover were produced. Cloud cover values were calculated for the specified time. A third order

Fourier analysis was used to obtain cloud cover values for times such as 0945 and 1030 MAST. Time was continually being updated based on the satellite subpoint latitude. Time adjustments for each satellite subpoint latitude are given in Table 1, which was provided by Locke Stuart, NASA Goddard Space Flight Center.

The cloud cover values were calculated at evenly spaced gridpoints. Longitudinally there are 72 gridpoints (spaced 5 degrees apart). Latitudinally there are 33 gridpoints, spaced evenly according to the sine of the latitude. Bilinear interpolation was used for contouring. Maps were created for January, April, July, and October. Also, difference maps were created for the 1030 MAST mean minus the 0945 MAST mean.

Maps of mean cloud cover are presented in figures 1 through 4. The maps are in pairs, where map a (the top map) is the mean cloud cover for the month at 1030 MAST and map b (the lower map) is the difference between the 1030 MAST and 0945 MAST mean cloud cover for the given month. There are four pairs of these maps, one for each mid season month.

3b. Fractional Cloud Cover Frequency Maps

These maps show frequency of cloud cover over the earth given a particular area size, cloud cover threshold, and time. The months and times used are the same as with the mean cloud cover. The area sizes are squares 30 km and 90 km on a side. Cloud cover thresholds are 30% or less, 20% or less, 10% or less, and 0%. Difference maps were produced also for this set of maps. The headers on these maps are abbreviated. For example: JAN-1030-90KM-30% is the frequency of cloud cover less than or equal to 30% at a 1030 MAST equatorial crossing time, during January, using a 90 km cell size.

As with the mean cloud cover maps, the frequency of fractional cloud cover maps are presented in pairs. The frequency maps are found in figures 5 through 8. Map a in each pair is the frequency of 20% or less cloud cover occurring at 1030 MAST in the given

month using a 30 kilometer grid size. Map b is the difference of the frequencies between 1030 MAST and 0945 MAST.

3c. Graphs

Graphs at selected locations are the third method of presentation. Each graph shows mean sky cover, probability of cloud cover less than or equal to 30% (for land stations), 20% (for oceanic stations), and 10% (for all locations). These graphs are similar to those in the Steeves and Boehm report (Morning Versus Afternoon EOS-A Orbit). However, these new graphs are based on a larger, more reliable set of data.

Graphs are produced in a manner similar to the maps, but consist of all times (from 0000 MAST to 2400 MAST). Another difference is the use of sky cover instead of cloud cover. Sky cover is a measure of cloudiness over the skydome observed while looking up. Cloud cover is obtained looking down, e.g. from a satellite. The different viewing perspectives cause values of the two to be different.

A list of the areas for graphs are as follows:

<u>Figure No.</u>	<u>Location</u>	<u>Latitude</u>	<u>Longitude</u>
<u>Jan.</u>	<u>Jul.</u>		
9	10	Alabama	33.31 -86.49
11	12	Sahara Desert	23.44 10.00
13	14	Amazonas	-4.15 -64.30
15	16	Indian Ocean	0.00 75.00
17	18	Atlantic Coast	-15.00 -34.00
19	20	Pacific Ocean	-15.00 -105.00
21	22	Pacific Ocean	-30.00 -135.00

- = South, - = West

4. RESULTS AND ANALYSIS

Difference maps give the clearest results. On these maps clear areas indicate less than $\pm 1\%$ difference between 0945 and 1030 MAST. Hatched areas as indicated are negative values, with less cloud cover at 1030. Other hatched styles show greater cloud cover at 1030.

The difference maps clearly show that cloud cover changes between 0945 and 1030 MAST vary from location to location. Most regions show marginal change (plus or minus one percent). There is little, if any, change greater than five percent. In several there is less cloud cover observed for the 1030 MAST equatorial crossing than the 0945 equatorial crossing. However, time of year and location affect these values.

5. ERROR ANALYSIS

The original merged cloud data base was closely quality controlled. However, cloud climatologies have several types of errors.

Sampling error is high in cloud climatologies. As a rule, the number of equivalent independent data is about one third the number of days of data. Thus, for the month of January, the Nimbus-7 data with six Januarys has only $6 \times 31 / 3 = 62$ equivalent independent samples. Surface data has a satisfactory period of record in most of the Northern Hemisphere. But in the Southern Hemisphere, especially south of latitude 60°S , surface data is sparse. Some areas have less than 10 equivalent independent samples.

In the Arctic and Antarctic surface data is sparse and satellite cloud measurements suffer from the fact that cloud and surface radiances are similar both in the visible and infrared.

The parameterization using only the mean and mean correlation yields good results. Mean square errors are about 2%.

Spatial analyses using the weighted spectral analysis technique have about a 0.95 multiple correlation coefficient. At least some of this error is due to the sampling error as opposed to spatial analysis error per se. However, local effects due to terrain, etc.

are not taken into account by this type of analysis. That is, the spatial analysis results are quite good for the average point in a small region, but a particular point may have considerable error.

The above errors refer to values at 0945 or at 1030 MAST. The statistic of interest is the difference in values between the two times. Comparison of the fractional coverage statistics show that the time difference for all the various coverages depends almost entirely on the differences in the mean. Errors in parameterization and sampling error are effectively canceled out. In statistics this effect is sometimes referred to as a paired sample statistic - if there is a similar and highly correlated bias in a pair of statistics, the difference between the statistics will be nearly unbiased.

Therefore the error in the difference is believed to be less than 2% excepting the Arctic and regions south of 60°S latitude.

6. ACKNOWLEDGMENT

This work was supported in part by the Phillips Laboratory, Geophysics Division, contract number F19628-88-C-0089, and also by NASA/GSPFC, contract number NAS5-30440.

7. REFERENCES

Boehm, A., 1992: CUB: A General Purpose Algorithm. Preprint of Fifth International Meeting On Statistical Climatology, Toronto, Canada. American Meteorological Society, Boston, MA.

Burger, C. F., 1985: World Atlas of Total Sky Cover. AFGL-TR-85-0198, Air Force Geophysics Laboratory, Hanscom Air Force Base, MA, ADA-170474.

Burger, C. F., and Gringorten, I. I., 1984: Two Dimensional Modeling for Linear and Areal Probability of Weather Conditions.

AFGL-TR-84-0126, Environmental Research Papers No. 875, Air Force Geophysics Laboratory, Hanscom AFB, MA, ADA-147970.

Grantham, D. and Boehm, A., 1986: The Effect of Viewing Aspect on Climatological Cloud Distributions. Proceedings of the Third International Conference on Statistical Climatology, Vienna, Austria, June 23-25, 1986.

Hahn C., 1987: Climatological Data for Clouds Over the Globe from Surface Observations. Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO, 80309.

Hwang, P. H. et al., 1988: An Overview of the NIMBUS-7 THIR/TOMS Cloud Data Archive. Submitted for publication to the Bulletin of the American Meteorological Society.

Malick, J., J. Allen, and Zakancyz, 1979: Calibrated Analytical Modelling of Cloud-free Intervals, Proc. Soc. of Photo-Optical Instru. Engineers (SPIE) Vol. 195, 142-147.

Steeves, J., and Boehm, A., 1991: Morning Versus Afternoon EOS-A Orbit. Preprint Volume of the Seventh Conference on Applied Climatology, September 10-13, 1991, Salt Lake City, Utah. American Meteorological Society, Boston, MA.

Warren, S., Hahn, C., London, J., Chervin, R., and Jenne, R., 1986: Global Distribution of Total Cloud Cover and Cloud Type Amounts Over Land. United States Department of Energy. National Center for Atmospheric Research. DOE/ER/60085-HI and NCAR/TN-272+STR.

Willand, J. H., and Steeves, J., 1991: Processing of Cloud Databases for the Development of an Automated Global Cloud Climatology. PL-TR-91-2163, Contract F19628-88-C-0089, ST Systems Corporation. ADA251593

Willand, J. H., 1988: Users Manual for C Cloud S Database. AFGL-TR-88-0060, Contract F19628-87-C-0046, Systems and Applied Sciences Corporation, ADA-196497.

MAP OF JAN-1030-MEAN CLOUD COVER

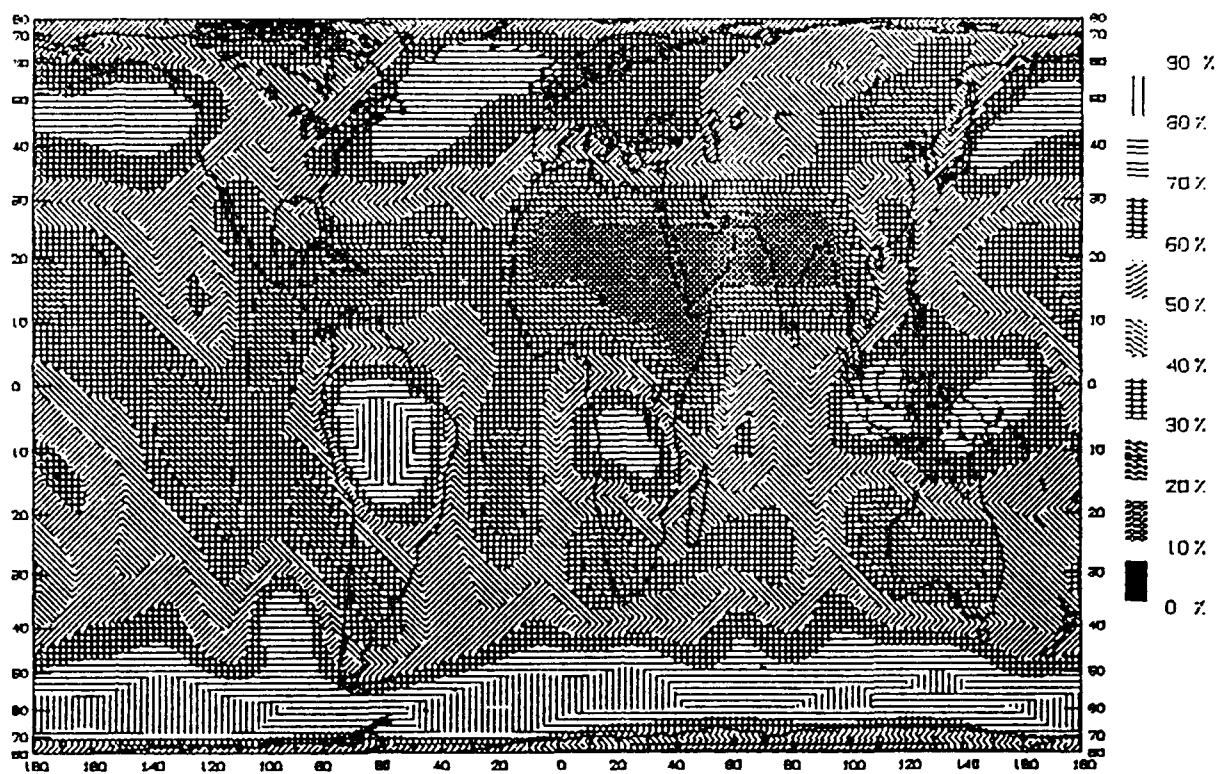


Figure 1a.

MEAN CLOUD COVER DIFFERENCE MAP : JAN-1030-MEAN MINUS JAN-945-MEAN

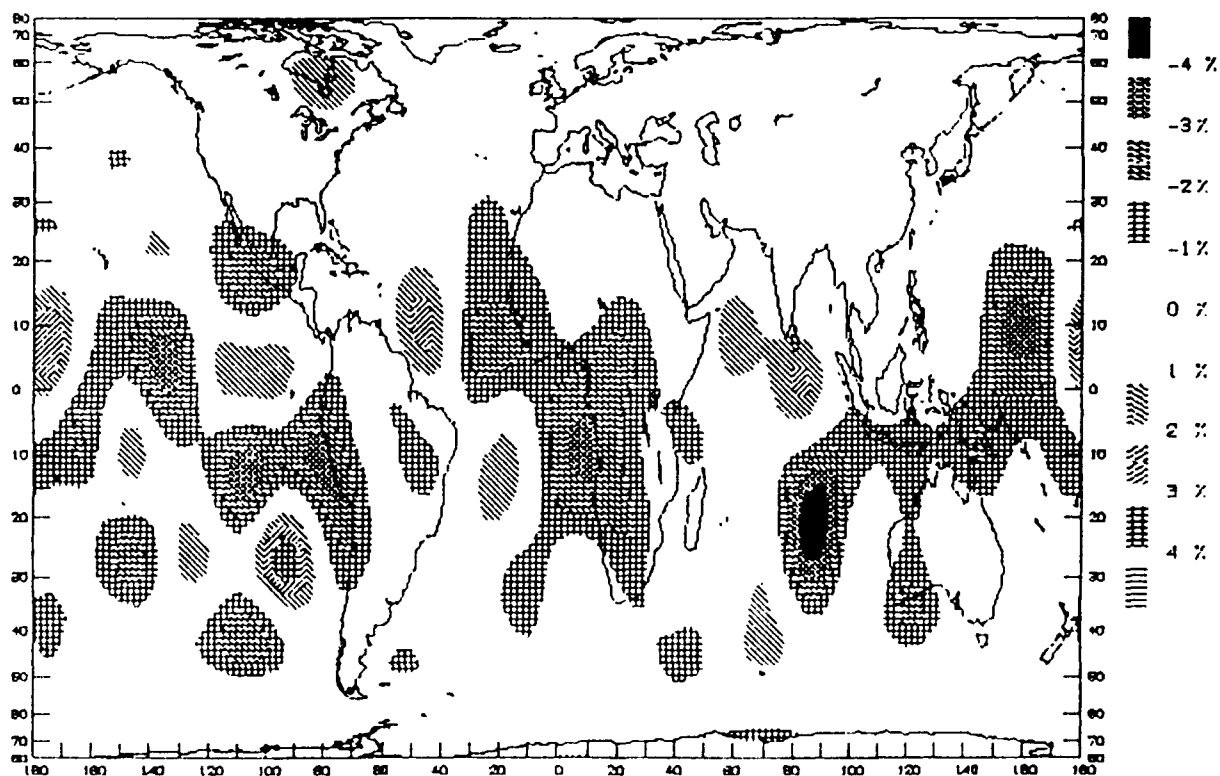


Figure 1b.

MAP OF APR-1030 MEAN CLOUD COVER

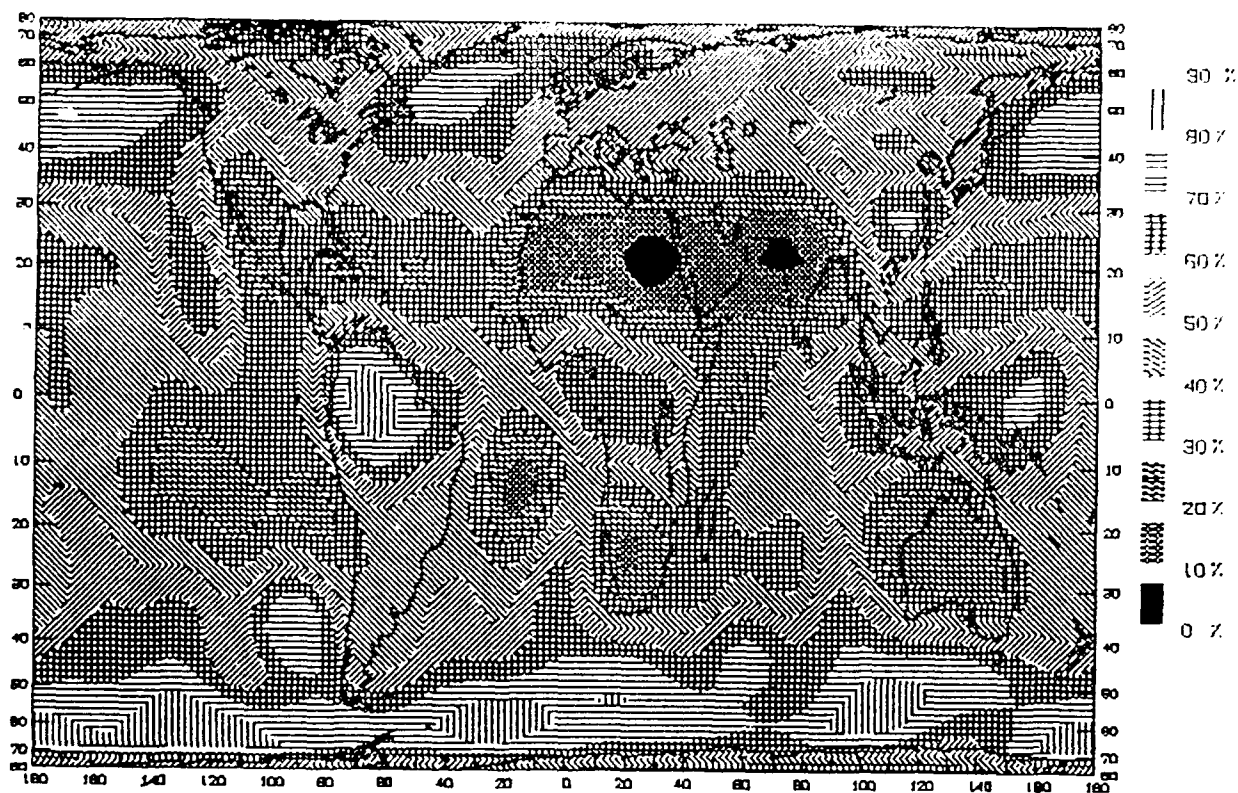


Figure 2a.

MEAN CLOUD COVER DIFFERENCE MAP : APR-1030-MEAN MINUS APR-945-MEAN

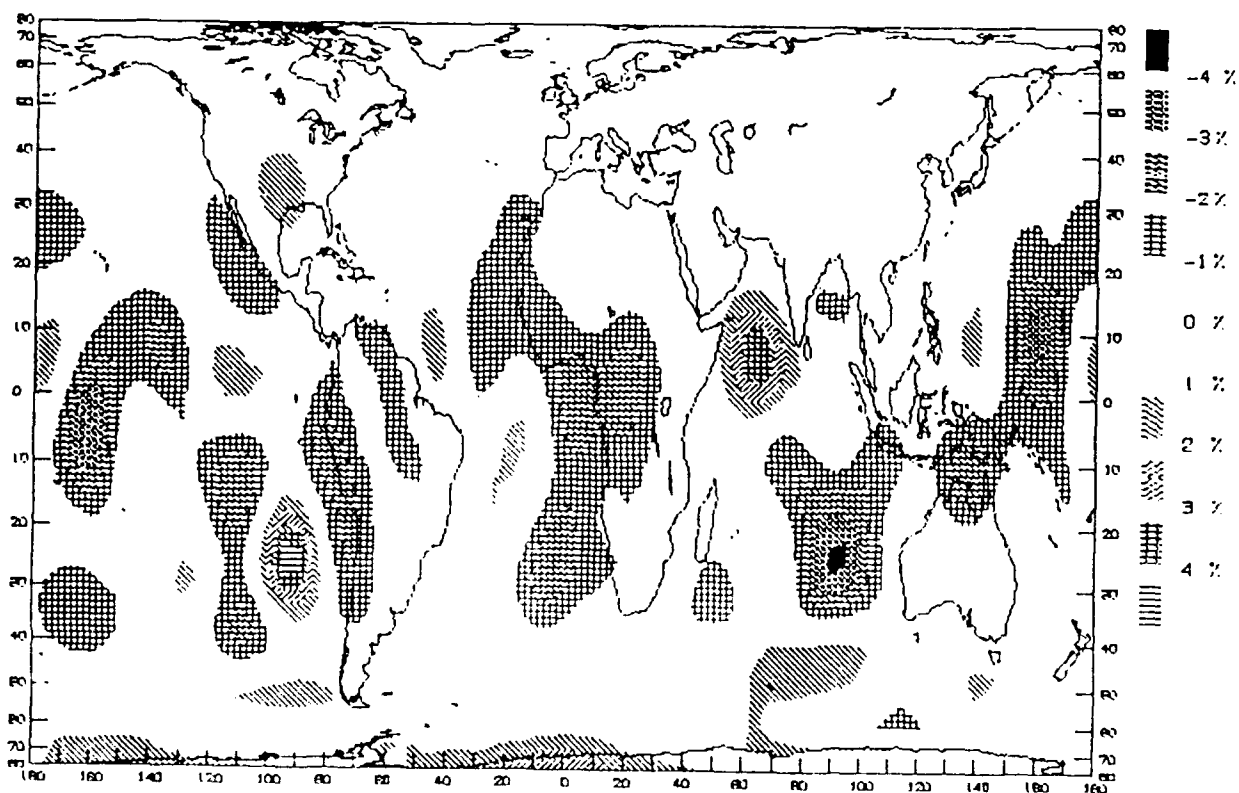


Figure 2b.

MAP OF JUL-1030-MEAN CLOUD COVER

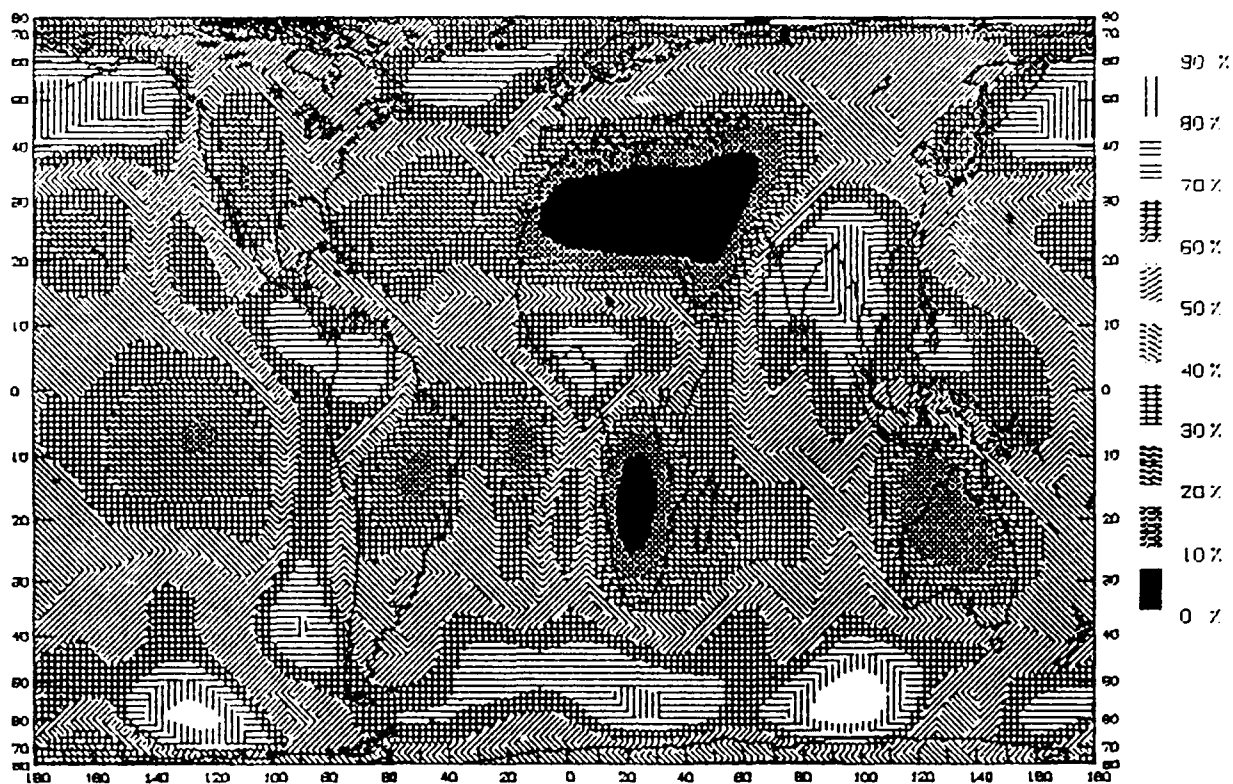


Figure 3a.

MEAN CLOUD COVER DIFFERENCE MAP : JUL-1030-MEAN MINUS JUL-945-MEAN

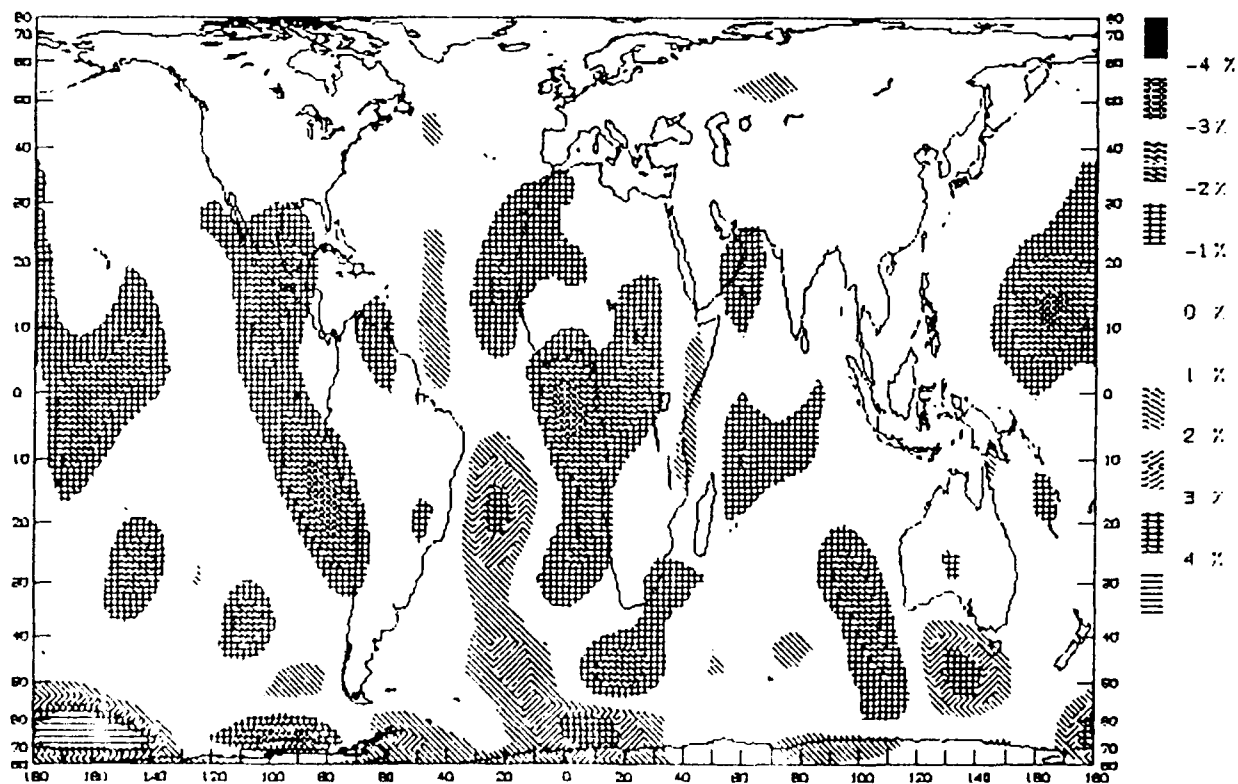


Figure 3b.

MAP OF OCT-1030-MEAN CLOUD COVER

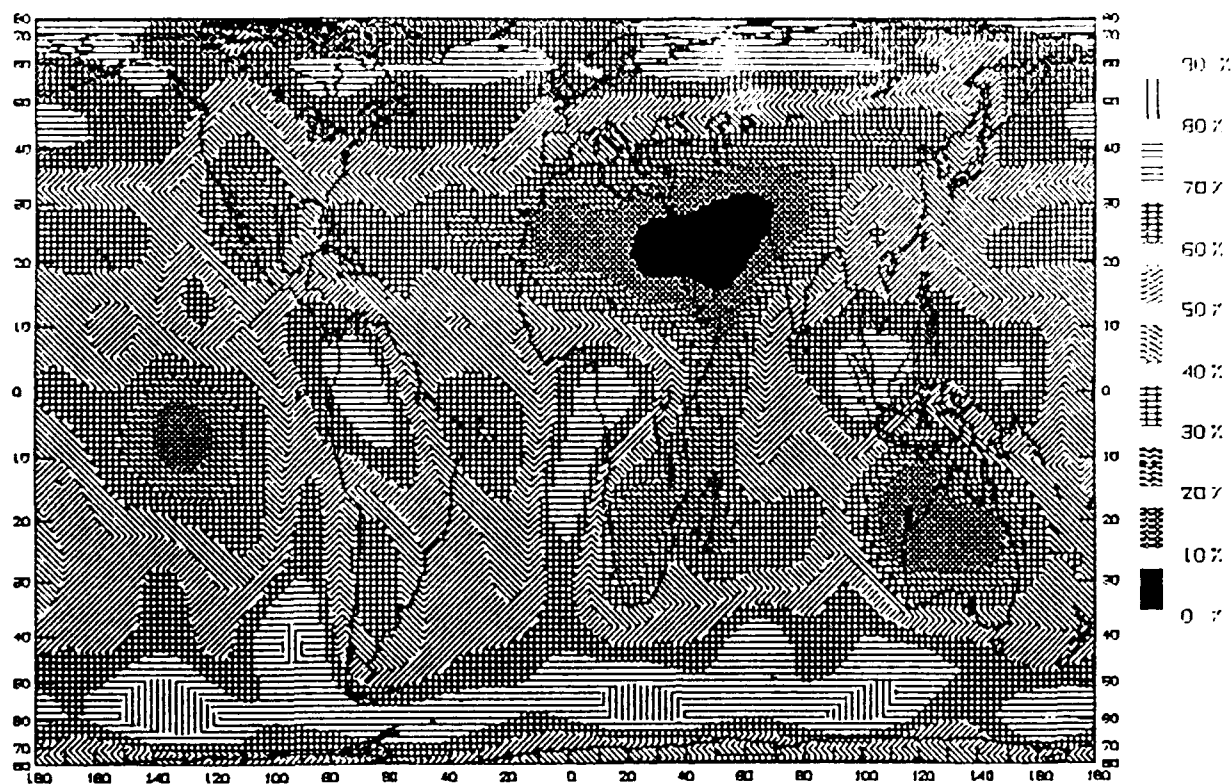


Figure 4a.

MEAN CLOUD COVER DIFFERENCE MAP : OCT-1030-MEAN MINUS OCT-945-MEAN

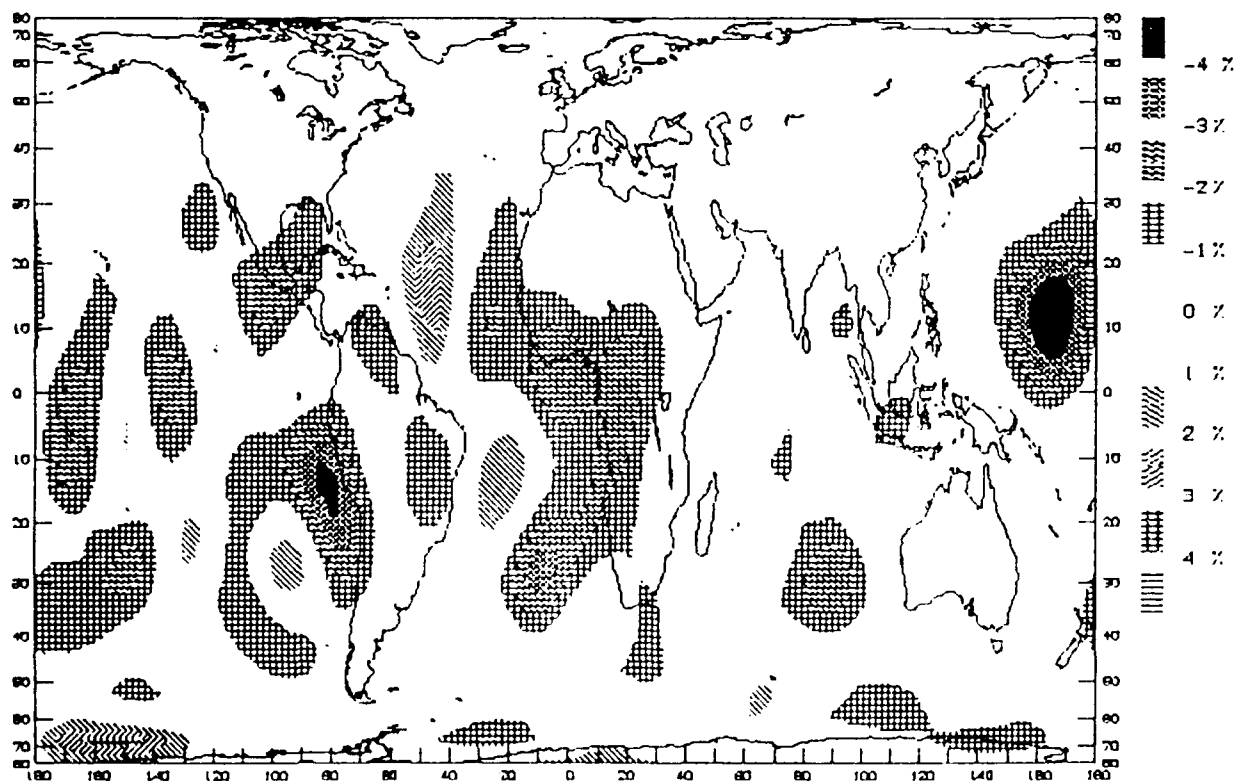


Figure 4b.

PERCENT OCCURENCE MAP FOR : JAN-1030-30KM-20%.

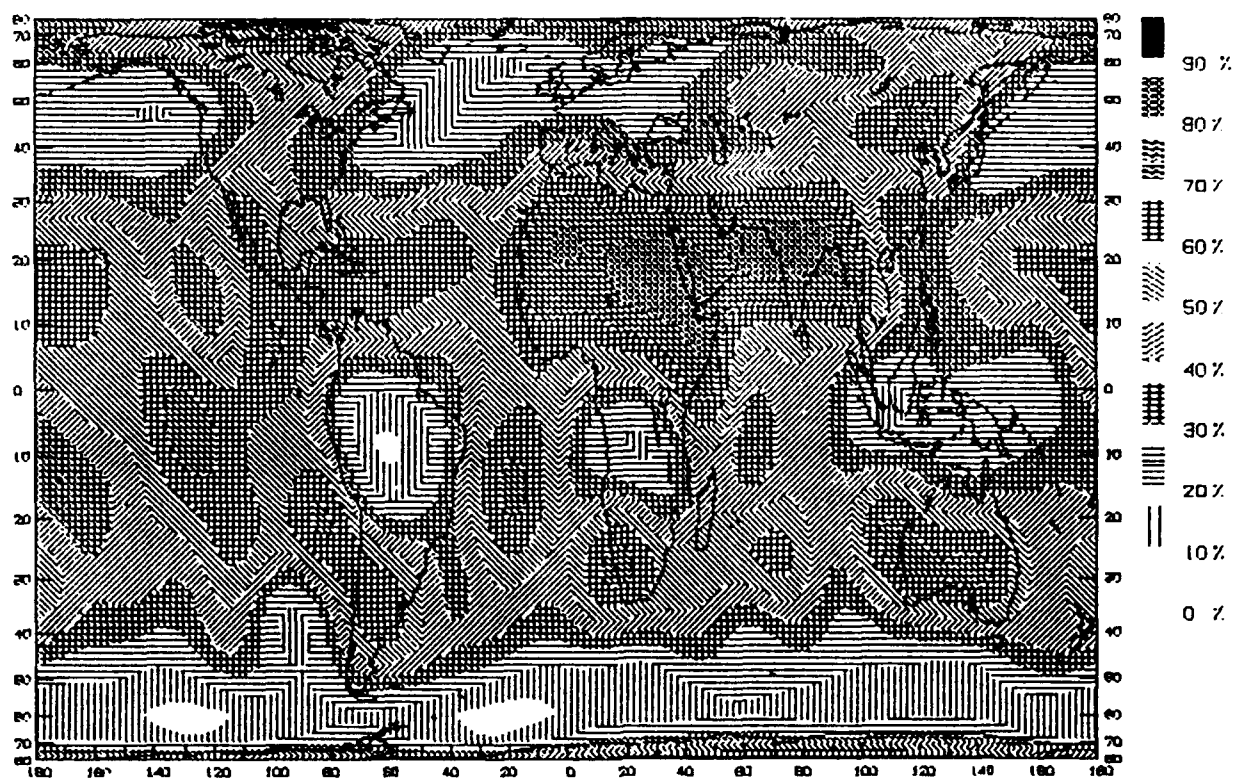


Figure 5a.

PERCENT OCCURENCE DIFFERENCE MAP : JAN-1030-30KM-20% MINUS JAN-945-30KM-20%.

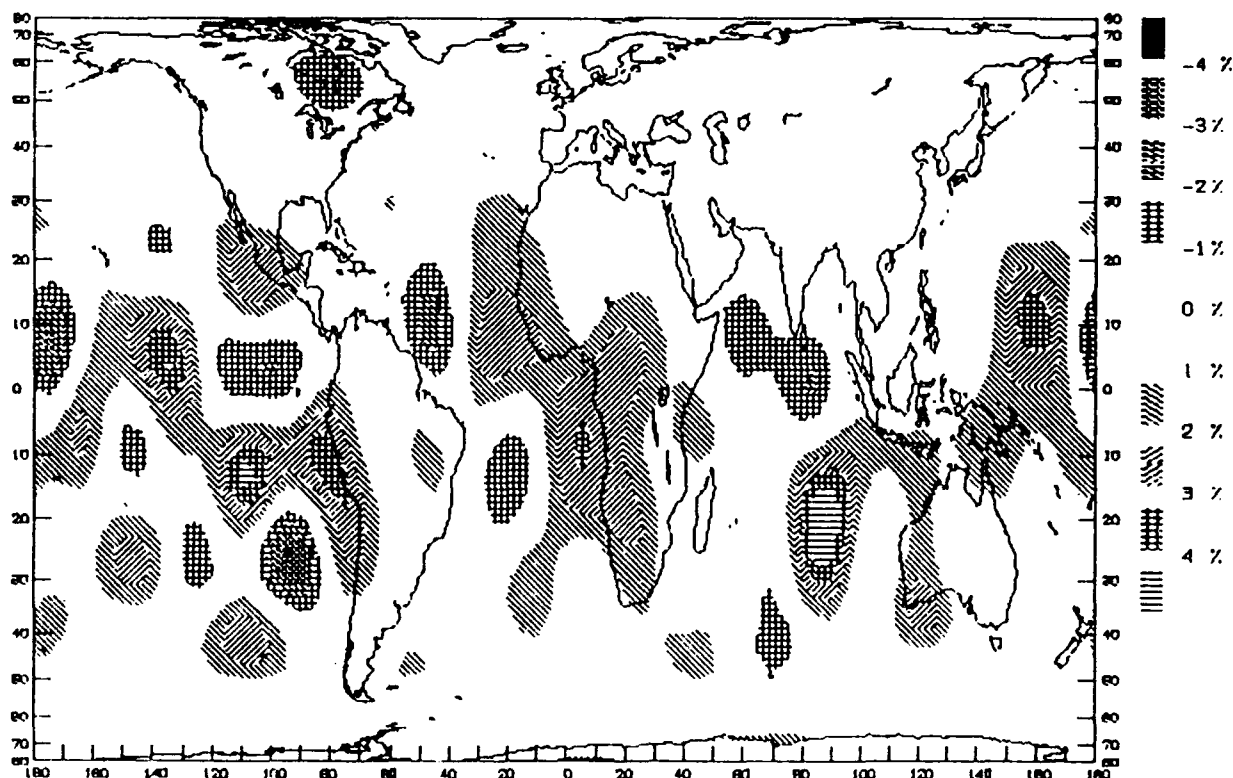


Figure 5b.

PERCENT OCCURENCE MAP FOR : APR-1030-30KM-20%

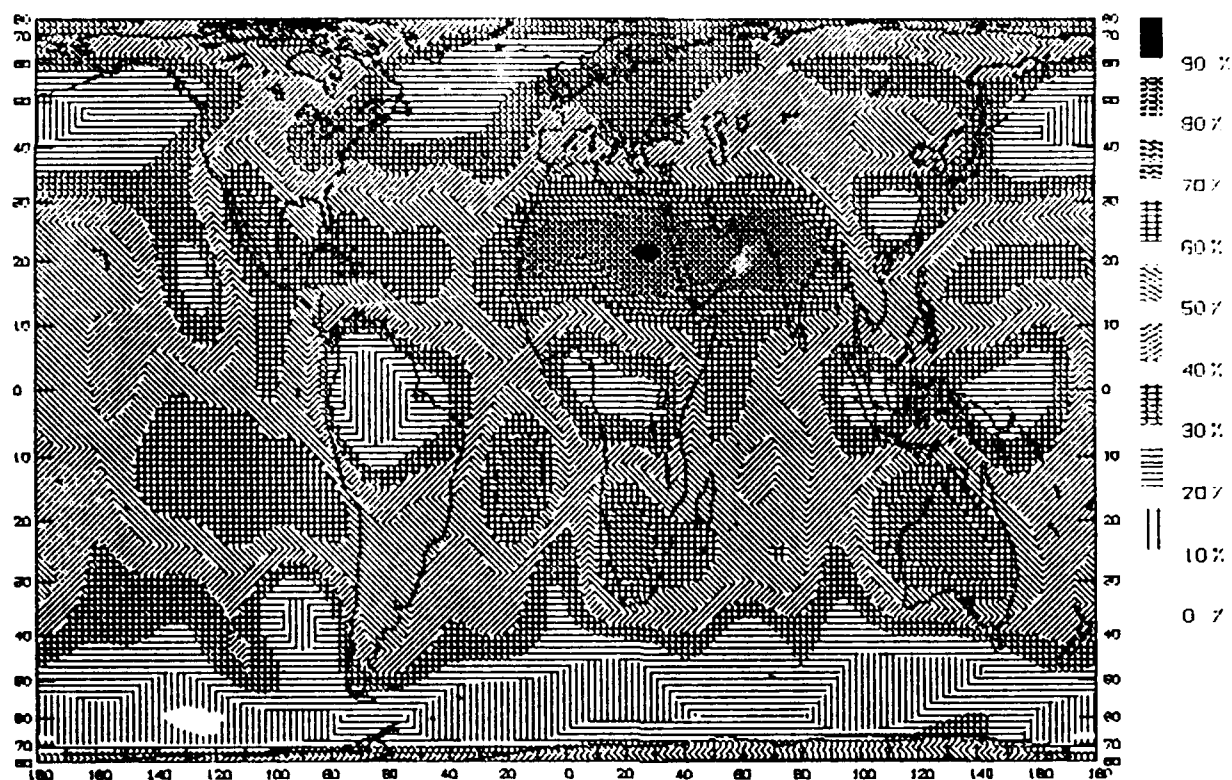


Figure 6a.

PERCENT OCCURENCE DIFFERENCE MAP : APR-1030-30KM-20% MINUS APR-945-30KM-20%

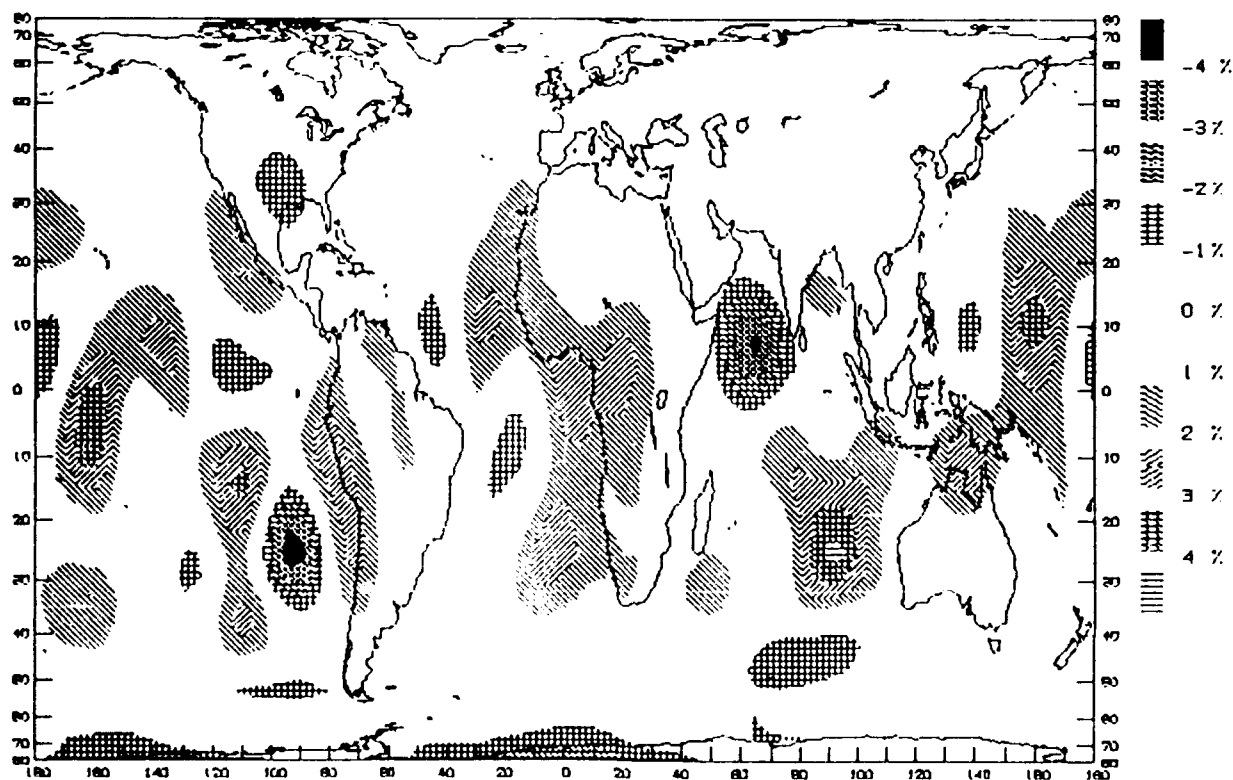


Figure 6b.

PERCENT OCCURENCE MAP FOR : JUL-1030-30KM-20%

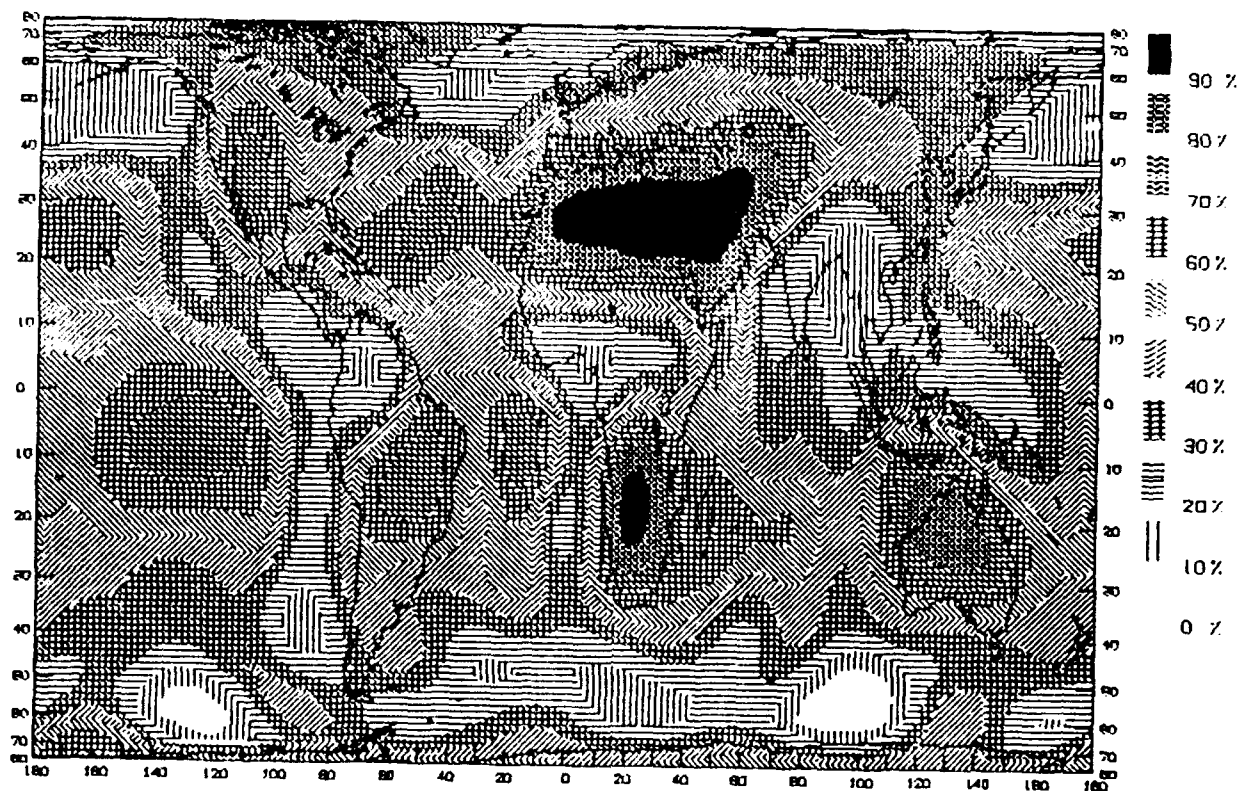


Figure 7a.

PERCENT OCCURENCE DIFFERENCE MAP : JUL-1030-30KM-20% MINUS JUL-945-30KM-20%

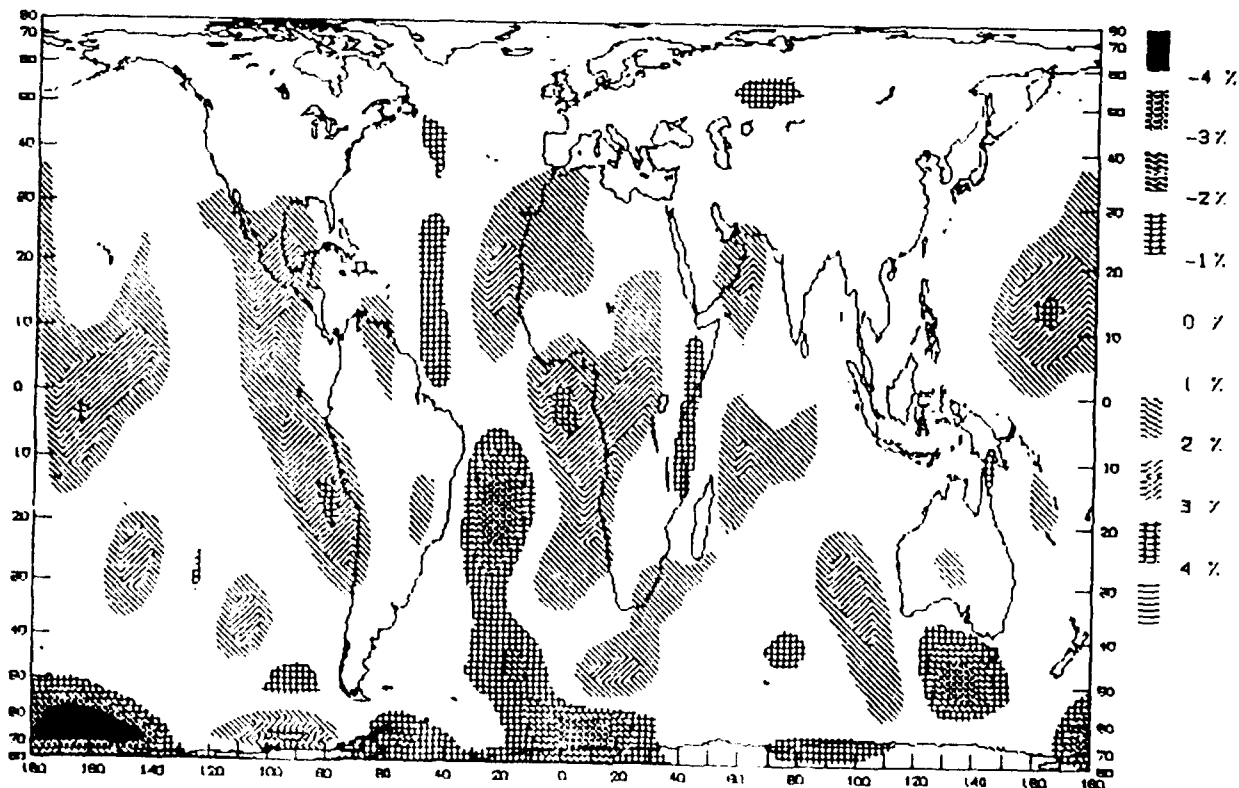


Figure 7b.

PERCENT OCCURENCE MAP FOR : OCT-1030-30K11-20%

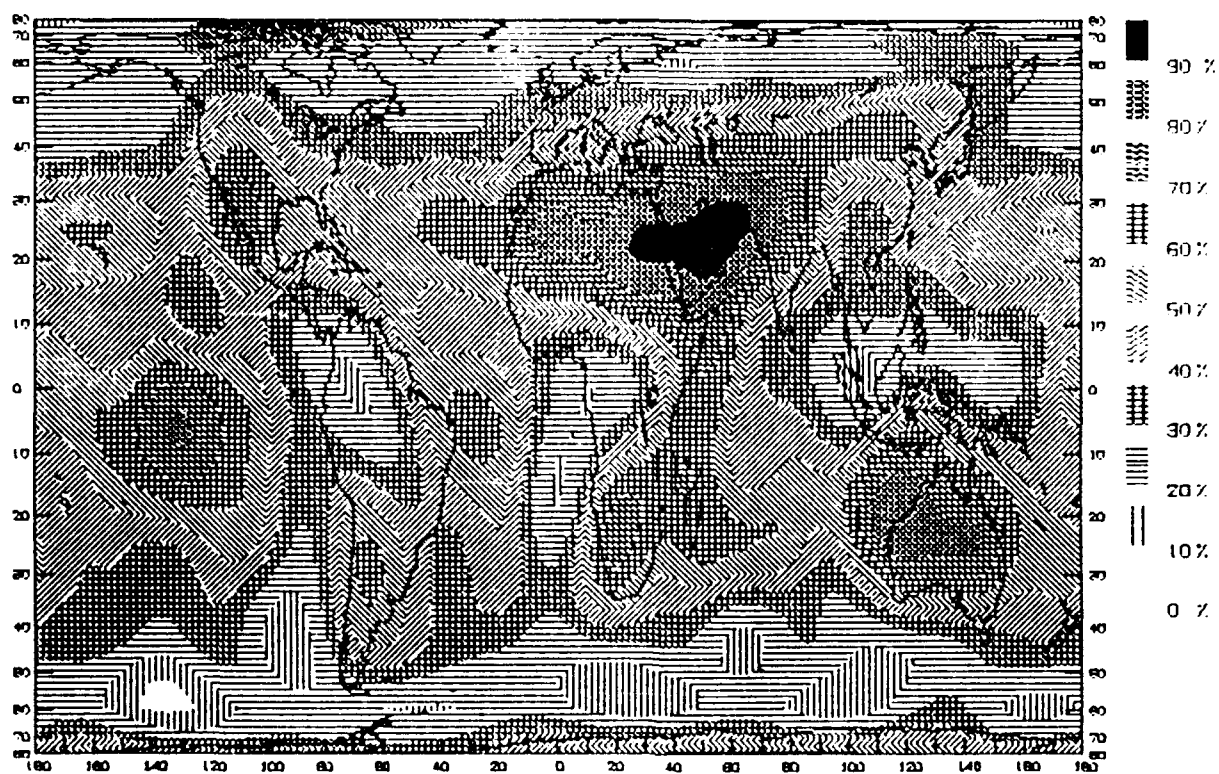


Figure 8a.

PERCENT OCCURENCE DIFFERENCE MAP : OCT-1030-30K11-20% MINUS OCT-945-30K11-20%

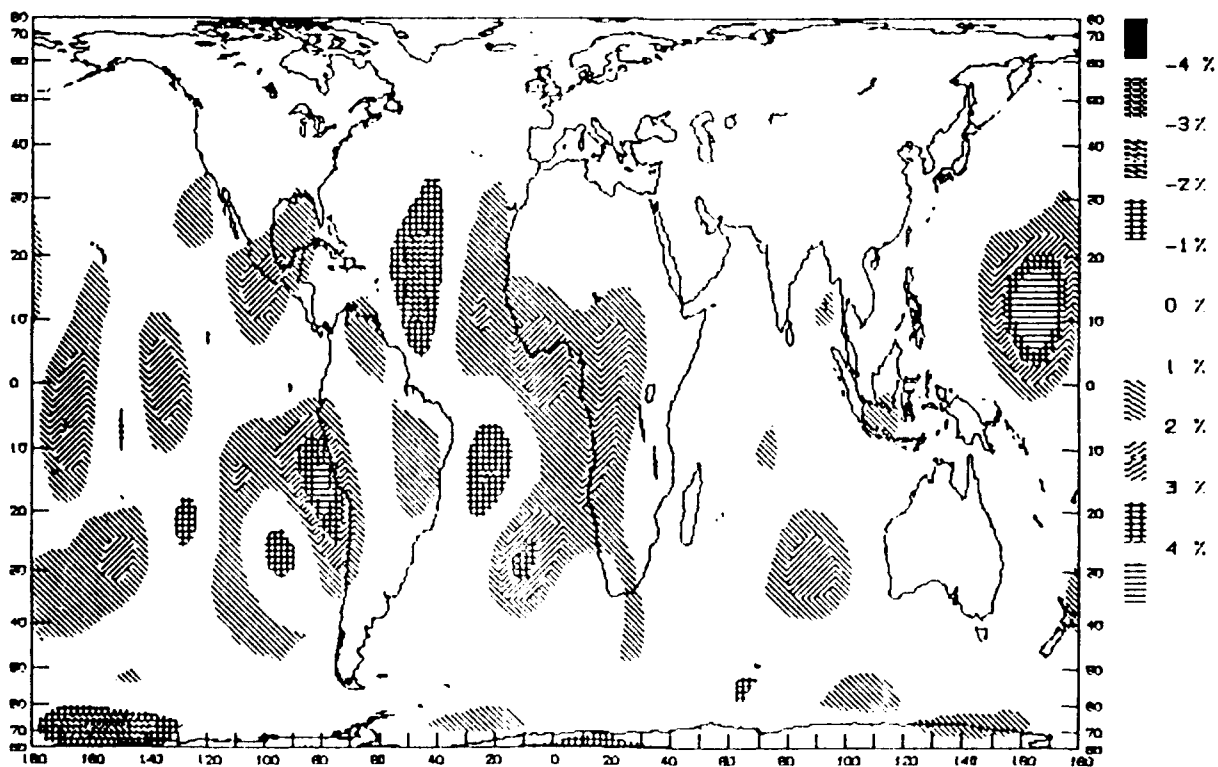


Figure 8b.

SE USA (ALABAMA) / JANUARY LAT= 33.31 LON= -86.49

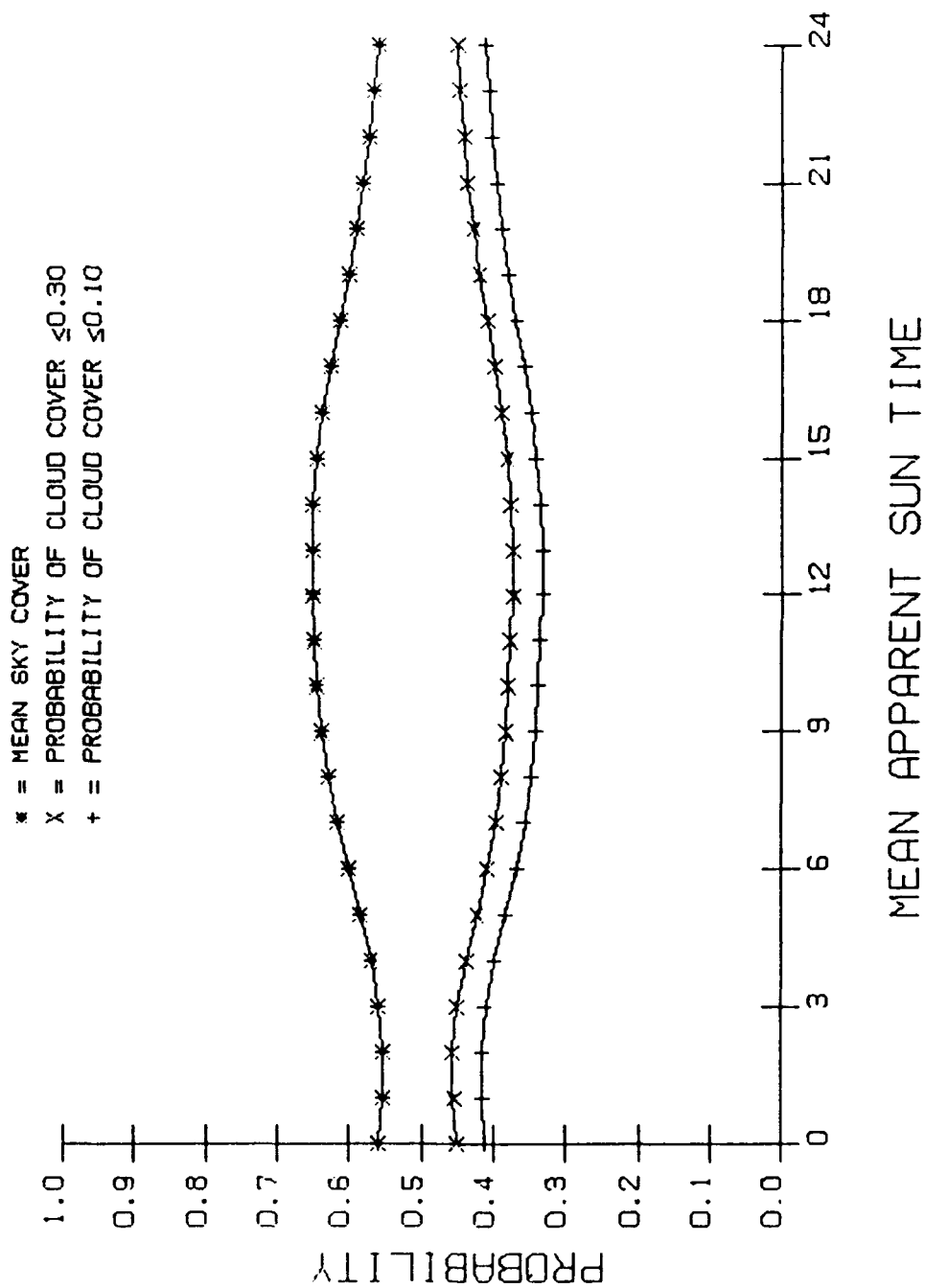


Figure 9.

SE USA (ALABAMA) / JULY LAT= 33.31 LON= -86.49

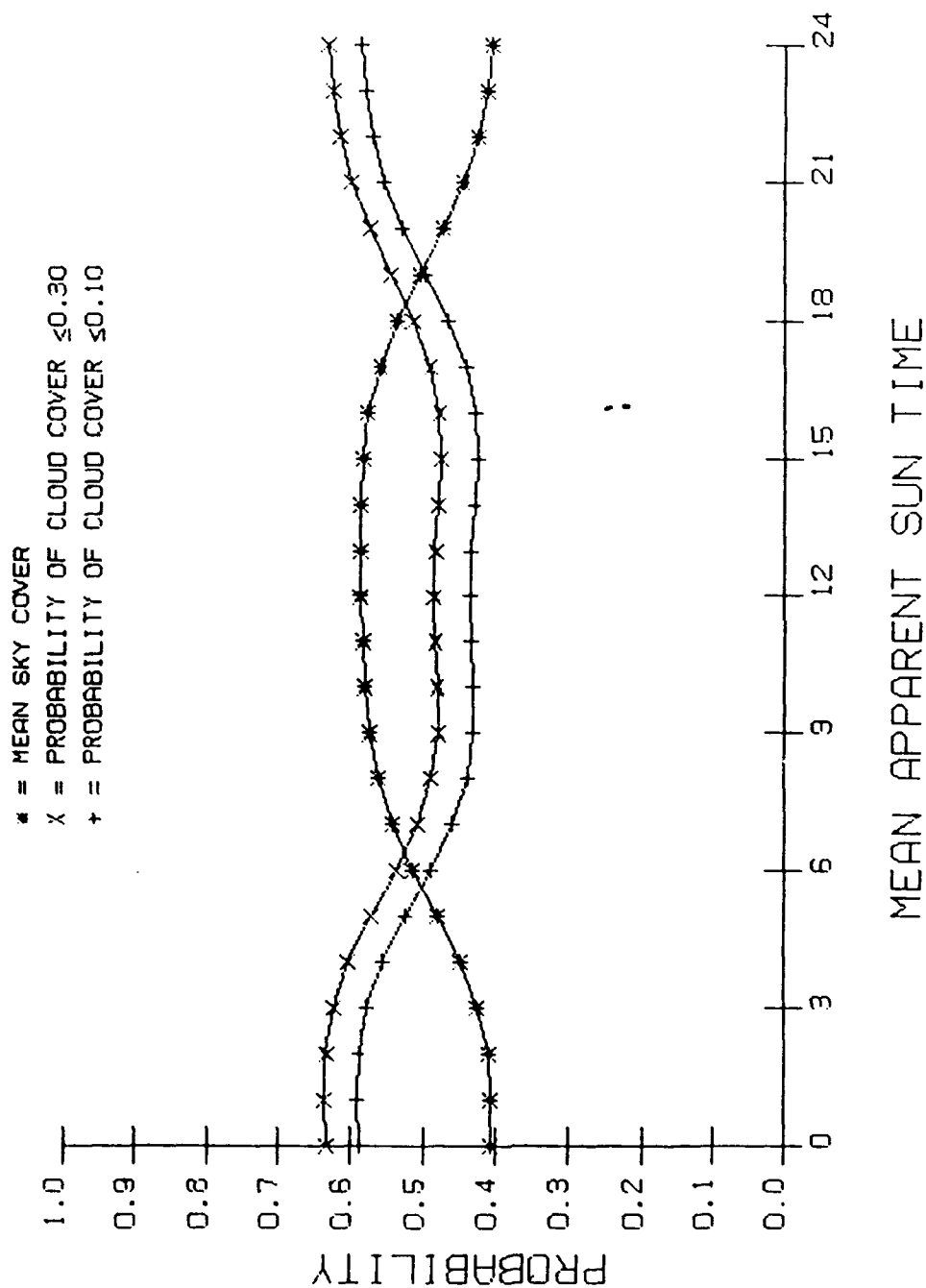


Figure 10.

SAHARA DESERT / JANUARY LAT= 23.44 LON= 10.00

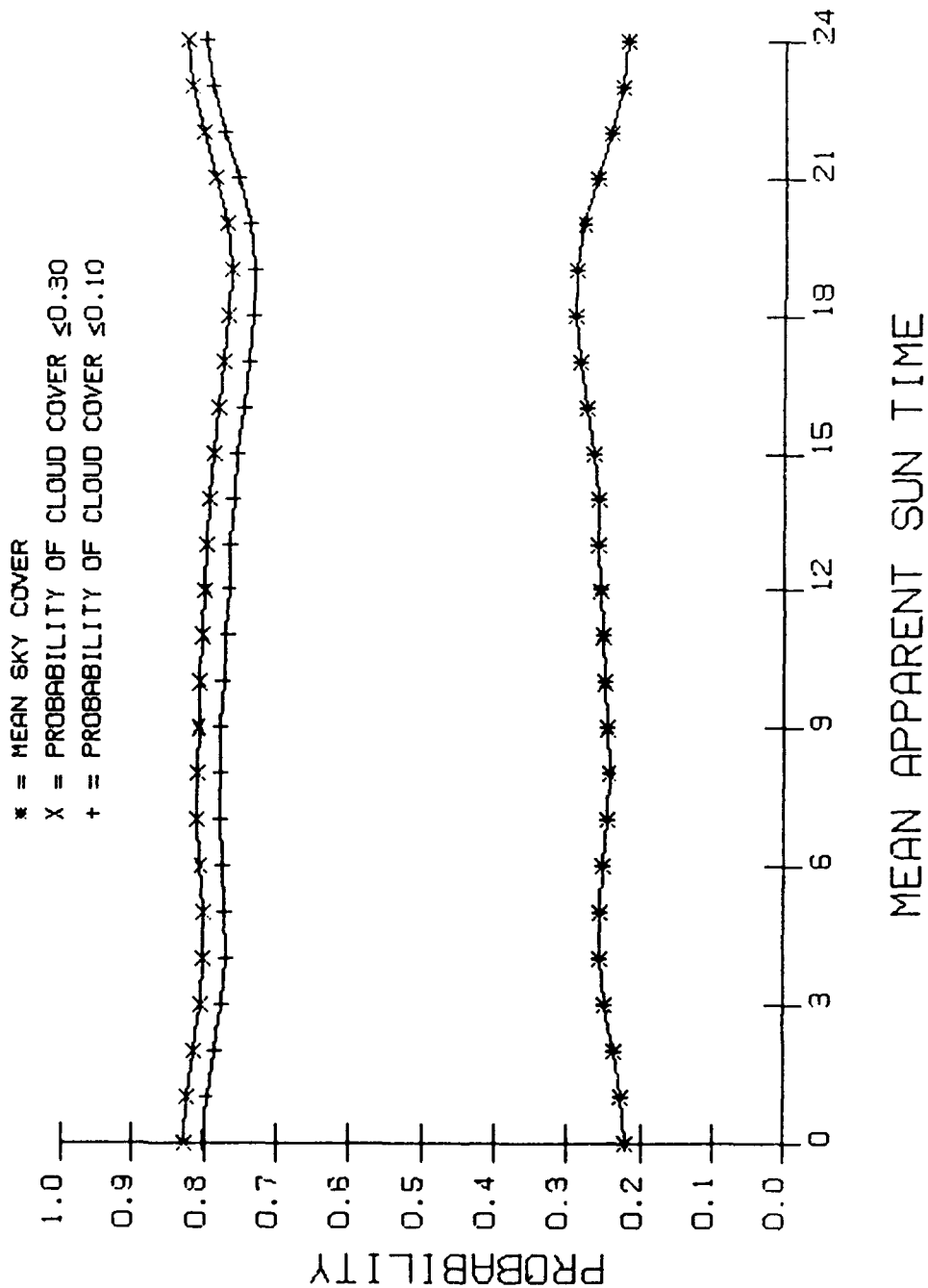


Figure 11.

SAHARA DESERT / JULY

LAT= 23.44 LON= 10.00

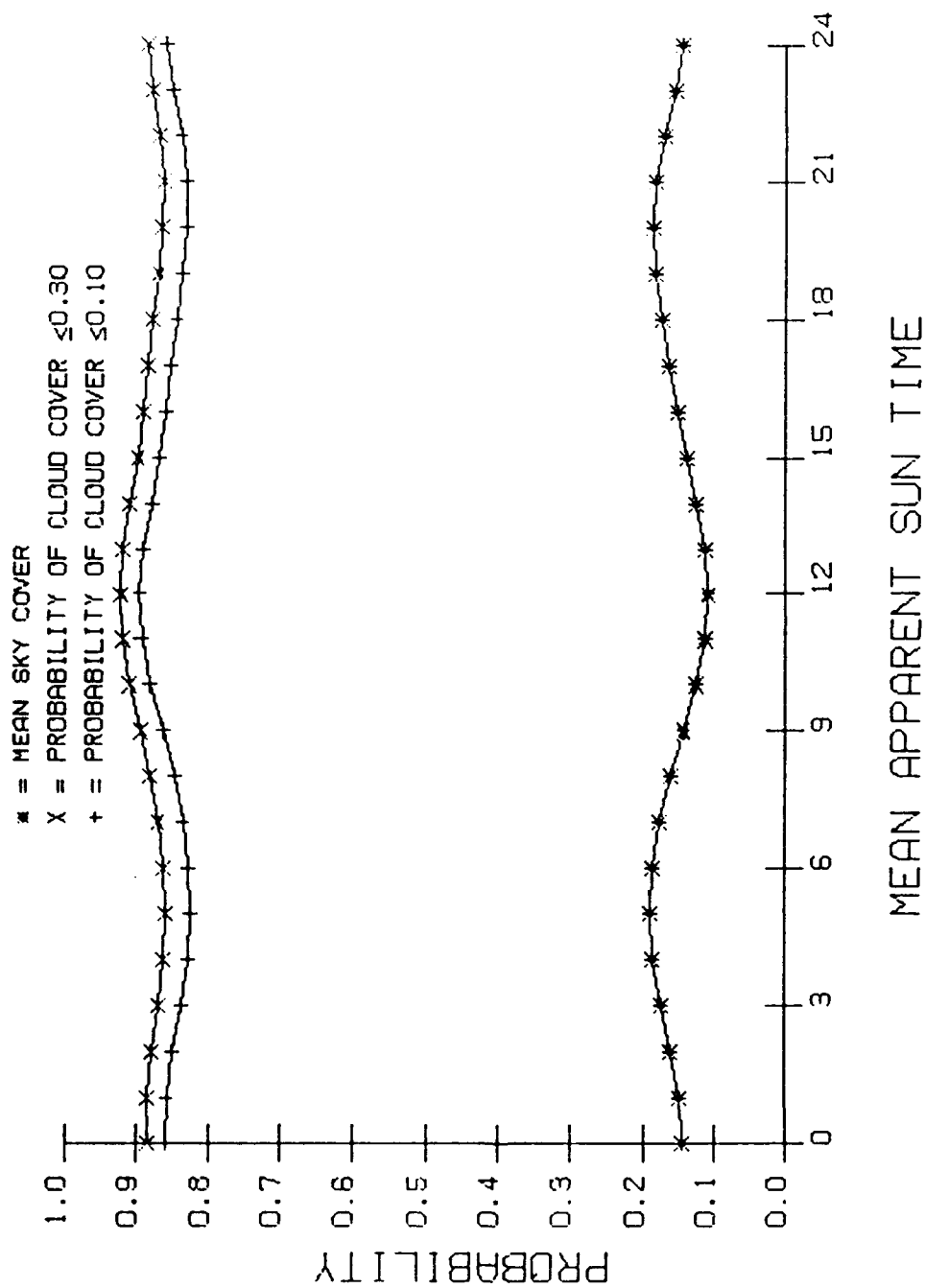


Figure 12.

AMAZONAS / JANUARY

LAT= -4.15 LON= -64.30

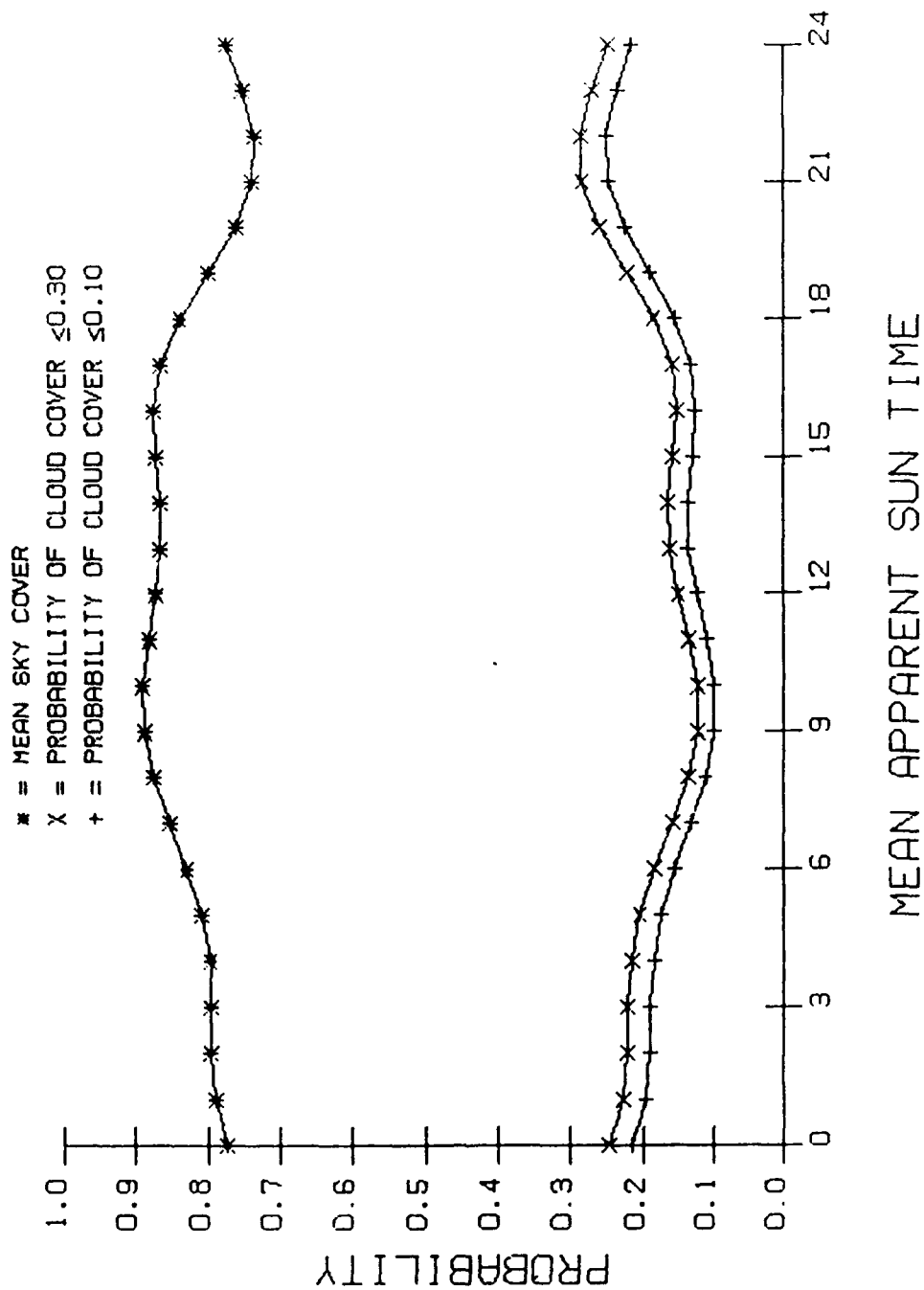


Figure 13.

AMAZONAS / JULY

LAT= -4.15 LON= -64.30

* = MEAN SKY COVER

x = PROBABILITY OF CLOUD COVER ≤ 0.30

+ = PROBABILITY OF CLOUD COVER ≤ 0.10

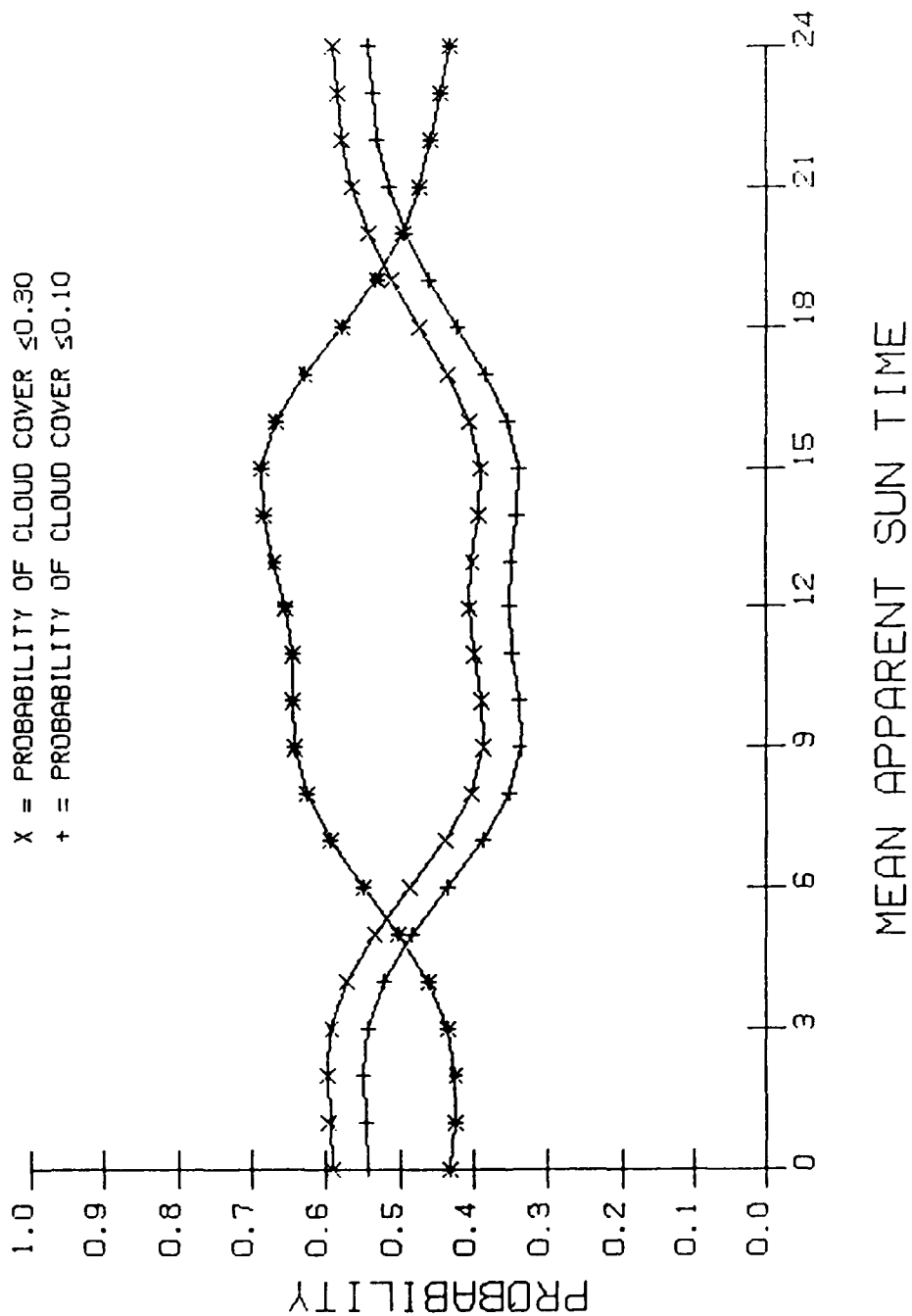


Figure 14.

INDIAN OCEAN / JANUARY LAT= 0.00 LON= 75.00

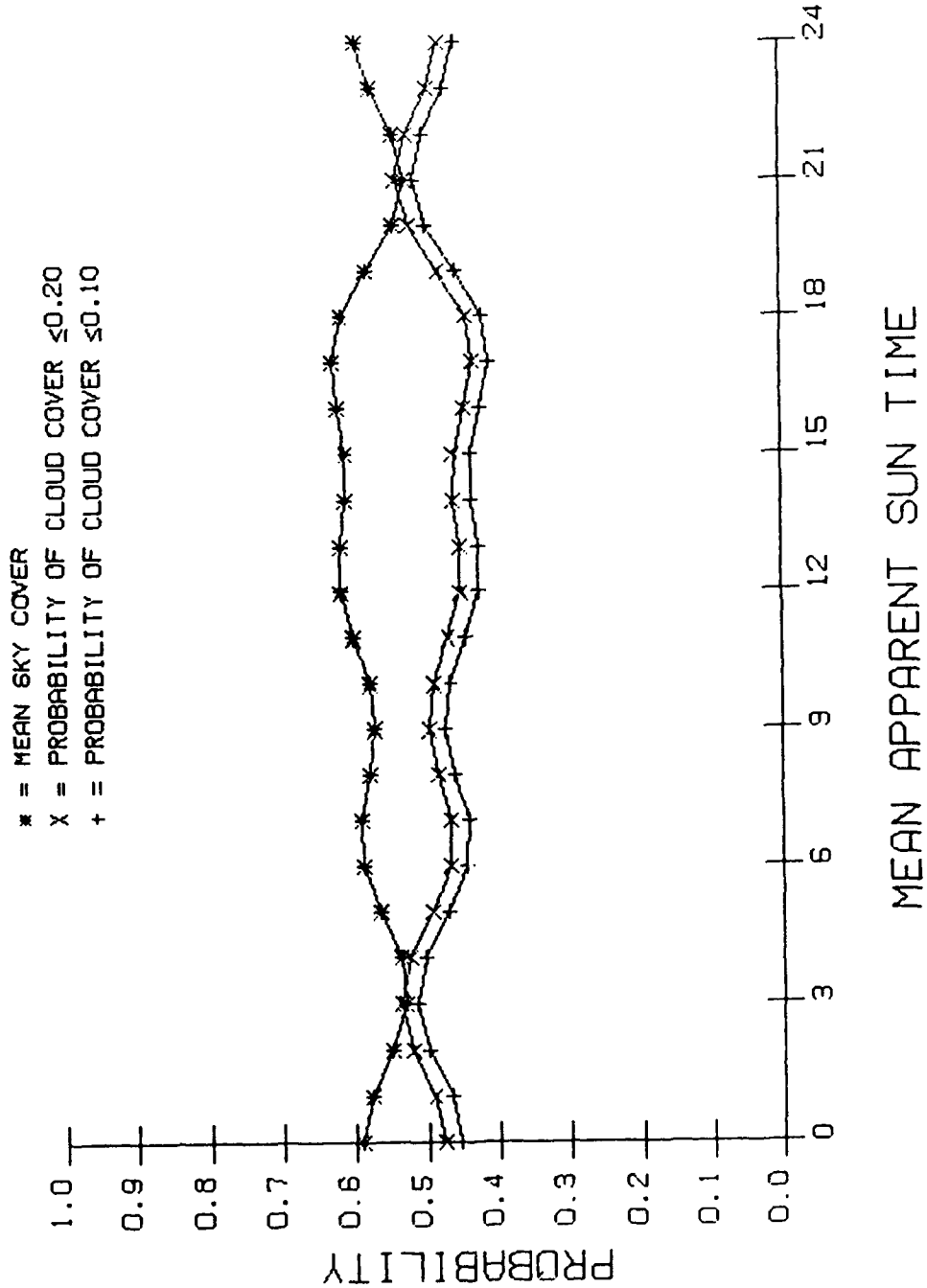


Figure 15.

INDIAN OCEAN / JULY LAT= 0.00 LON= 75.00

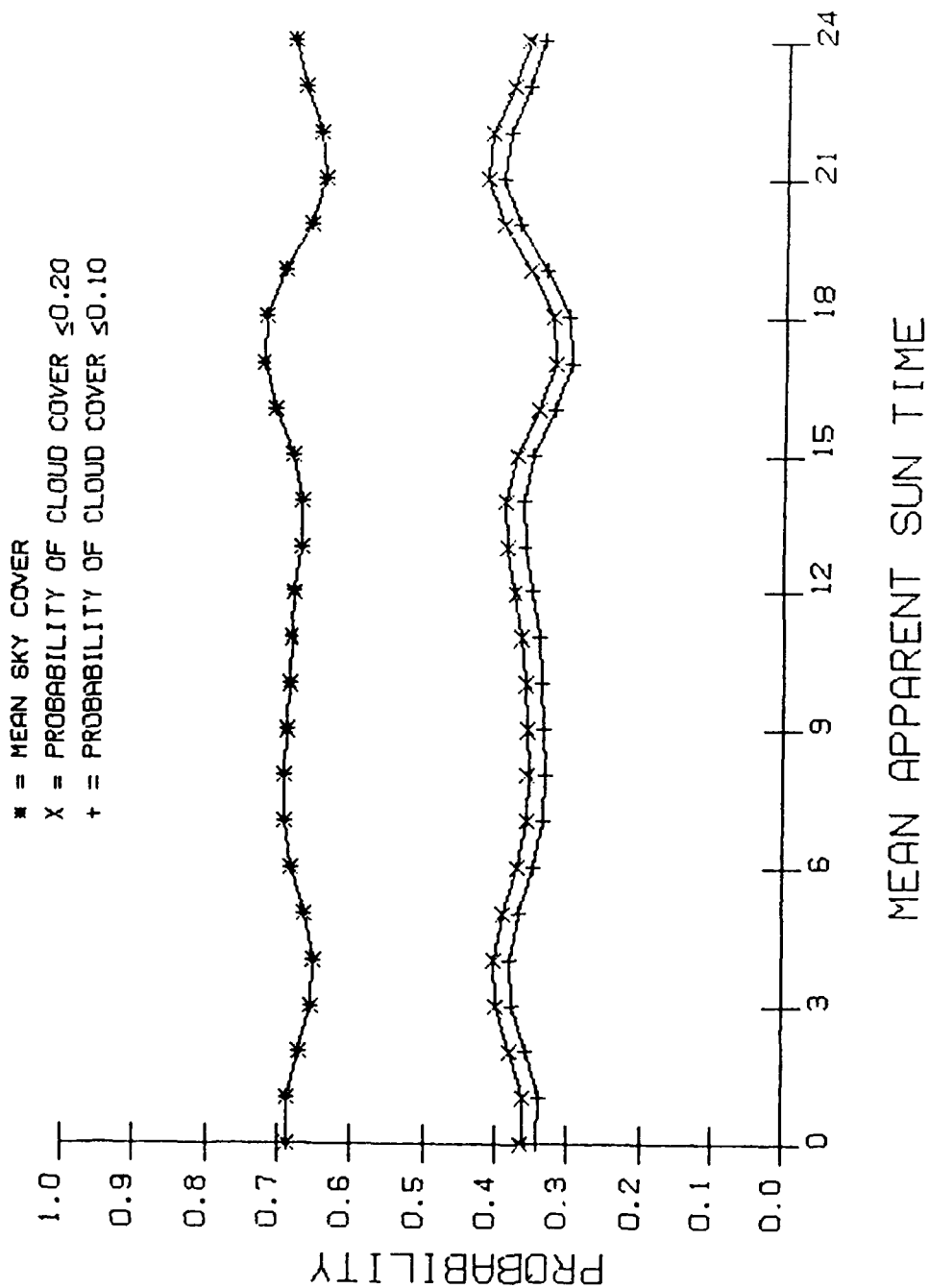


Figure 16.

ATLANTIC COAST / JANUARY LAT= -15.00 LON= -34.00

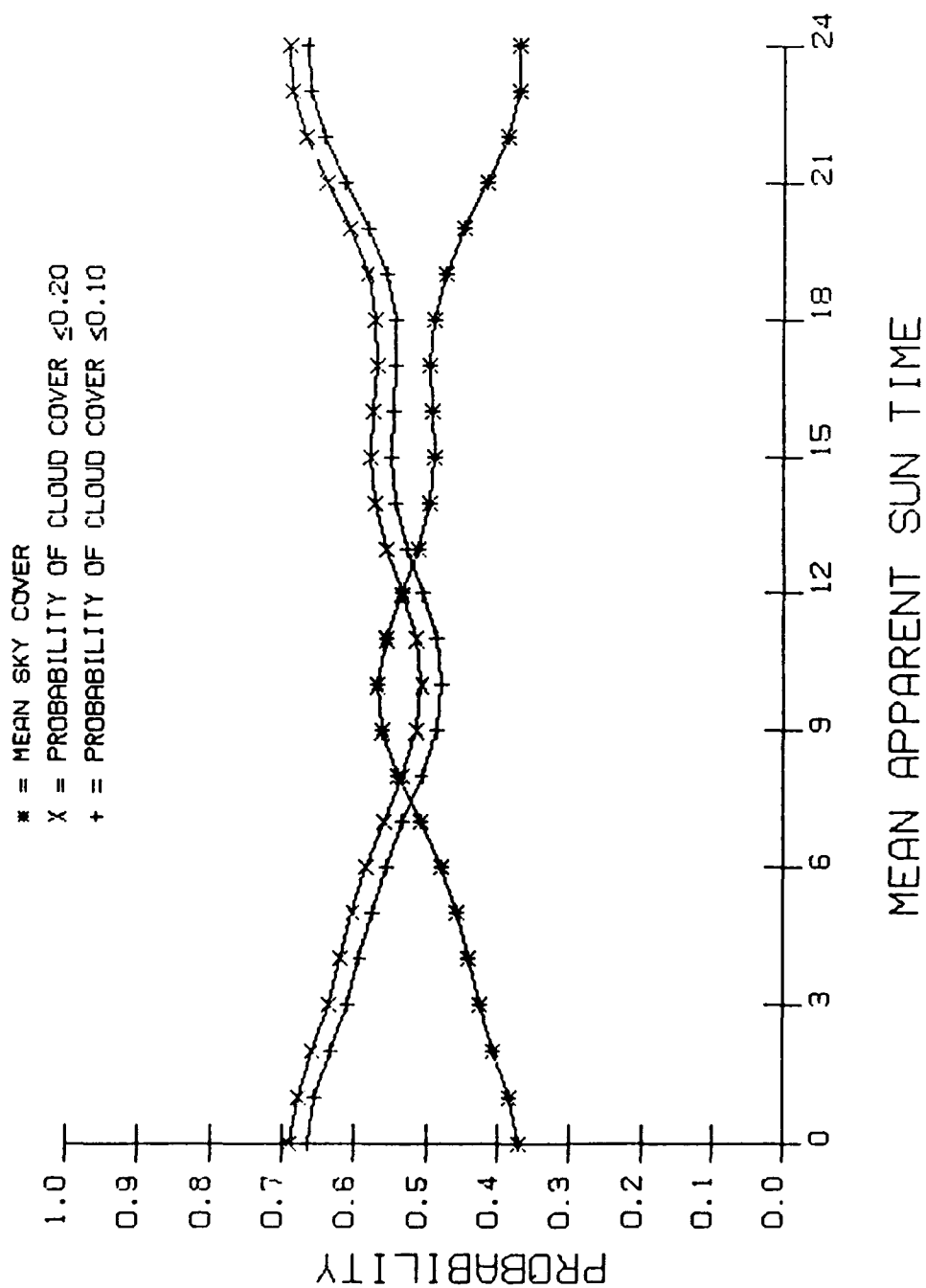


Figure 17.

ATLANTIC COAST / JULY LAT= -15.00 LON= -34.00

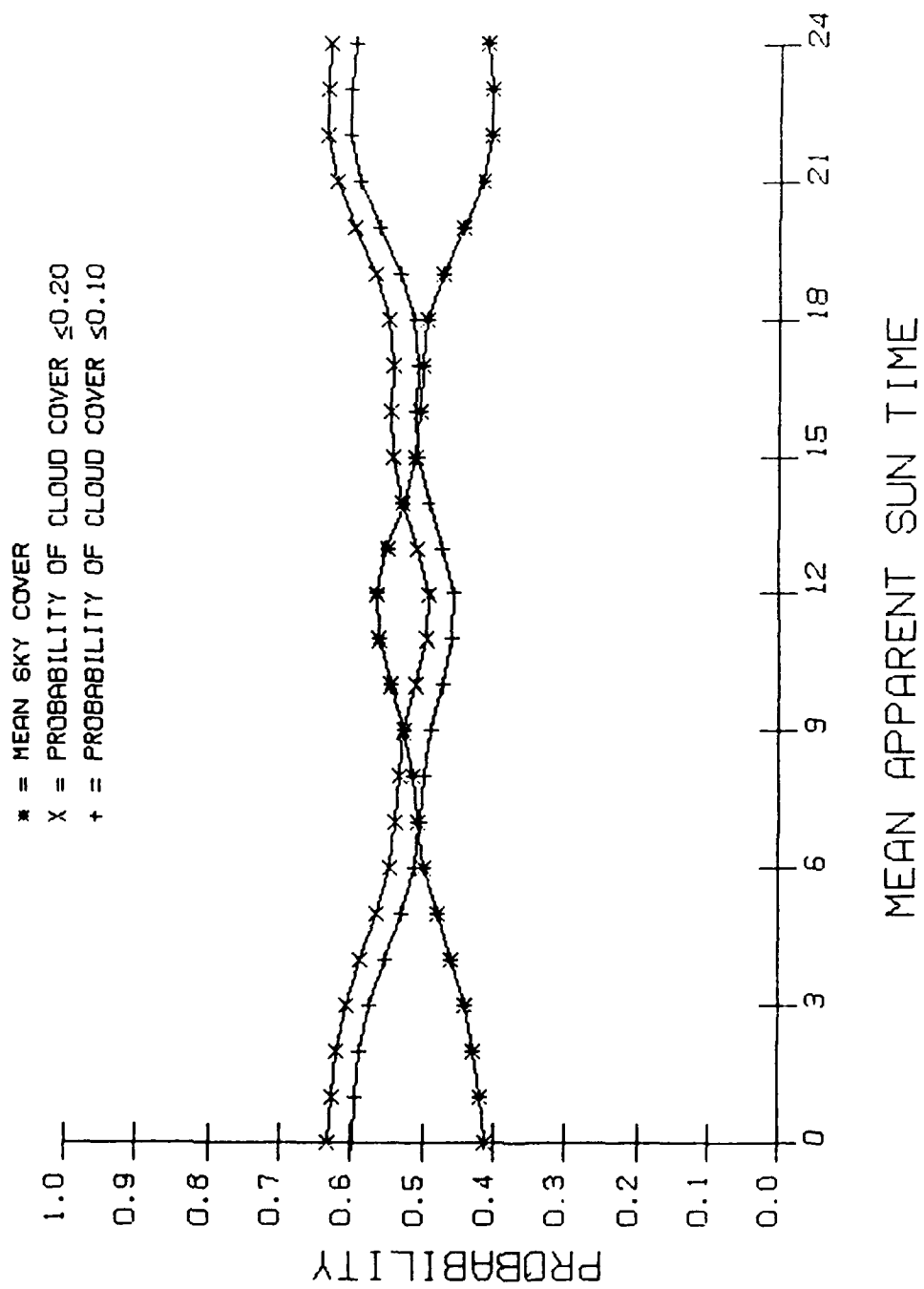


Figure 18.

PACIFIC OCEAN / JANUARY LAT= -15.00 LON= -105.00

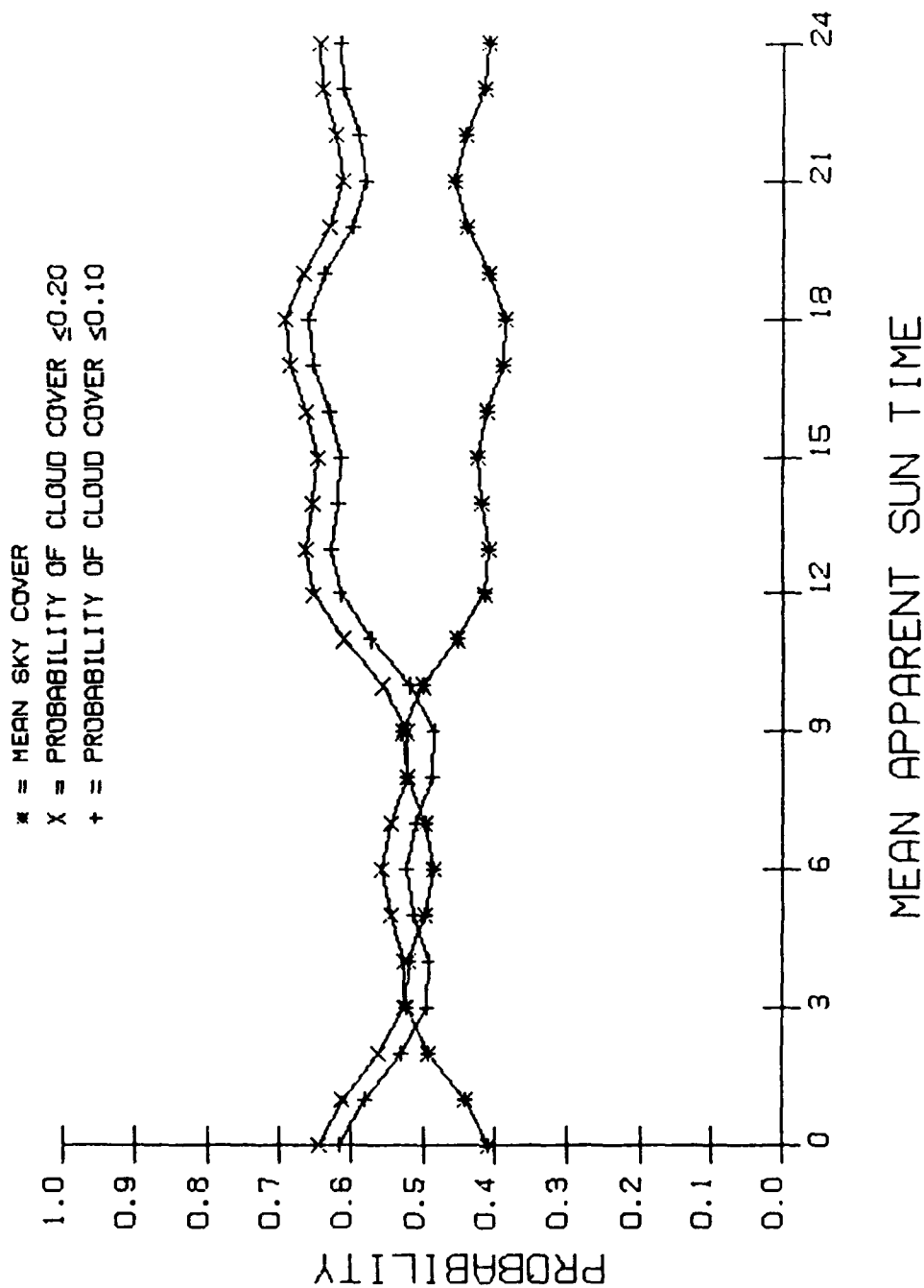


Figure 19.

PACIFIC OCEAN / JULY LAT= -15.00 LON= -105.00

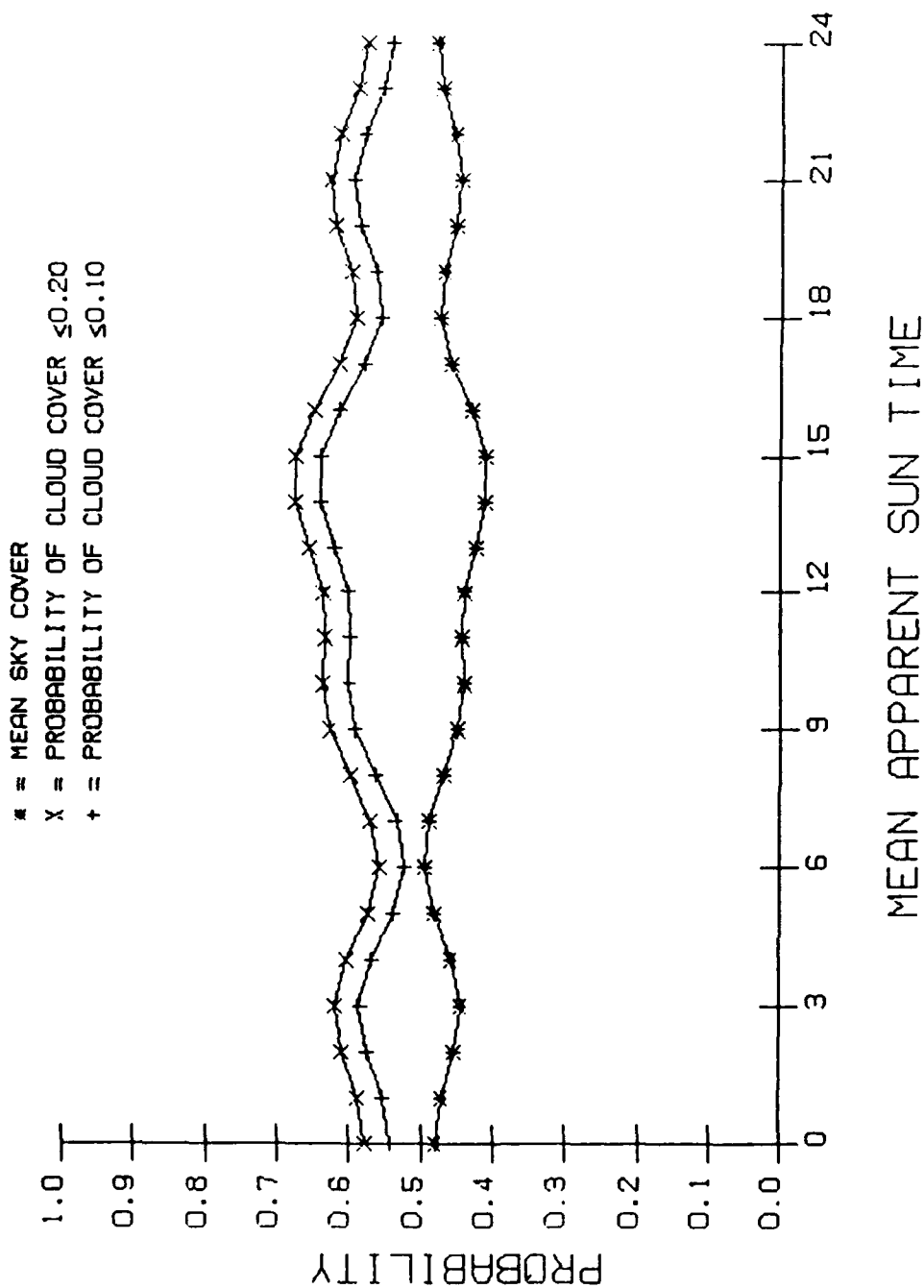


Figure 20.

PACIFIC OCEAN / JANUARY LAT= -30.00 LON= -135.00

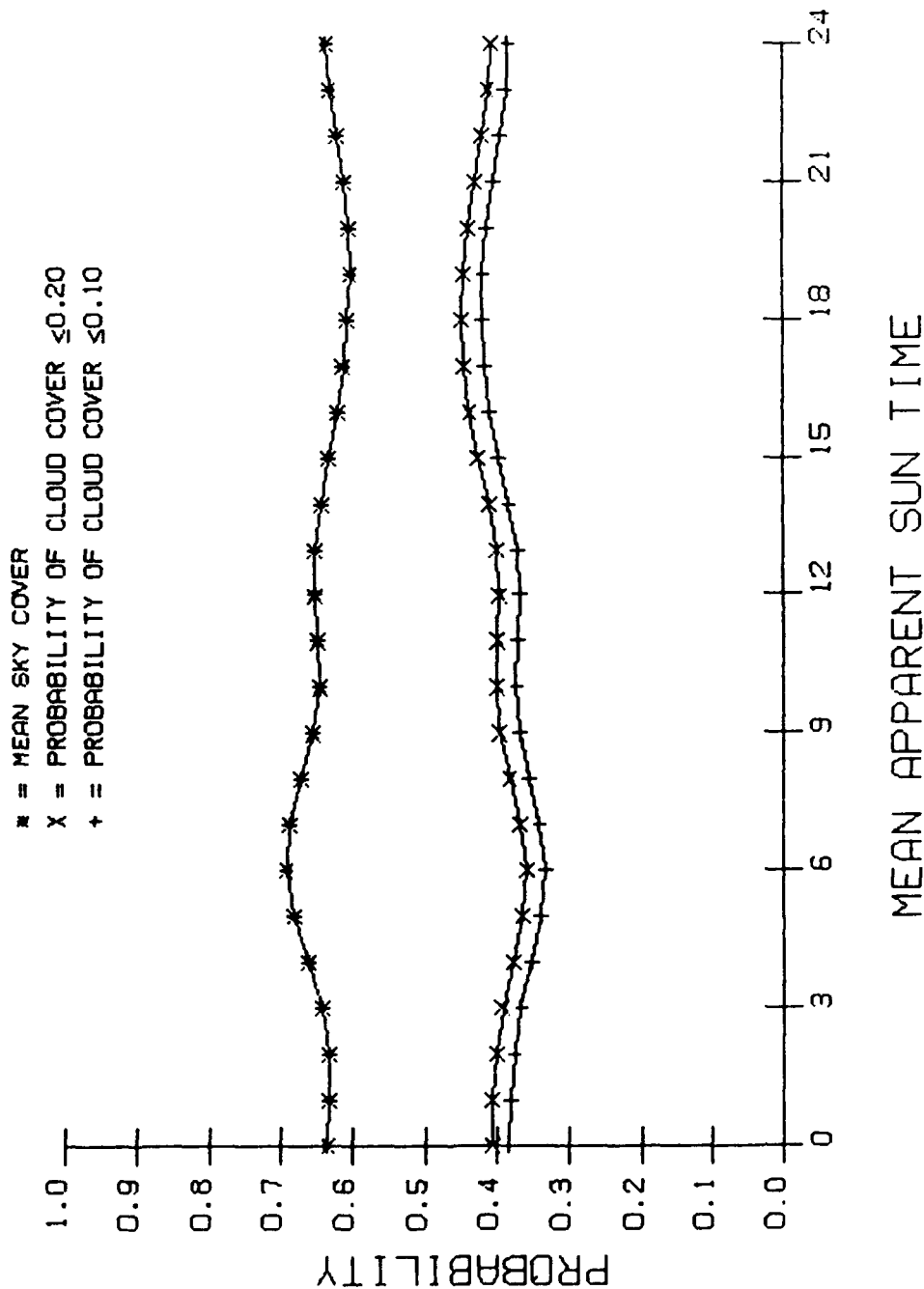


Figure 21.

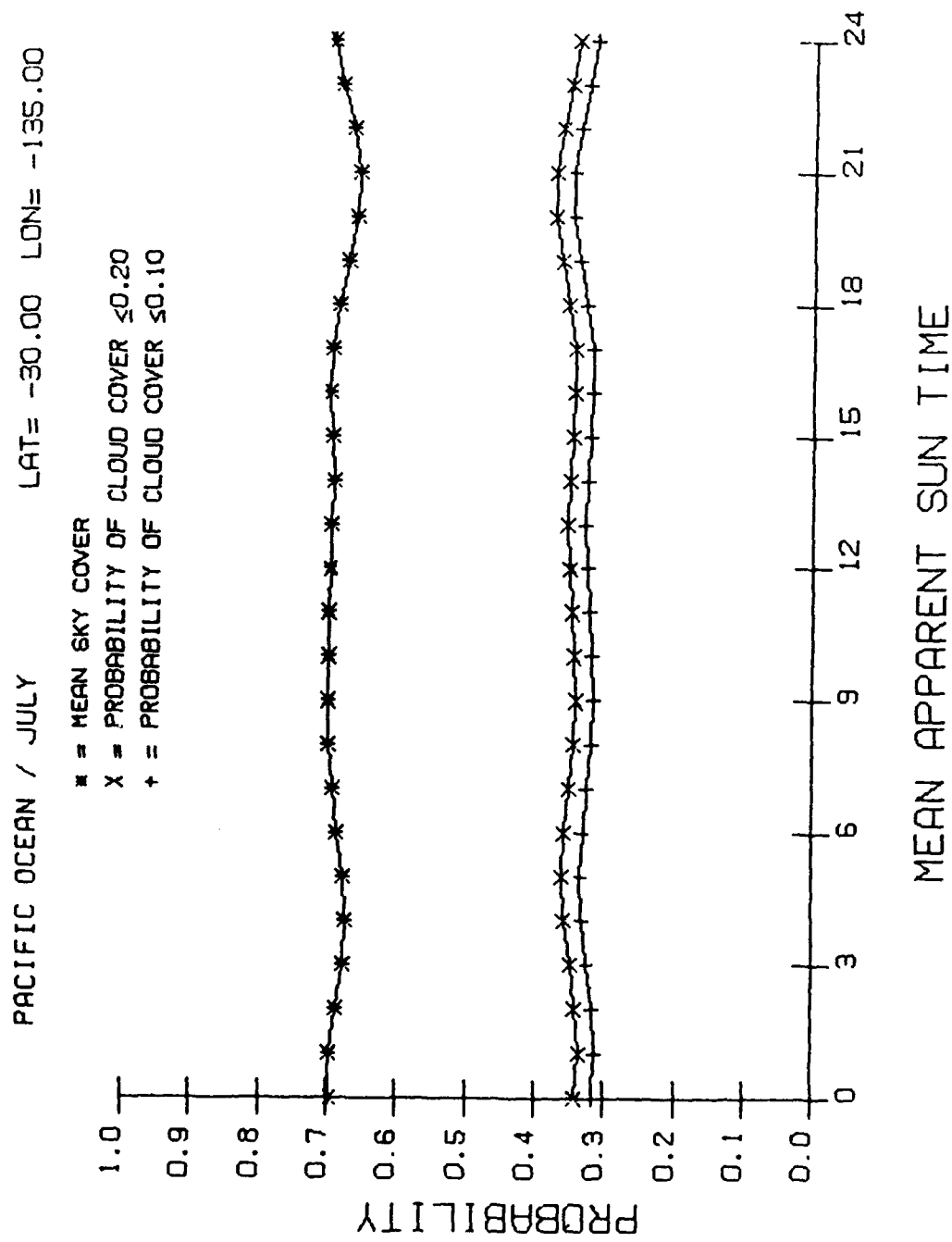


Figure 22.

Table 1.0

LANDSAT TIME OFFSET			
(From Local Mean Apparant Solar Time - Desc. Node Crossing)			
LATITUDE °		TIME ADJ mins.	
81.79		359.237	
81		262.253	
80		219.803	
79		191.453	
78		170.957	
77		154.483	
76		141.473	
75		130.167	
74		120.803	
73		112.537	
72		105.397	
71		98.993	
70		93.380	
65		72.057	
60		57.890	
50		39.643	
40		27.803	
30		19.107	
20		12.050	
10		5.833	
0		±0.000	
-10		-5.817	
-20		-12.033	
-30		-19.107	
-40		-27.787	
-50		-39.587	
-60		-57.817	
-65		-72.007	
-70		-93.403	
-71		-99.023	
-72		-105.390	
-73		-112.527	
-74		-120.753	
-75		-130.357	
-76		-141.303	
-77		-154.633	
-78		-171.067	
-79		-191.507	
-80		-219.737	
-81		-261.987	
-81.79		-359.490	