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EXAMPLES OF THE USEFULNESS OF SATELLITE DATA IN GENERAL ATMOSPHERIC CIRCULATION RESEARCH

Part II - An Atlas of Average Cloud Cover Over the Tropical Pacific Ocean

by

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16. Abstract

This atlas, based upon data from six TIROS and three ESSA satellites, depicts Pacific Ocean cloudiness from August 1962 through August 1968. The months of January, April, August, and October were selected for inclusion in the process of averaging data over areas 2° square from longitude 100°W to 130°E and from latitude 30°N to 25°S.

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ABSTRACT

This atlas depicting Pacific Ocean cloudiness over a six-year period has been produced using daily TIROS and ESSA television nephanalyses, and is intended to present the data in a convenient form for climatological research.

The nephanalysis data were averaged over latitude-longitude 2° squares from 100°W to 130°E, 30°N to 25°S, to form monthly averages of total cloud cover. A series for the months January April, August, and October of each year from August 1962 through August 1968 has been compiled.

The derivation of cloud climatology from remotely sensed data is discussed, and procedures for processing satellite data for cloud climatologies are reviewed.

A large-scale variation in total cloud cover was noted over the Pacific Ocean during the period of study.

CONTENTS

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PART II

AN ATLAS OF AVERAGE CLOUD COVER OVER THE TROPICAL PACIFIC OCEAN

by

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INTRODUCTION

Satellite television pictures have been routinely interpreted in terms of significant meteorological parameters and used extensively for synoptic meteorological analyses on a world-wide basis (Anderson, Ferguson and Oliver, 1966). Several researchers have attempted to summarize satellite data for climatological purposes with varying degrees of success (Arking, 1964; Clapp, 1964, 1968; Bristor and Calicott, 1964; Taylor and Winston, 1968; Sadler, 1968).

The purposes of this paper are to describe our method of satellite television data conversion, to compare ours briefly with other satellite cloud climatological systems, and to present an atlas of tropical cloudiness for the period August 1962 to August 1968.

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METHOD OF ANALYSIS

The series of mean cloud cover charts presented in Appendix A was derived from daily nephanalyses of TIROS and ESSA satellite pictures. This derivation was done with a technique developed by Godshall (1968, a) for the formulation of monthly averages of cloud cover in 2° square areas of latitude and longitude.

Television nephanalyses drawn by the National Environmental Satellite Center, ESSA, prior to January 1964 contained seven cloud cover categories; subsequent to that time, four cloud cover categories were used. Table 1 shows the code numbering of the old and new categories.

Table 1

Categories of Cloudiness and Approximate Equivalences of Cloud Cover in TIROS Nephanalyses.

Parameters	Sky Condition						
	Clear	Clear to Scattered	Scattered	Scattered to Broken	Broken	Broken to Overcast	Overcast
Tenths of cloud cover	0-1	2-3	4	5-6	7	8-9	10
Old nephanalysis code	1	2	3	4	5	6	7
New nephanalysis code	1		2	3		4	

Table 2

Weighting Factors for Categories of Cloudiness in TIROS Nephanalyses.

Old nephanalysis code	1	2	3	4	5	6	7
Weighting factors	2	2	1	2	1	2	1
New nephanalysis code	1		2	3		4	
Weighting factors	4		1	3		3	

The method used for determining the mean cloud cover in each 2° square was to count the nephanalysis cloudiness categories occurring in each area during the averaging period.

The category frequencies were then weighted according to a scheme illustrated in Table 2. It was necessary to weight the category frequencies because the conventional scale of cloud cover in tenths was unevenly apportioned among the nephanalysis cloud cover codes. The weighted frequencies were multiplied by the mean cloud amount of the respective nephanalysis categories and summed. This total was divided by the sum of weighted frequencies to get the mean cloud cover for the 2° square. The frequency distribution of cloud cover amounts over tropical maritime areas has not been clearly established; uniform distribution has been assumed in the assignment of weighting factors.

The convention was adopted, in summarizing satellite data into 2° square area averages, of choosing the nephanalysis cloud category that most filled the square as the observation for that satellite pass. The categories were not averaged. For example, if, in a particular satellite pass, the nephanalysis showed a particular 2° square area to be mostly covered by code 4 cloud cover but partially covered by code 1, code 4 was chosen as the cloud condition for that square and satellite pass.

It must be emphasized that the system employed in formulating these cloud charts can be affected by several possible sources of error. The subjectiveness of the data handling technique, with its assignment of weighting factors and mean cloud amount to neph-code, could easily introduce a data bias. Variations in interpretation of cloud amount by the satellite data analysts and degradation of the vidicon tube with time can also adversely affect results (Clapp, 1968). The degradation caused by temperature increases or decreases of the vidicon camera system from late 1966 onward, does cause an underestimation of thin cirrus and/or clouds of low albedo but does not tend to effect the interpretation of clouds of higher albedos (Schwalb and Gross, 1969).

SATELLITE CLOUD CLIMATOLOGIES

A method of averaging satellite data for a cloud cover climatology was suggested by Clapp (1964). He used satellite nephanalyses and digitized these data by assigning code numbers to the nephanalysis cloud cover categories. The code numbers appropriate to each 5° square were averaged for the averaging period and converted to mean cloud amount.

Sadler (1968) also formulated a cloud climatology from satellite nephanalysis data. He averaged the cloud amounts using an octadic scale that corresponded to each nephanalysis category, directly into 2-1/2° square areas over monthly periods in the tropical belt 30°N to 30°S around the world. Note that Sadler's charts for April 1967 (Figure 1) compare only qualitatively with the large-scale cloud features shown in our April 1967 chart (Figure 2).

Taylor and Winston (1968) produced monthly brightness averages from global television analog data; a sample is shown in Figure 3. Eleven levels of brightness are indicated by digits 0 through 10. Brightness levels 4 and 5 appear to correspond to heavy cloud cover in the eastern and southwestern Pacific, while levels 1 and 2 overlie the area of clear skies shown in Figures 1 and 2.

Booth and Taylor (1968) utilized digitized video data to produce full resolution and eight-fold reduction of brightness data on a polar stereographic or Mercator base. Minimum, maximum, and average brightness charts have been produced operationally for various time periods, i.e., 5, 10, 15, 30, and 90 days. However, this satellite vidicon system, with its non-uniform cloud brightness from satellite to satellite and its lack of on-board calibration, has permitted researchers to use relative cloud brightness as only an approximate measure of true cloud cover.

Kornfield and Hasler (1968) experimented with a photographic technique for combining ESSA satellite photographs. Daily satellite pictures were photographed one after an other on the same film to produce a monthly picture of the combination. Figure 4, the photographic combination of April 1967 ESSA III television pictures, illustrates the technique; it is reproduced here, with permission of the researchers, for comparison with the other April 1967 cloud climatologies, Figures 1, 2, and 3. The product of photographic averaging must be carefully interpreted in order to express the data in conventional terms of total cloud cover. It is of interest to note, in Figure 4, that details such as the cloudband at 5° to 7°S in the southeastern Pacific, the cloudy California current area in the northeastern Pacific, and the Southern Hemisphere Convergence Zone indicated by the band of cloud oriented northwest to southwest through Samoa are faithfully reproduced. Cloud-free regions are shown by darker photographic tones. Monthly cloudiness composites of ATS spin-scan camera pictures have also been assembled by this research team.

Bohan (1969) utilized another photographic system to produce mean monthly composites from rectified ESSA III photographs. An example of this composite technique for April 1967, reproduced here with permission of the author, is shown in Figure 5. The cloud image detail reproduced in this composite is similar to that produced in Figure 4 by Kornfield, and is useful in making monthly film loops for climatological research.

Barnes and Chang (1968) have used multichannel radiometer data from the Nimbus II satellite to examine the relationship of light reflection to cloud amount, cloud type, and cloud thickness. They found variation of 25% in light reflection from clouds of the same type and of 50% to 70% in reflection from clouds of different types. Godshall (1968, b) has shown that there is 100% variation in the transmittance of light, in the visual range through overcast cloud cover. In general, one would expect that the greater the transmittance of light through the cloud, the less is the reflectance from the cloud. One must conclude that there is a great variation of reflected light from an overcast cloud due to its opacity (i.e., thickness, droplet size distribution, and liquid and ice content). Cloud morphology or nature of cloud top surface also would be expected to affect cloud-top reflectance.

MONTHLY CLOUD COVER

The mean cloud cover for the months January, April, August, and October from August 1962 through 1968 is shown in the Appendix, in Figures A1 through A25. These months were selected to represent cloud conditions during specific periods of the seasonal oscillation in the large-scale wind circulation in the tropical Pacific Ocean. The mean monthly positions of the intertropical convergence (ITC) zone (Allison et al., 1969) were chosen as the indicator of the low-latitude circulation season. January and August were selected because during these months the ITC is positioned farthest to the south and north, respectively, from the equator in the western Pacific. April and October represent conditions during which the oceanic circulation was midway between the winter and summer regimes.

The areas enclosed by the isonephs (6/10 and greater) in the chart analyses were shaded to highlight the important cloud zones, and dashed lines were used to indicate regions of limited data coverage. The shaded areas of each chart were planimetered to determine the area covered by the 6/10 or greater cloud amount. A histogram (Figure 6) of the planimetered data for the latitude band 10° to 20°N latitude in the area of analysis between 100°W and 180°E illustrates the variation of cloud cover from 1962 to 1968.

Easily recognized climatological features are distinctive in the individual monthly charts. The east-west band of clouds between 5° and 10°N, shown typically in August 1962 (Figure A1), is associated with the intertropical zone of convergence and the location of the warm equatorial countercurrent. The clearer region from 5°N to 10°S in the central Pacific is believed to be related to the intensity of the cold upwelled water of the South Equatorial Current, which is in turn dependent upon the strength of the South Pacific Anticyclone (Berlage, 1966; Bjerknes, 1969, a, b).

A zone of cloudiness associated with northeast-southwest frontal systems which had penetrated to low latitudes is shown in the northwestern section of the January 1963 chart (Figure A3). An analogous zone of cloudiness extends northwest-southeast from the Solomon Islands toward Samoa and is well defined in the January 1967 chart (Figure A19). This South Pacific Convergence Zone had been identified by Gabites (1943). Additionally, typical low-level cloudiness associated with the cool upwelled water of the California Current in the eastern Pacific is shown on the same chart.

SATELLITE DATA COVERAGE

The monthly cloud charts were assembled from nephanalyses which were based upon TIROS V, VI, VII, VIII, IX, and X and ESSA I, III, V, and VII television pictures. Descriptions of the satellite data and camera systems may be found in the ESSA Key to Meteorological Records Documents listed with the references to this paper. TIROS V, VI, VII, and VIII camera systems did not provide overlapping pictures of the equatorial regions, but the remaining five satellites mentioned above, did have this coverage. Table 3 presents a summary of data coverage used in each of the monthly charts.

Table 3.

Satellite Data Utilized for Monthly Cloud Cover Charts.

Months		Number of Satellite Orbits Providing Television Data	Minimum and Maximum Number of Data Values per 2° Area
August	1962	62	1 to 15
October	1962	119	0 to 20
January	1963	118	0 to 11
April	1963	160	3 to 19
August	1963	115	0 to 11
October	1963	96	1 to 12
January	1964	177	0 to 14
April	1964	131	0 to 18
August	1964	115	0 to 21
October	1964	143	0 to 19
January	1965	101	2 to 15
April	1965	122	3 to 30
August	1965	103	0 to 15
October	1965	101	0 to 19
January	1966	92	Almost daily observations of cloud data available for each 2° square area (January 1966 – January 1968)
April	1966	192	
August	1966	141	
October	1966	153	
January	1967	Daily coverage of the analysis region (January 1967 – January 1968)	
April	1967		
August	1967		
October	1967		
January	1968		
April	1968		
August	1968		

CONCLUSIONS

It is evident from the monthly charts of cloud cover (Figures A1 through A25) and the histogram of planimetered cloudiness data (Figure 6) that there is considerable variability of cloud amount in the tropical Pacific even for similar months of different years. Thus, significant differences in monthly cloud amounts would be found if one compared these satellite-derived cloud averages to long-term means such as those presented for each month in published atlases (U. S. Navy, 1959), (U. S. Department of Commerce and U. S. Navy Hydrographic Office, 1961). At the present time, there is no completely automated computer processing technique which is completely satisfactory for conversion of satellite pictures of clouds into terms of conventional surface observations of clouds.

High-resolution visible and infrared scanning radiometers with on-board calibrations to be flown on the TIROS M and ITOS spacecraft may be more responsive to the true cloud brightness/cloud cover relationship. If so, these new instruments should permit the more rapid quantitative processing of the enormous volume of satellite data for the proposed Global Atmospheric Research Program (GARP) of the 1970's.

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Greenbelt, Maryland, October 15, 1969
160–44–03–02–51

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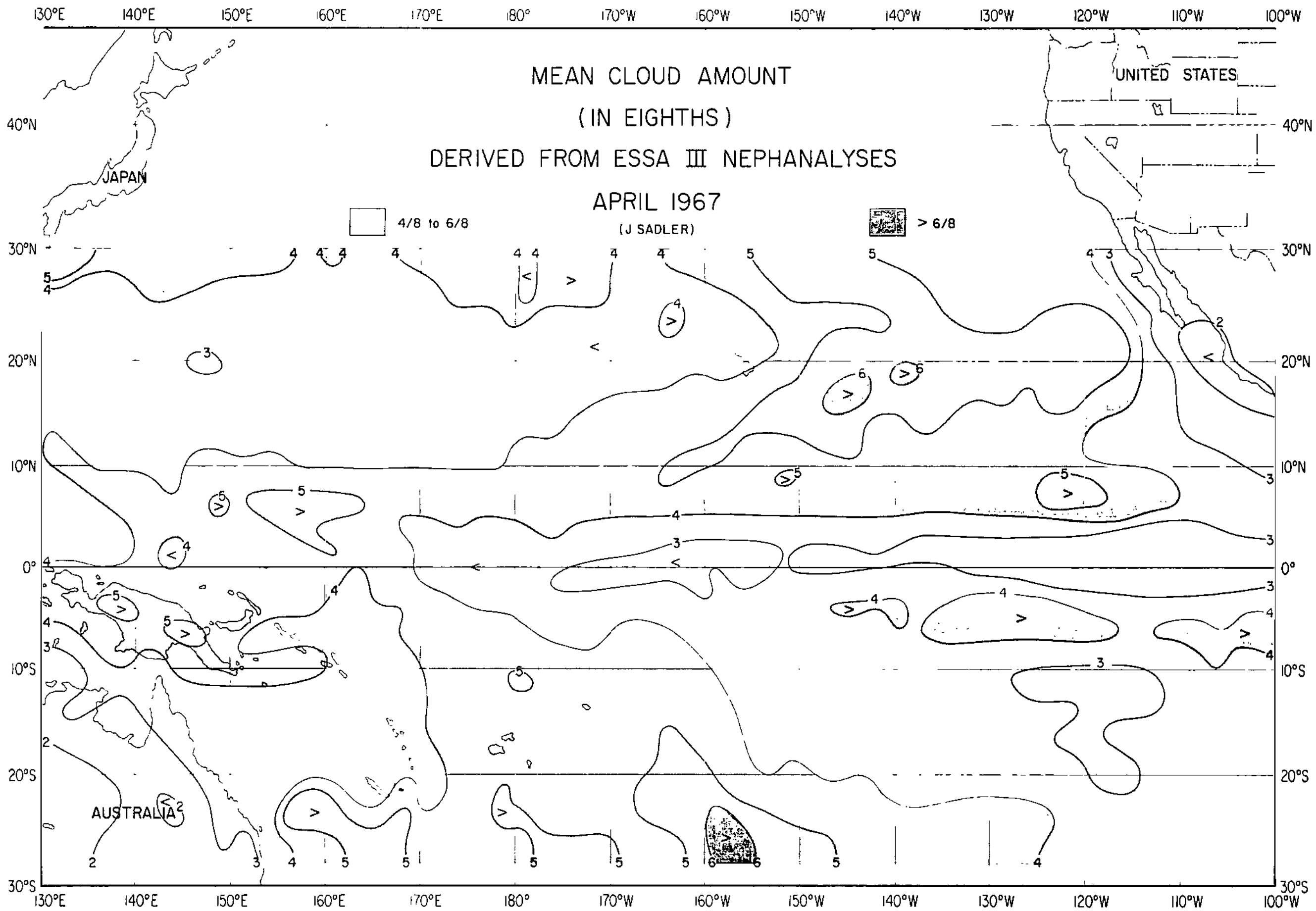

Figure 1—Mean cloud amount (in eighths) derived by Sadler (1968) from ESSA III April 1967 nephanalyses.

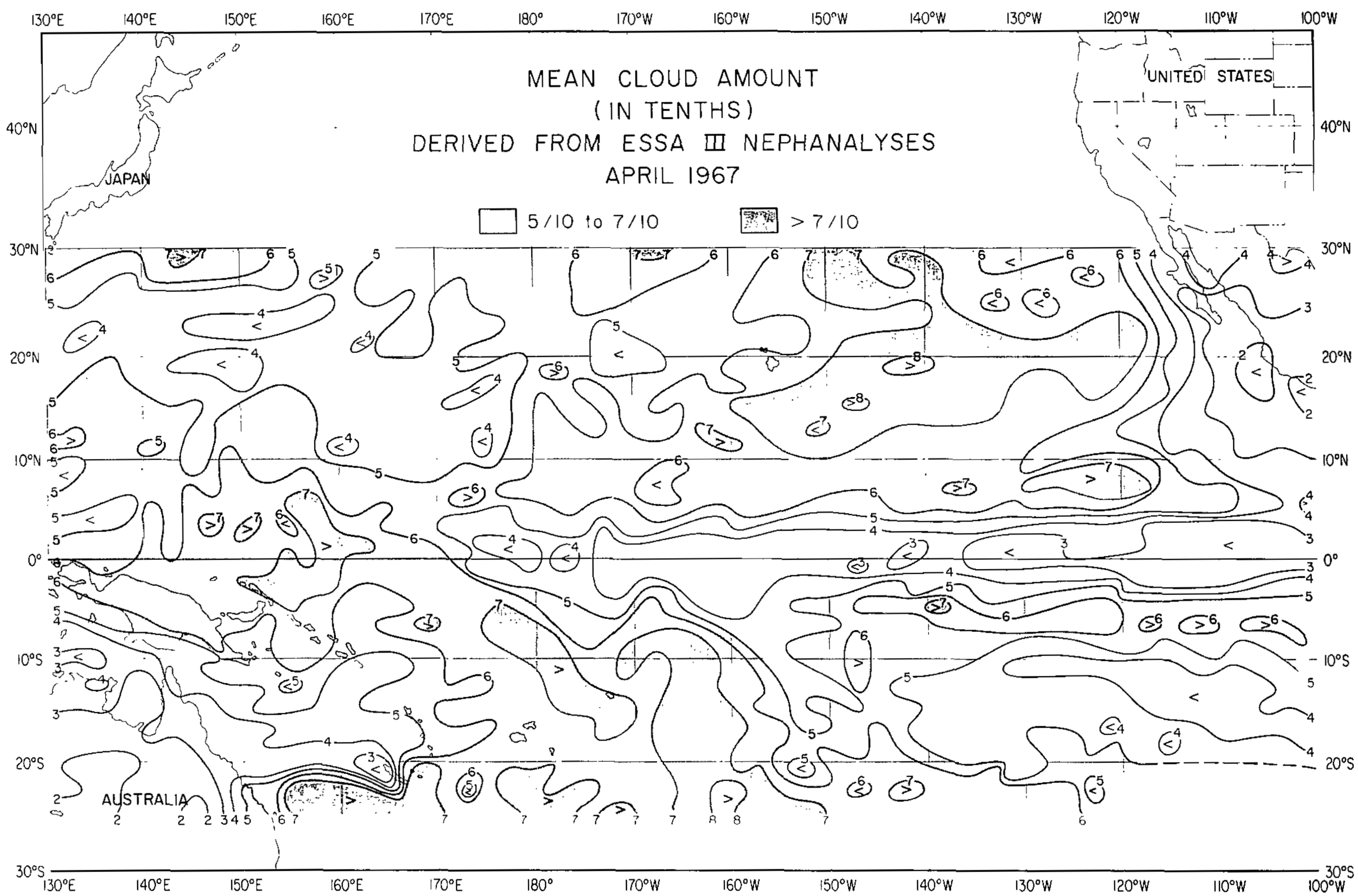

Figure 2—Mean cloud amount (in tenths) derived from ESSA III April 1967 nephanalyses.

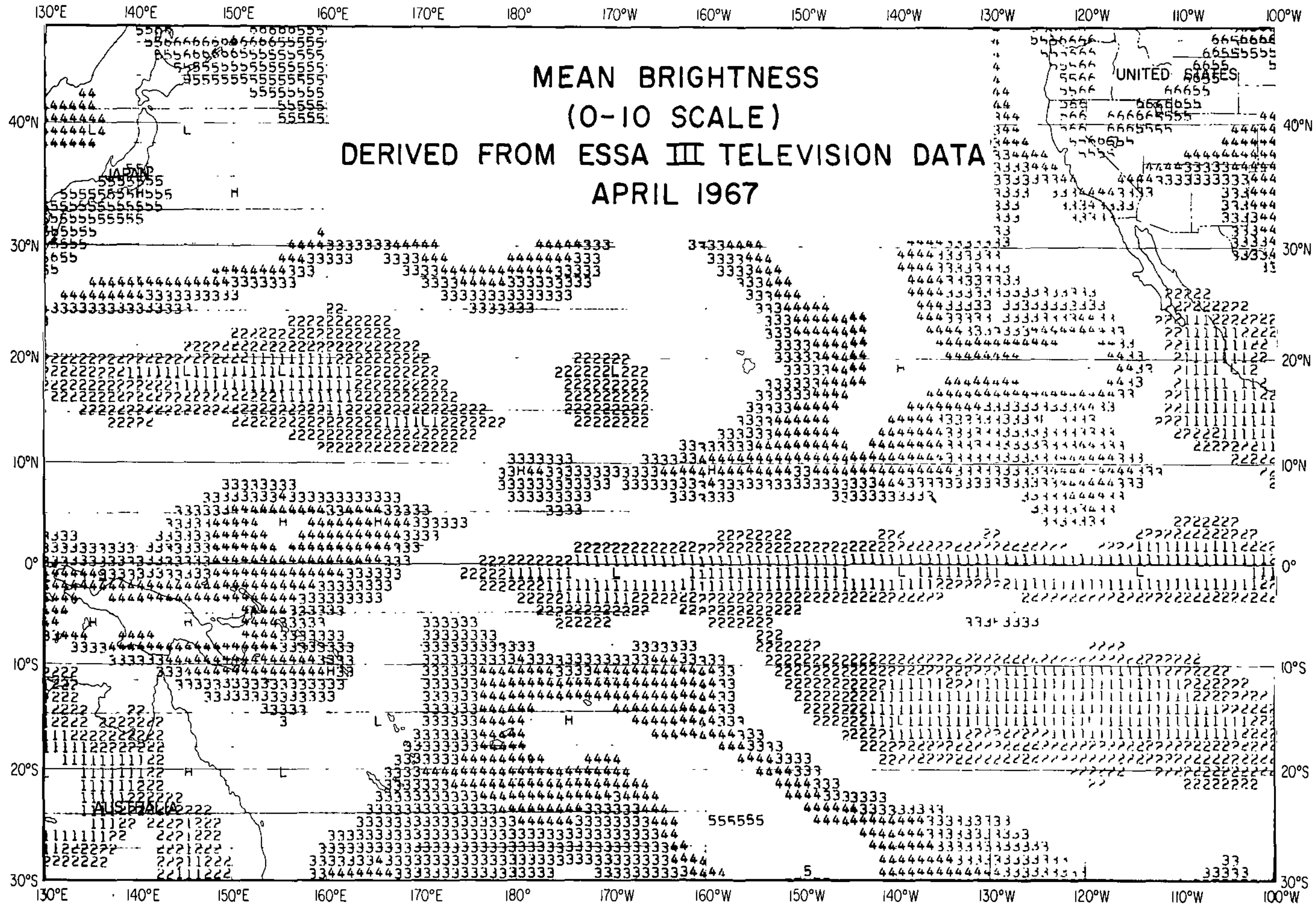

Figure 3—Mean brightness (0-10 scale) derived by Taylor and Winston (1968) from ESSA III April 1967 television analog data.

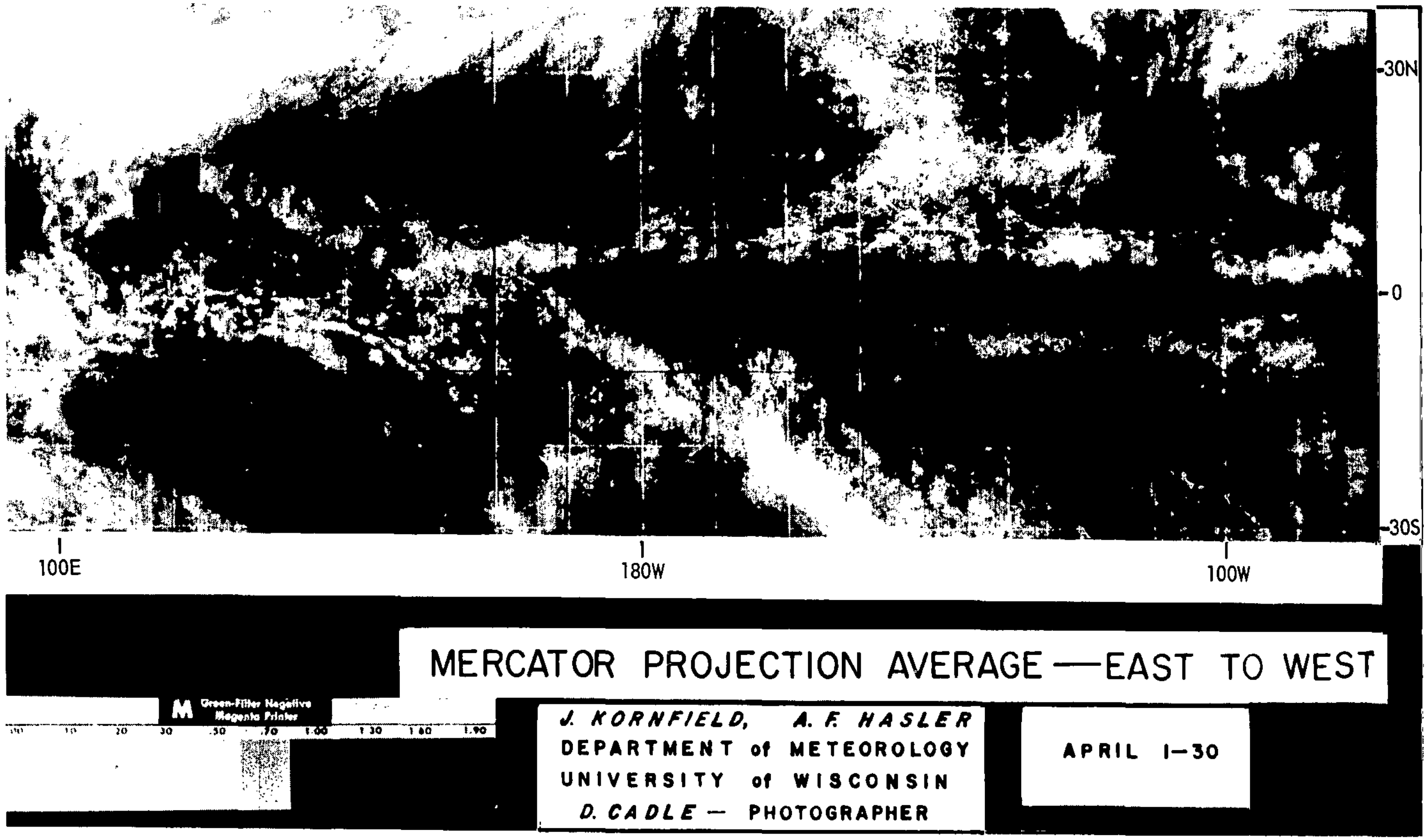

Figure 4—Monthly photographic composite by Kornfield and Hasler (1968) of rectified ESSA III April 1967 television pictures.

ONE-MONTH COMPOSITE CLOUD PATTERNS
ESSA 3 DIGITAL PRODUCT
APRIL 1, 1967 TO APRIL 30, 1967
(W. A. BOHAN)

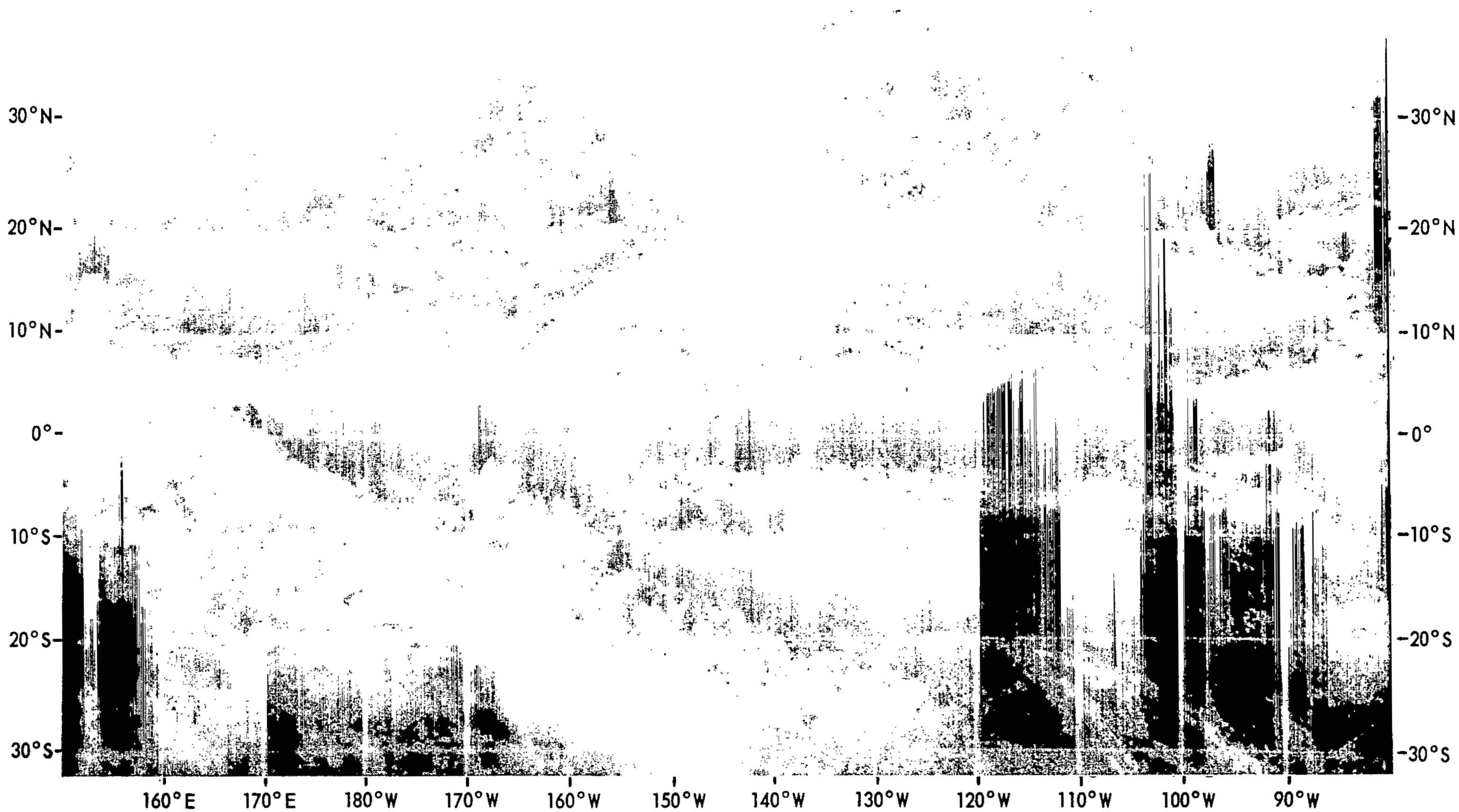

Figure 5—Monthly photographic composite by Bohan (1969) of rectified ESSA III April 1967 television pictures.

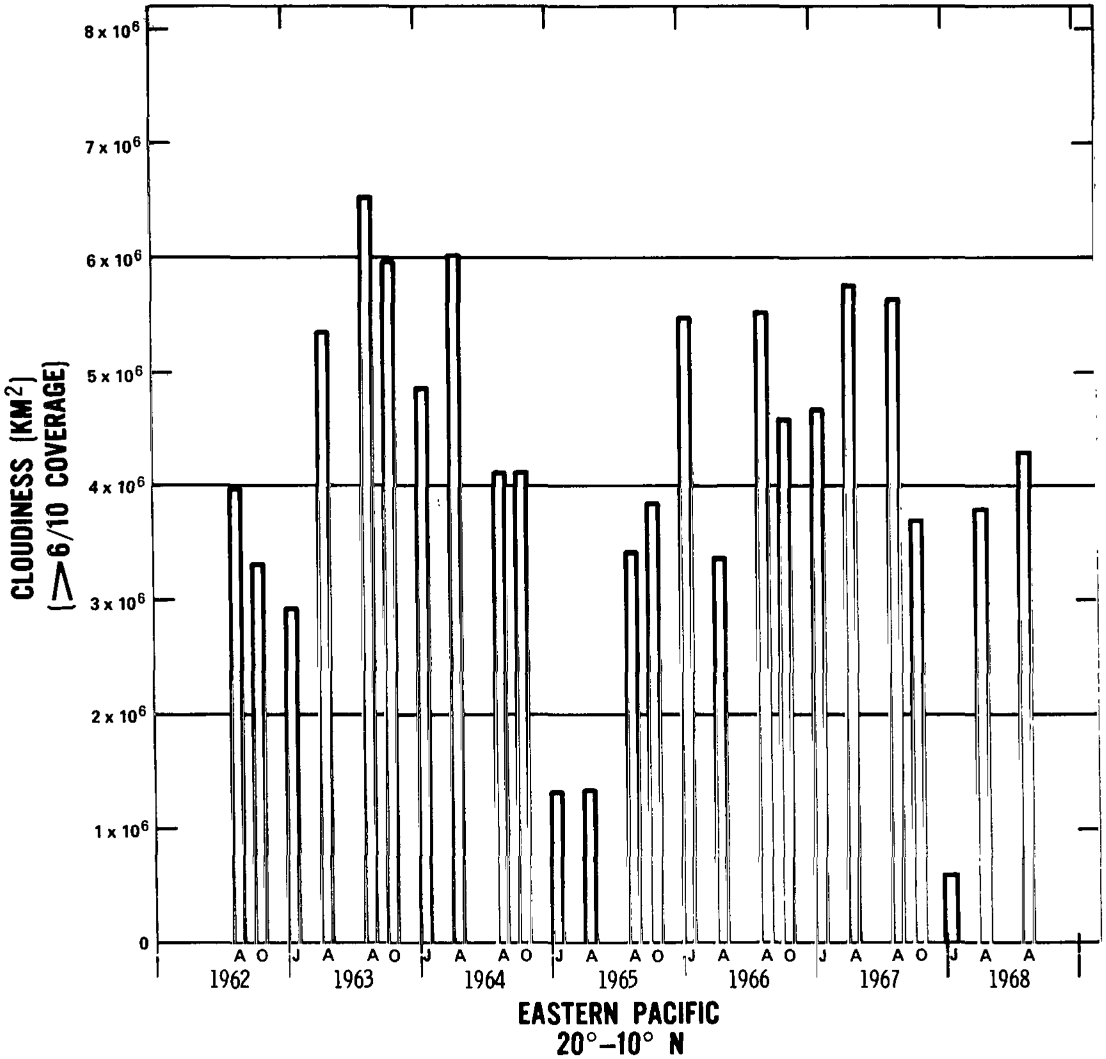

Figure 6—Histogram of planimetered area of >6/10 cloud cover in square kilometers over the northeastern Pacific Ocean, 10° to 20°N, 100°W to 180°.

Appendix A

Monthly Charts of Mean Cloud Amounts

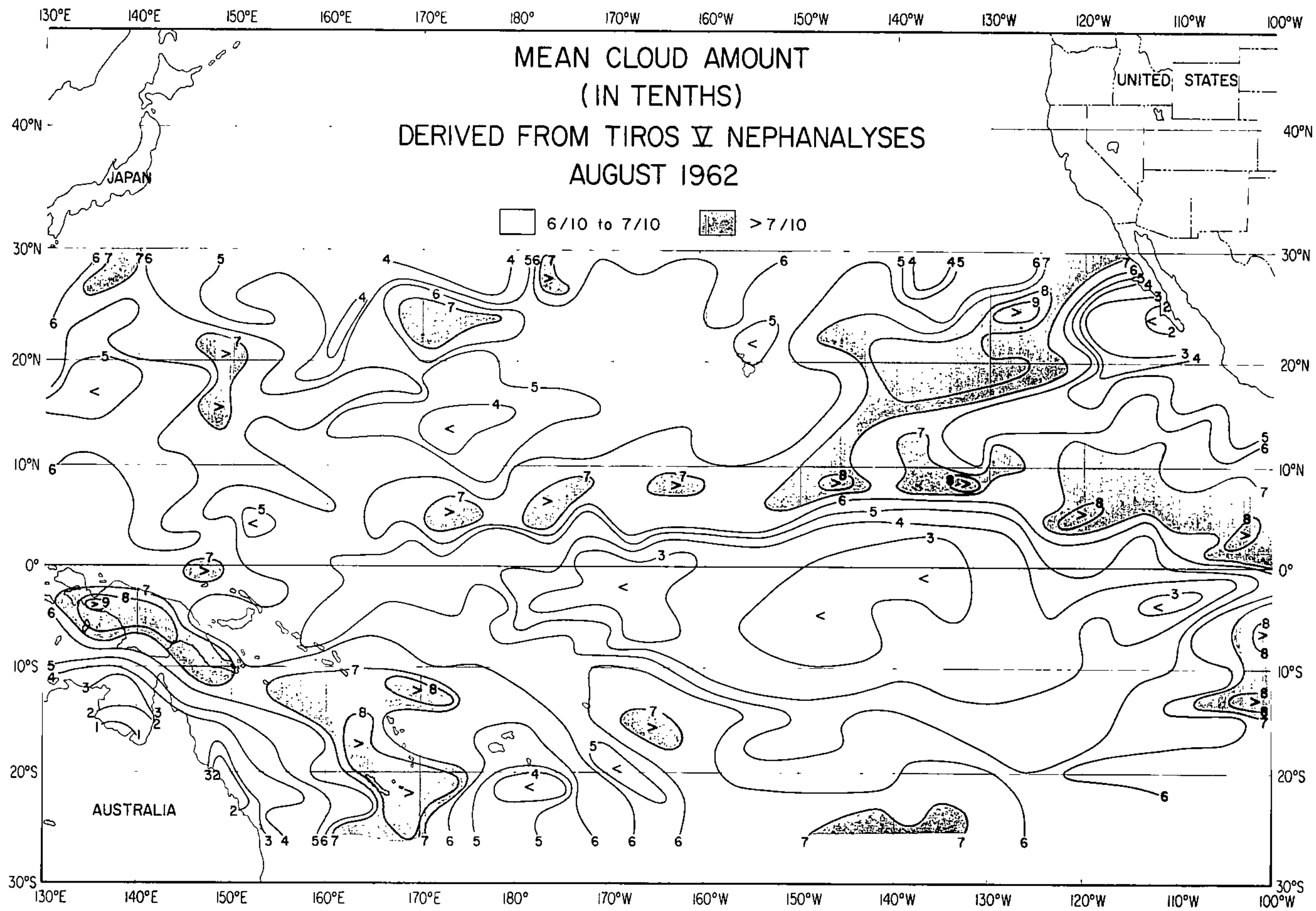

Figure A1—Mean cloud amount (in tenths) derived from TIROS V August 1962 nephanalyses.

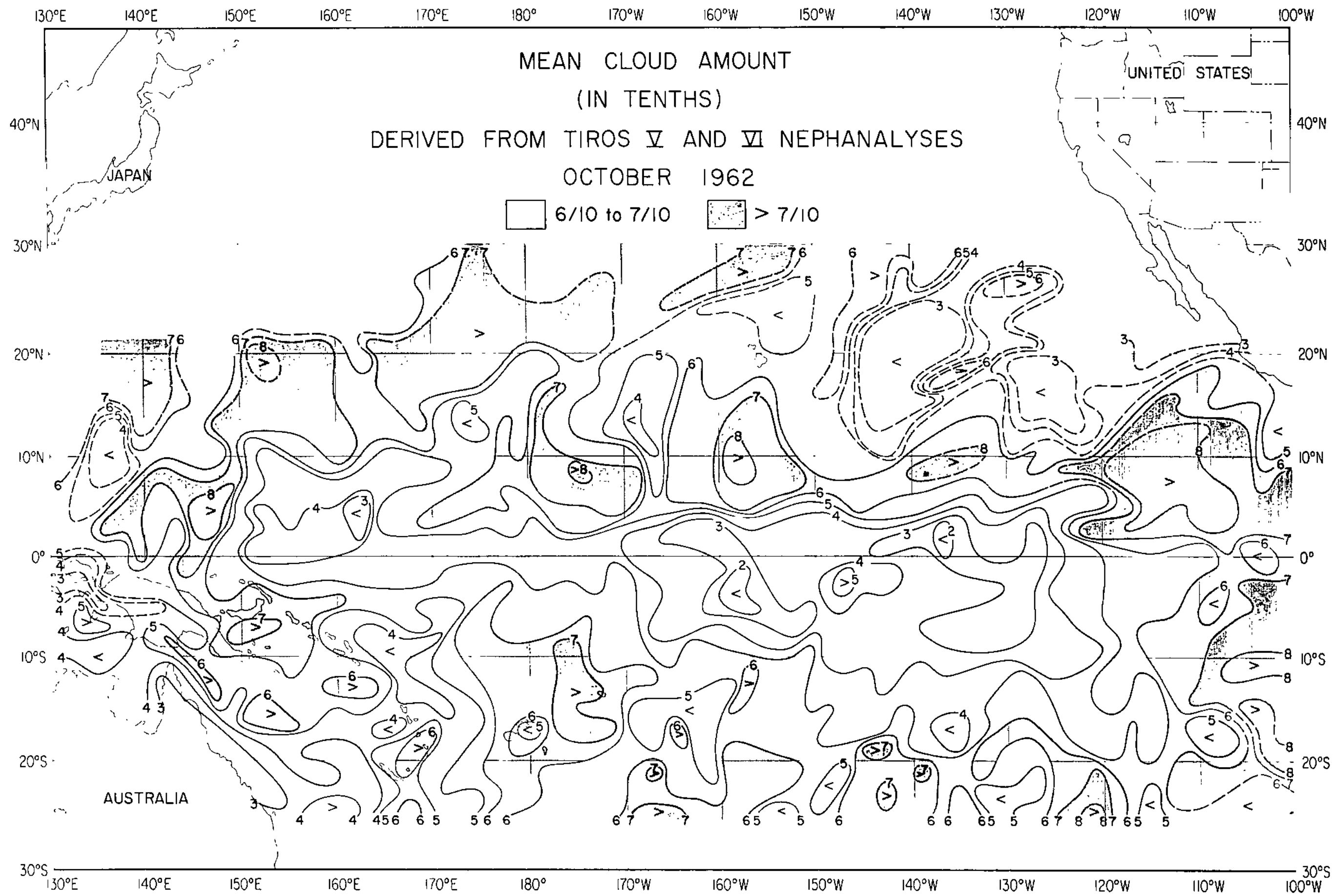

Figure A2—Mean cloud amount (in tenths) derived from TIROS V and VI October 1962 nephanalyses.

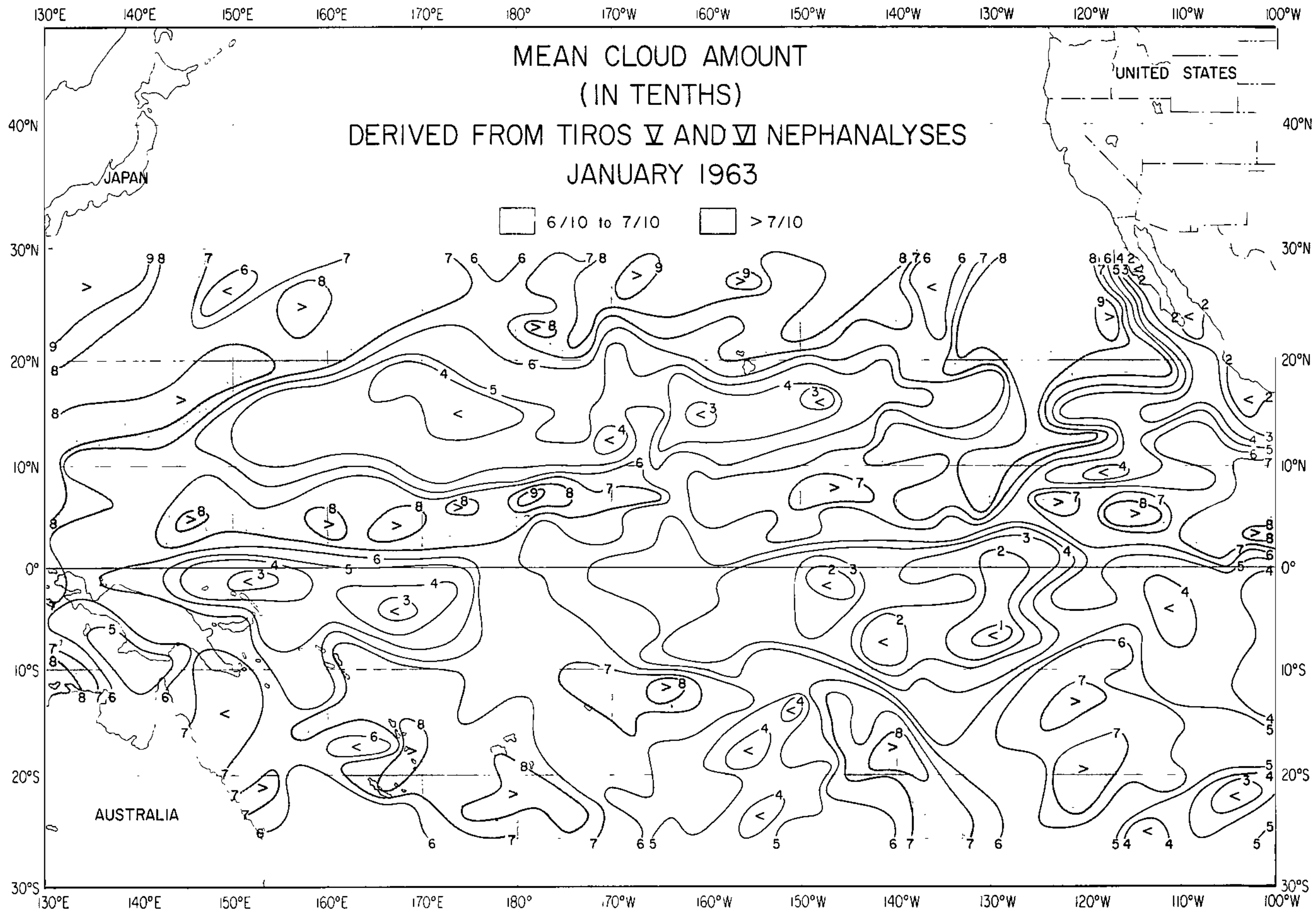

Figure A3—Mean cloud amount (in tenths) derived from TIROS V and VI January 1963 nephanalyses.

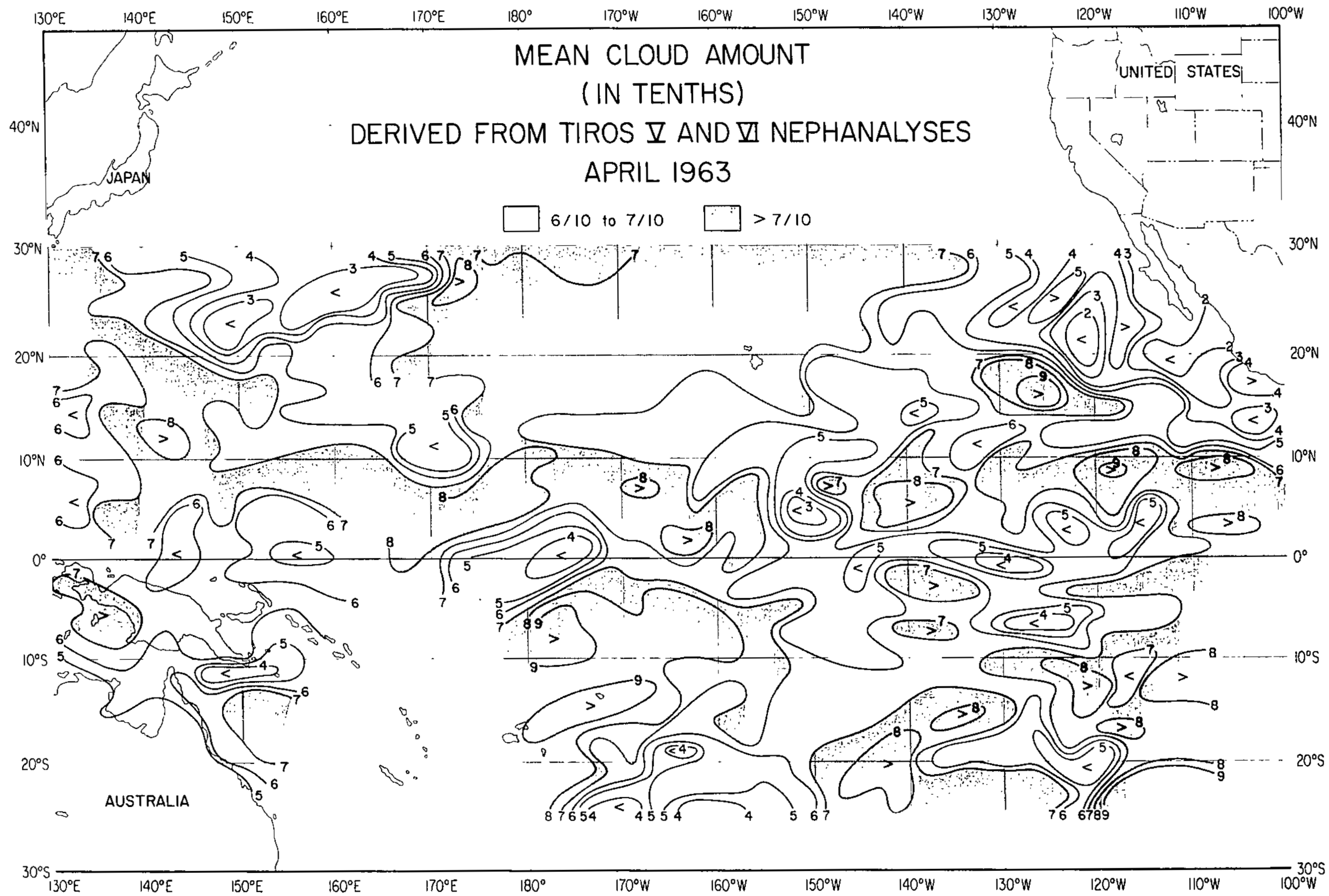

Figure A4—Mean cloud amount (in tenths) derived from TIROS V and VI April 1963 nephanalyses.

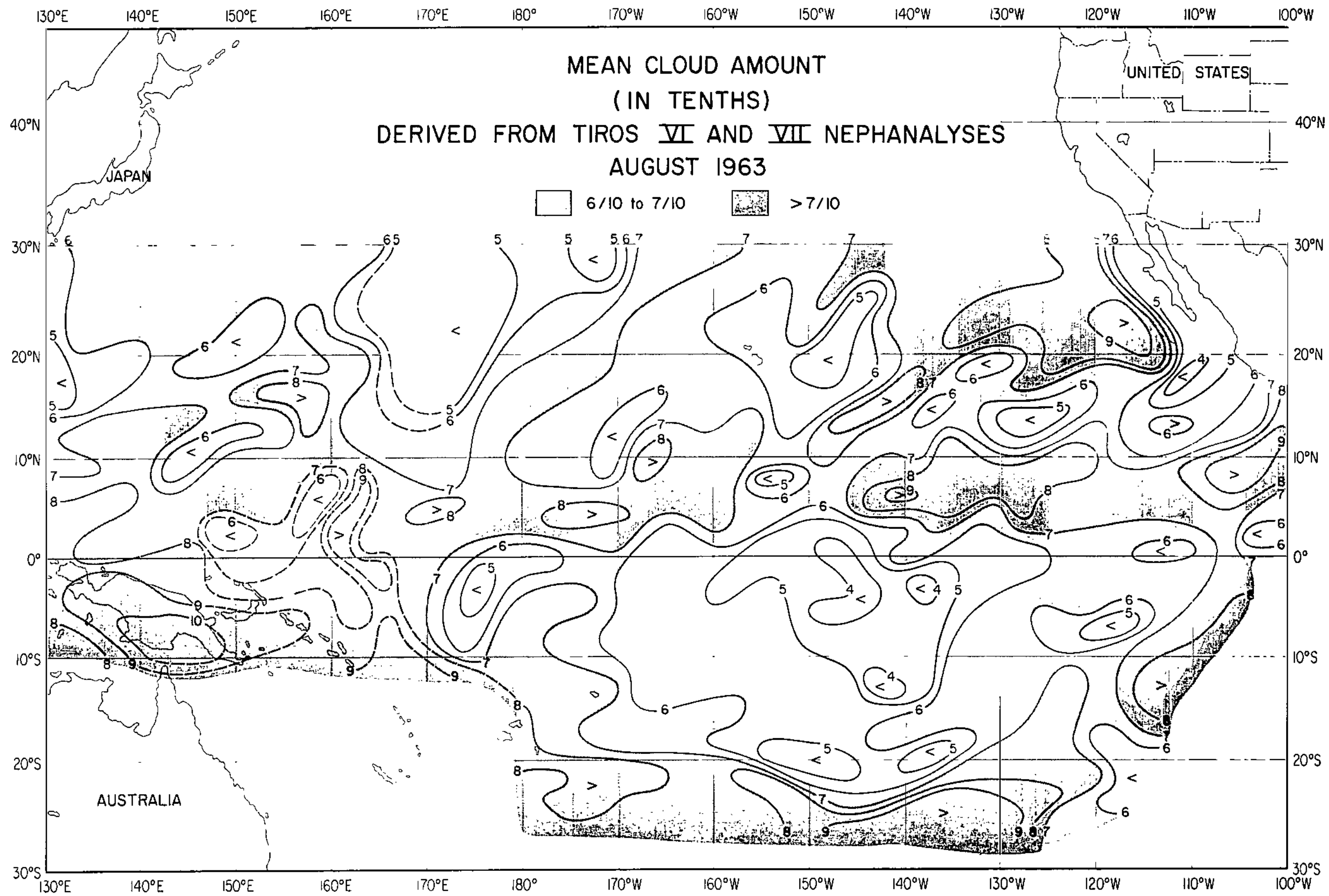

Figure A5—Mean cloud amount (in tenths) derived from TIROS VI and VII August 1963 nephanalyses.

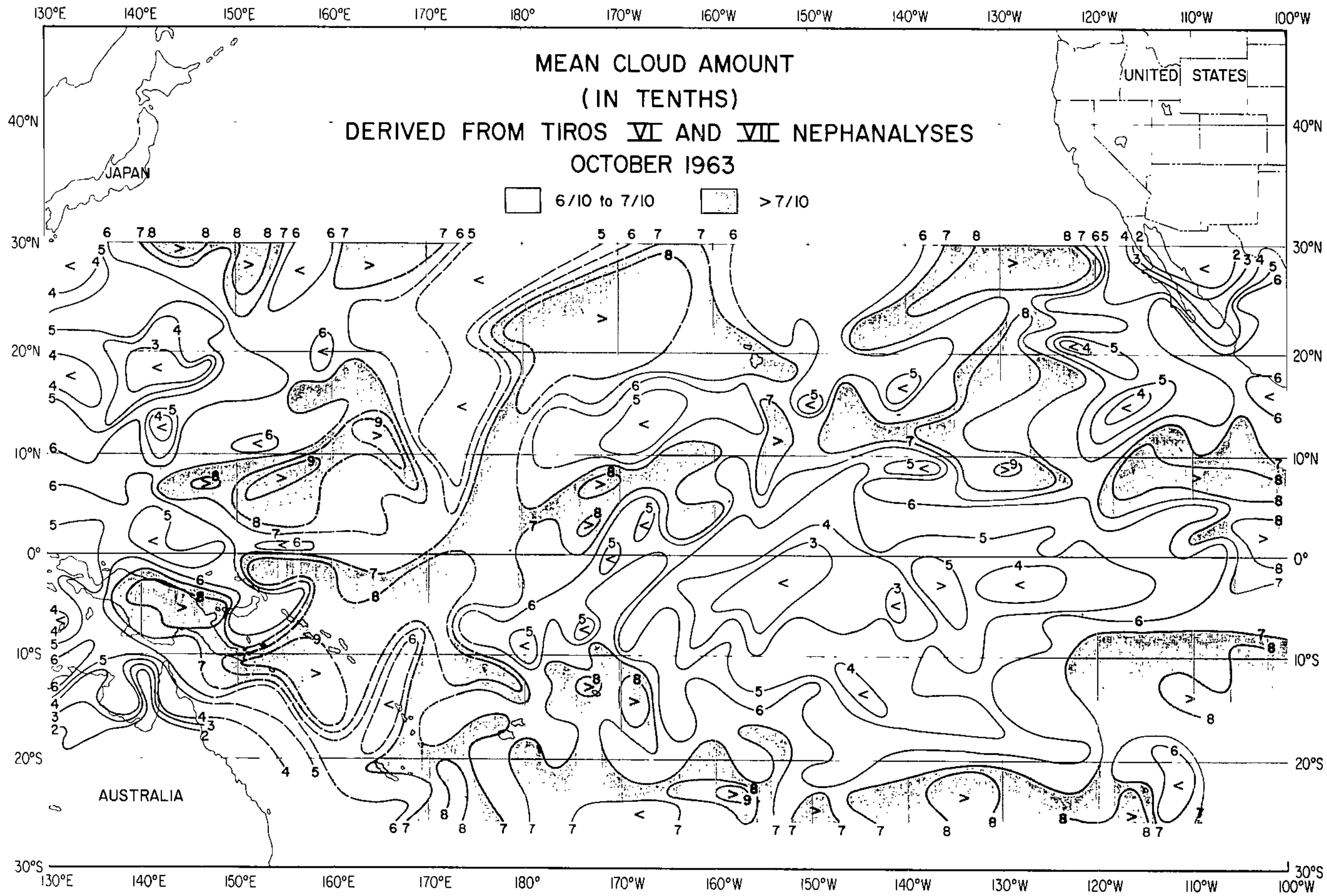

Figure A6—Mean cloud amount (in tenths) derived from TIROS VI and VII October 1963 nephanalyses.

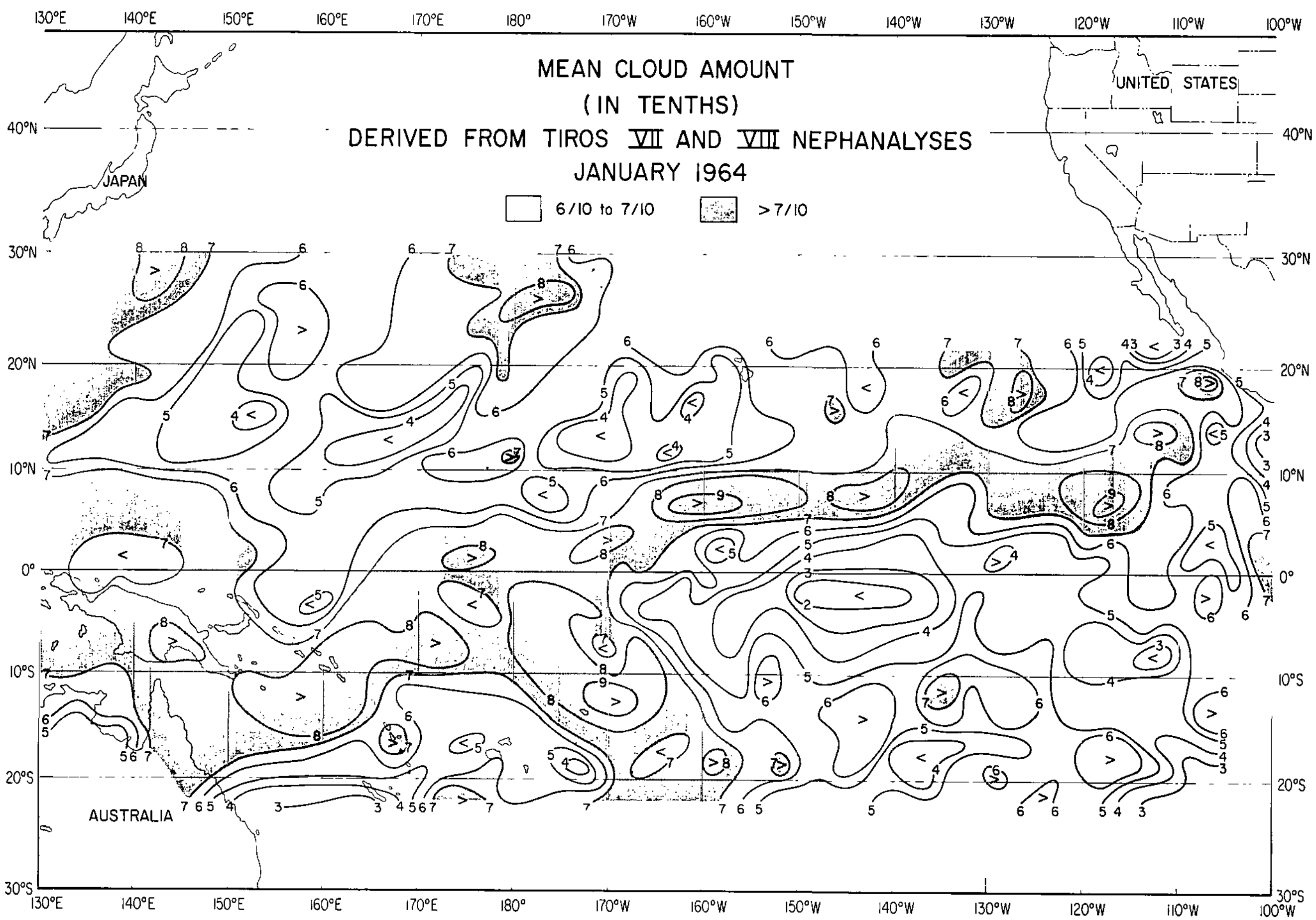

Figure A7—Mean cloud amount (in tenths) derived from TIROS VII and VIII January 1964 nephanalyses.

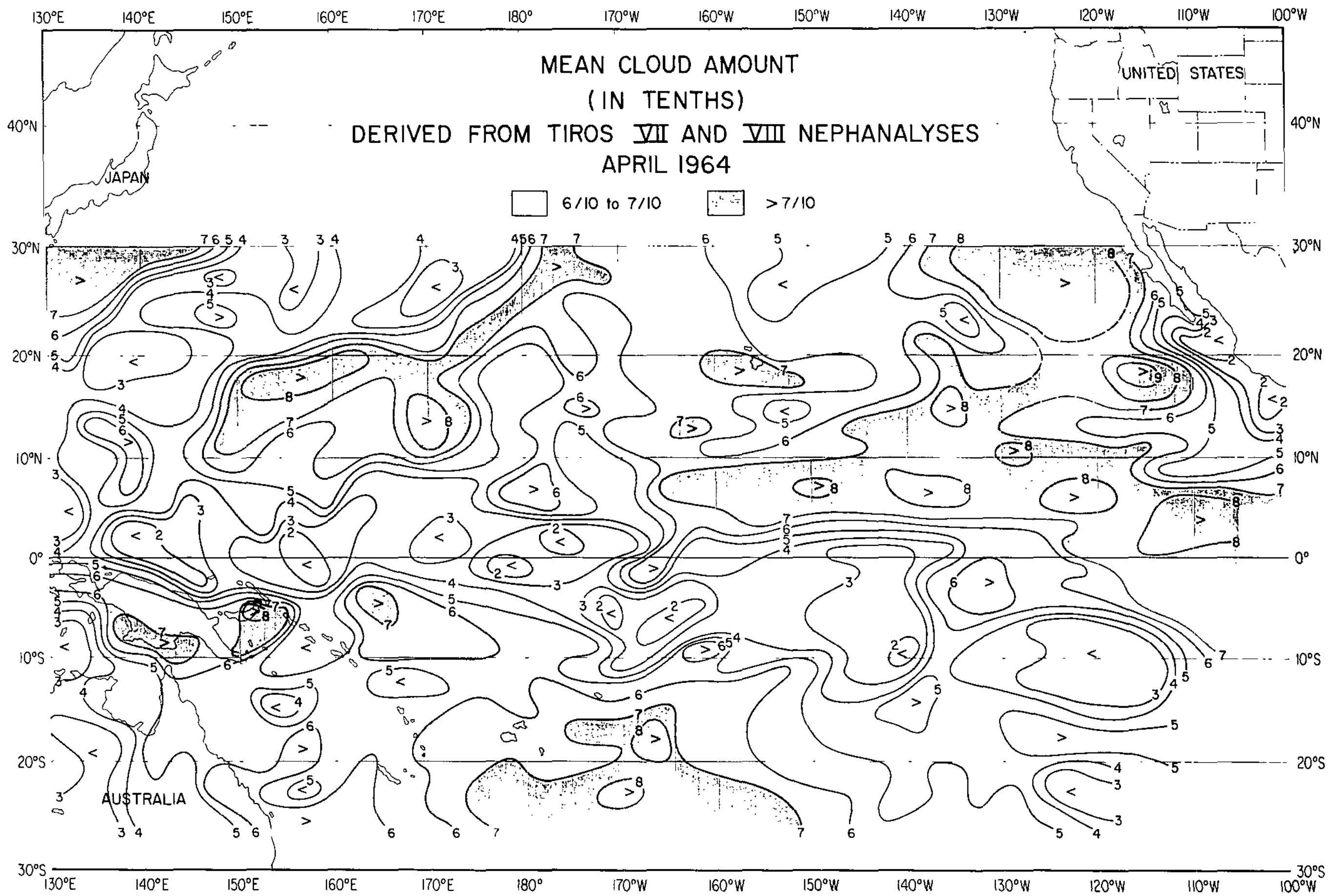

Figure A8—Mean cloud amount (in tenths) derived from TIROS VII and VIII April 1964 nephanalyses.

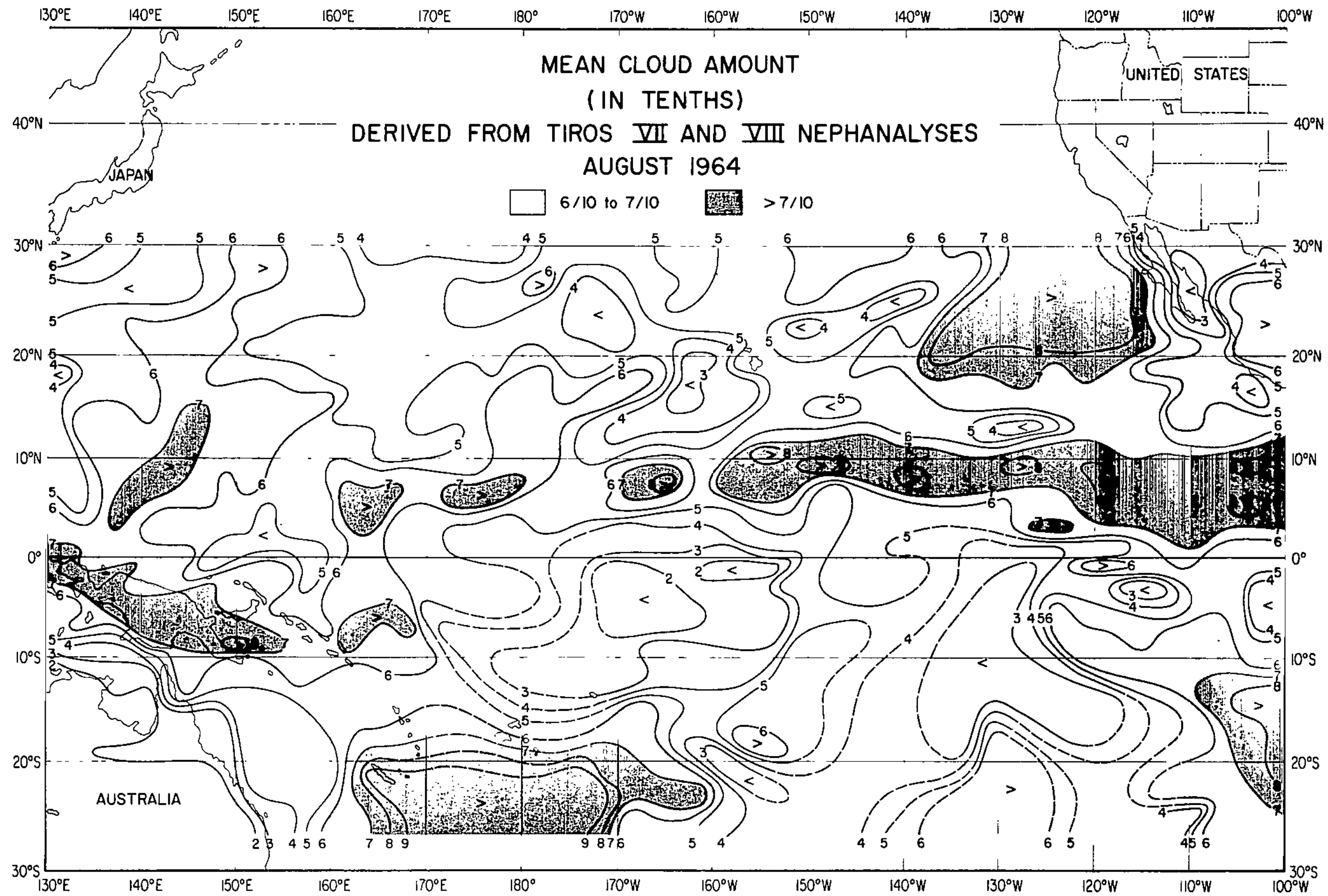

Figure A9—Mean cloud amount (in tenths) derived from TIROS VII and VIII August 1964 nephanalyses.

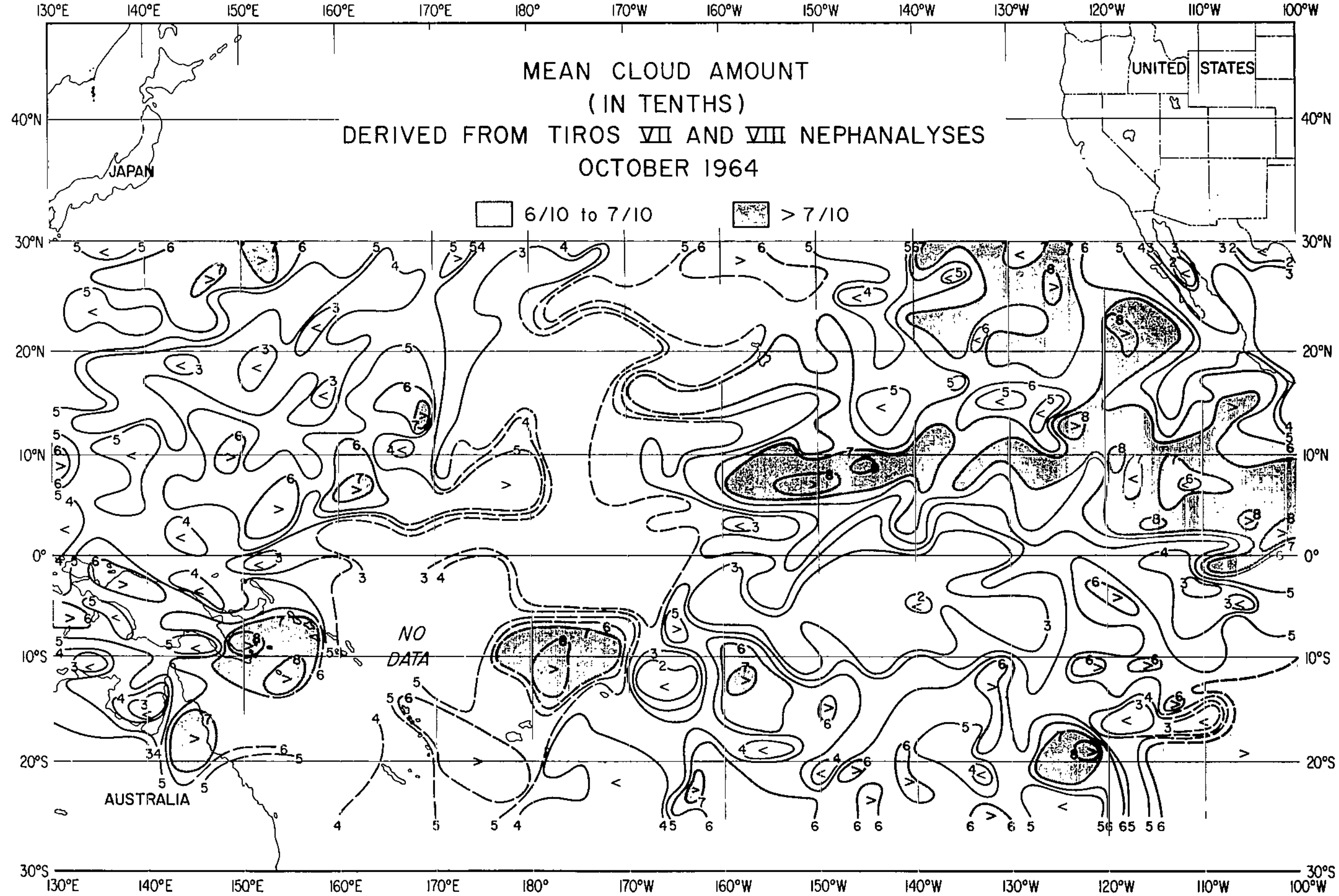

Figure A10—Mean cloud amount (in tenths) derived from TIROS VII and VIII October 1964 nephanalyses.

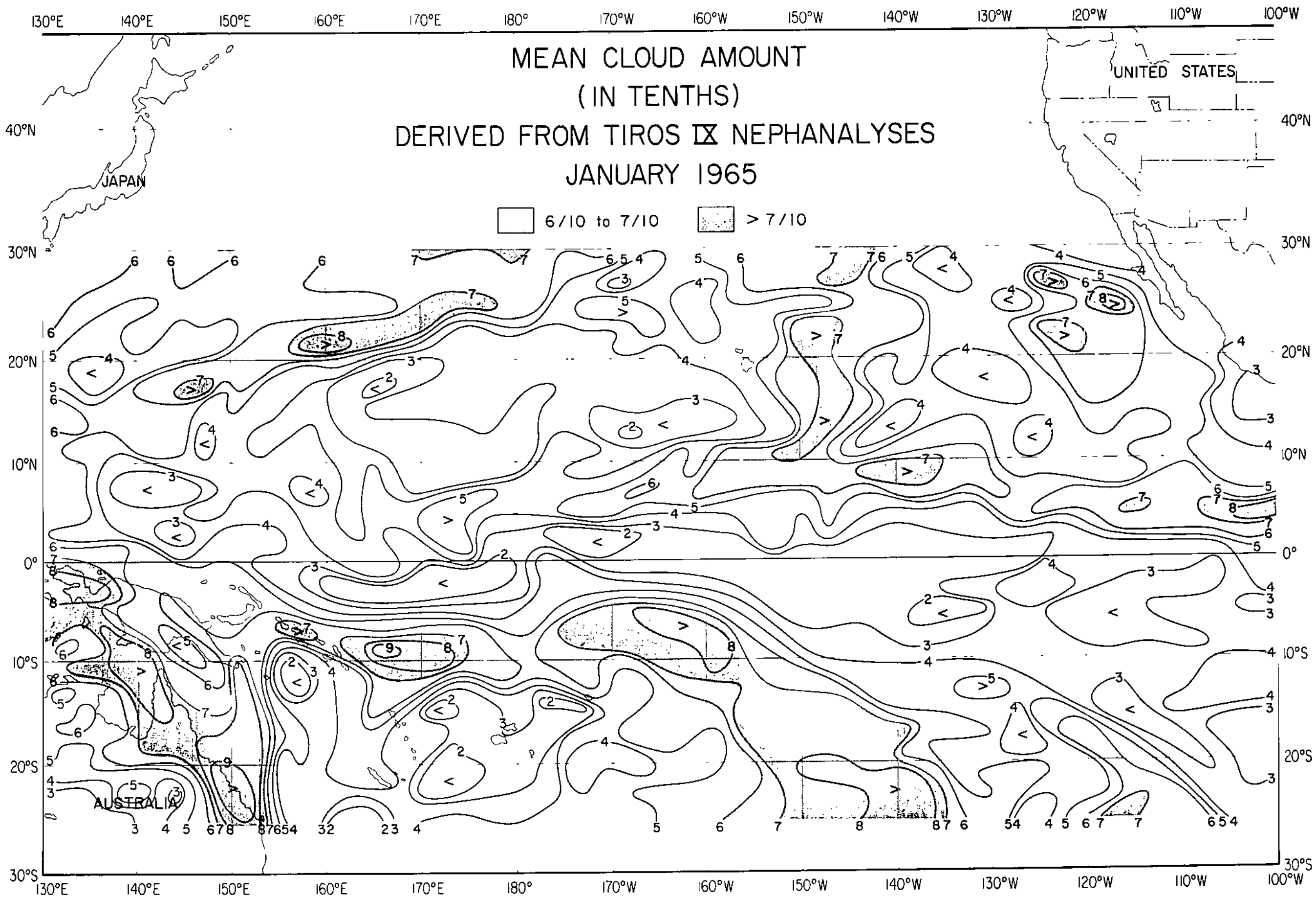

Figure A11—Mean cloud amount (in tenths) derived from TIROS IX January 1965 nephanalyses.

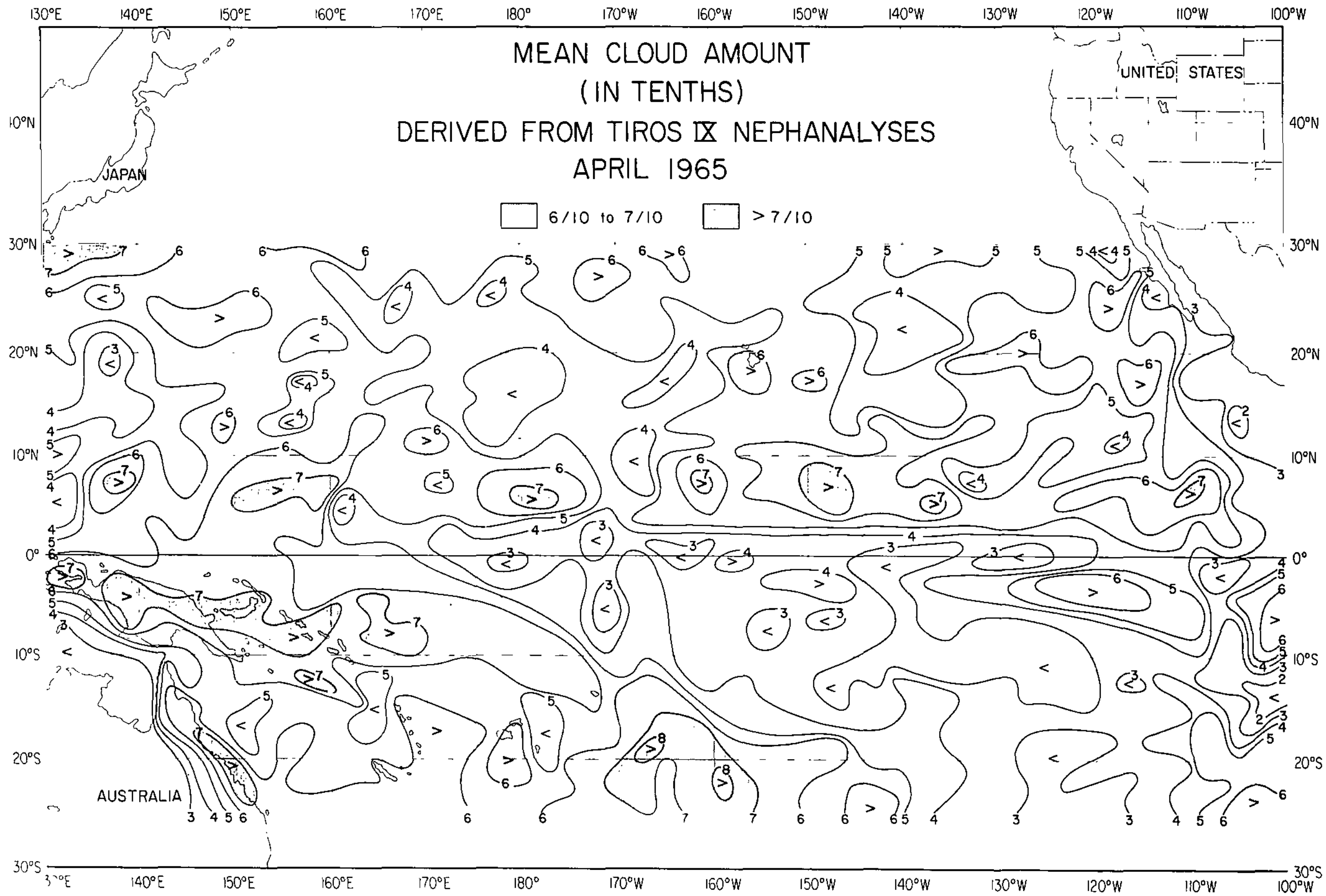

Figure A12—Mean cloud amount (in tenths) derived from TIROS IX April 1965 nephanalyses.

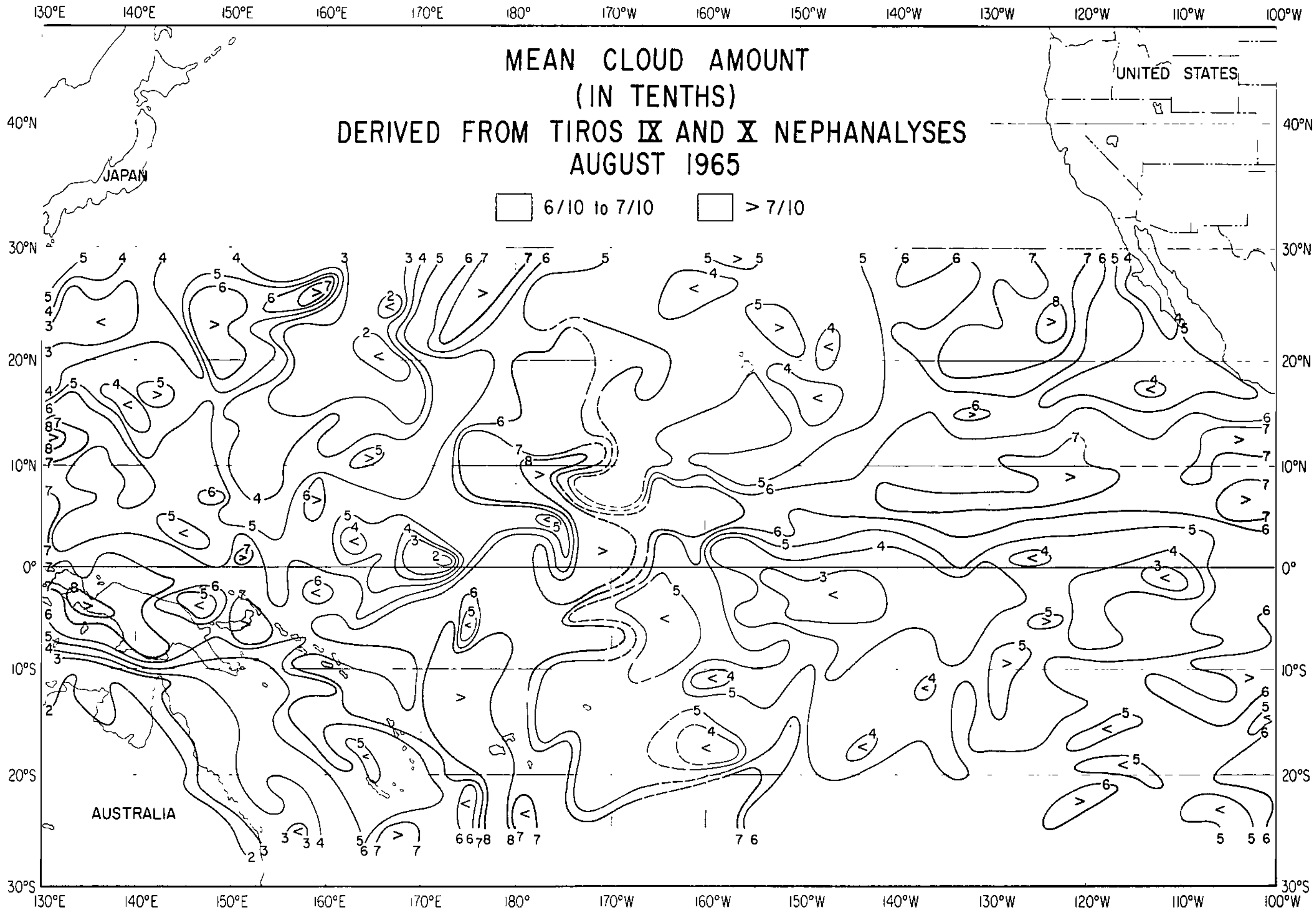

Figure A13—Mean cloud amount (in tenths) derived from TIROS IX and X August 1965 nephanalyses.

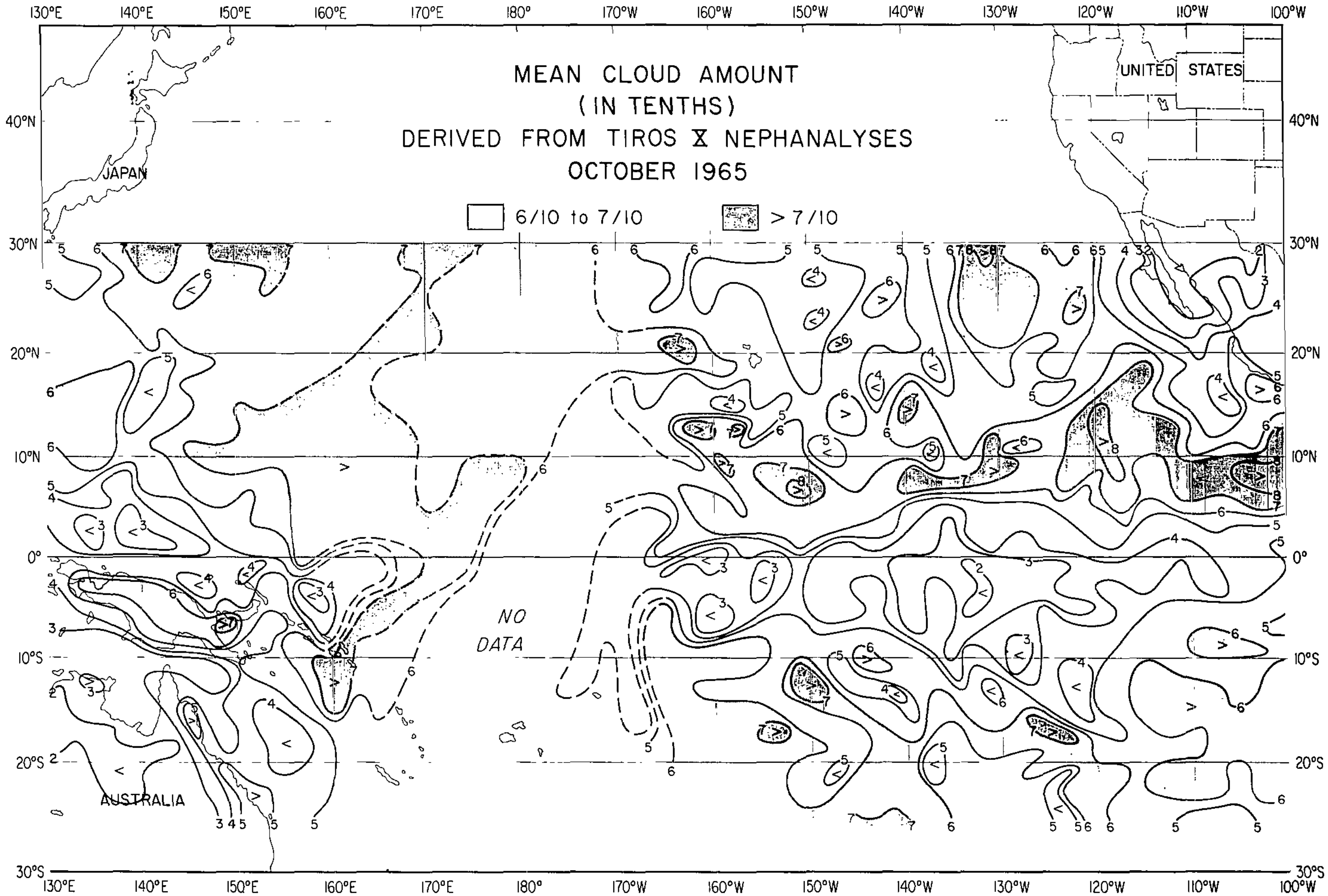

Figure A14—Mean cloud amount (in tenths) derived from TIROS X October 1965 nephanalyses.

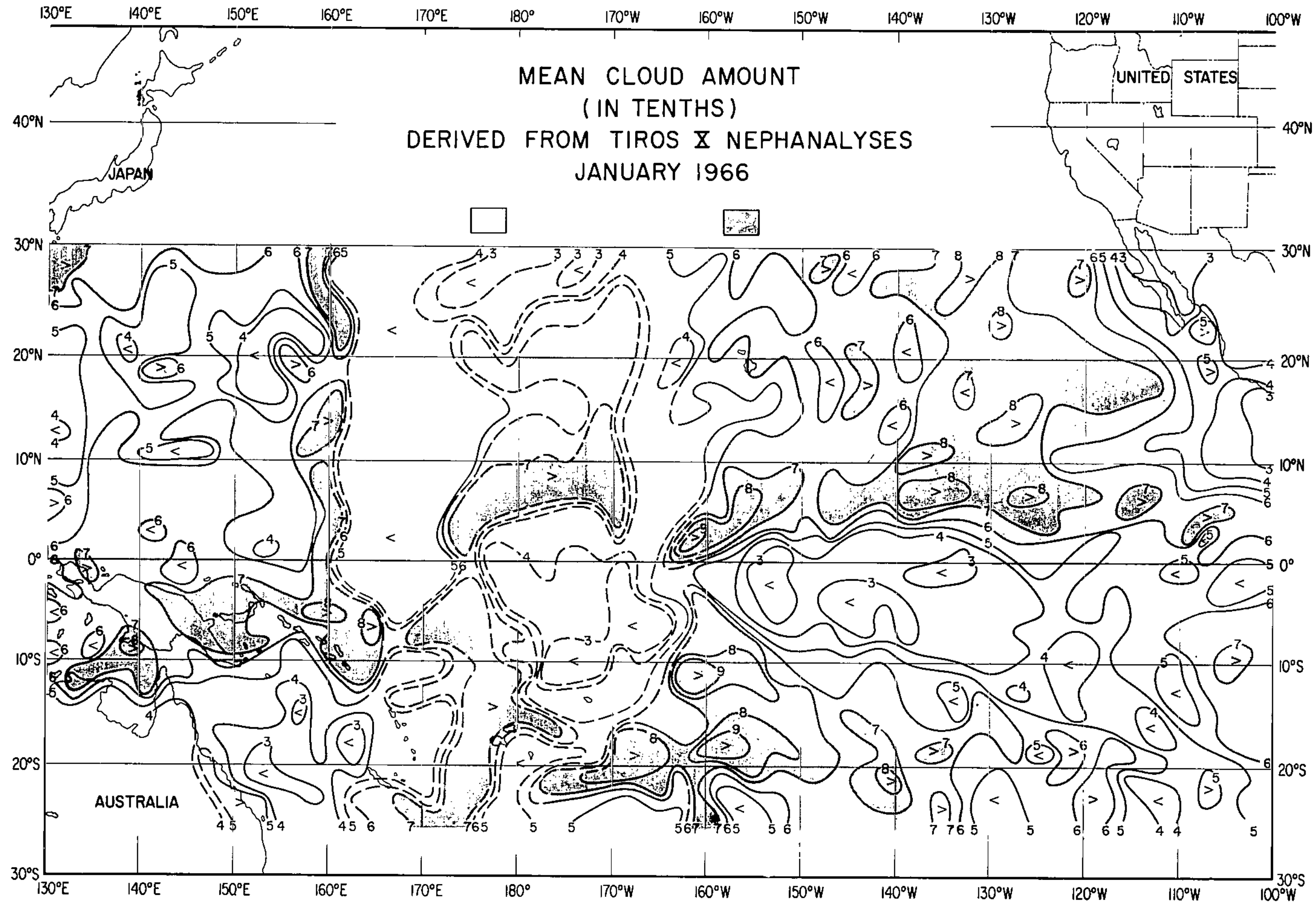

Figure A15—Mean cloud amount (in tenths) derived from TIROS X January 1966 nephanalyses.

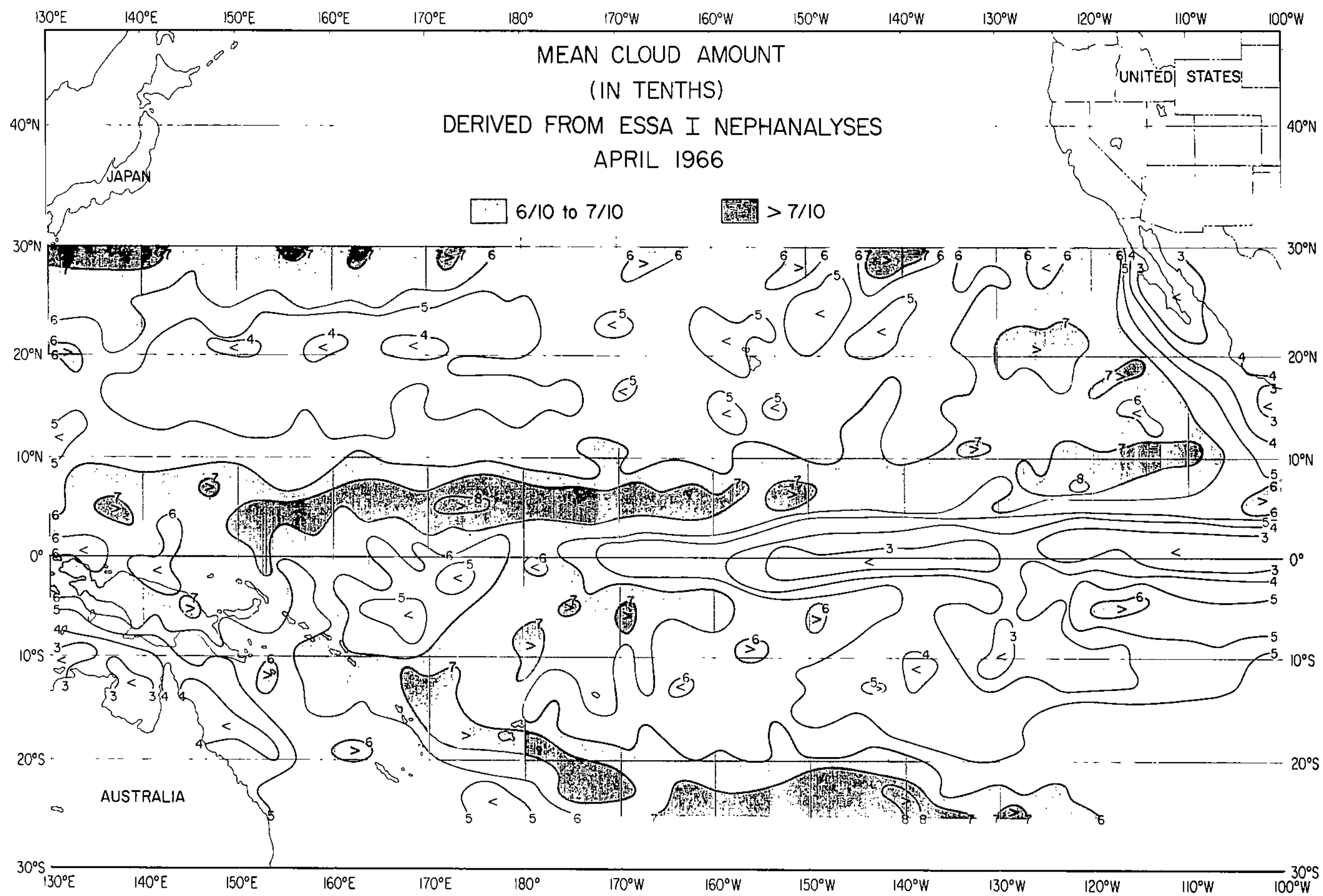

Figure A16—Mean cloud amount (in tenths) derived from ESSA I April 1966 nephanalyses.

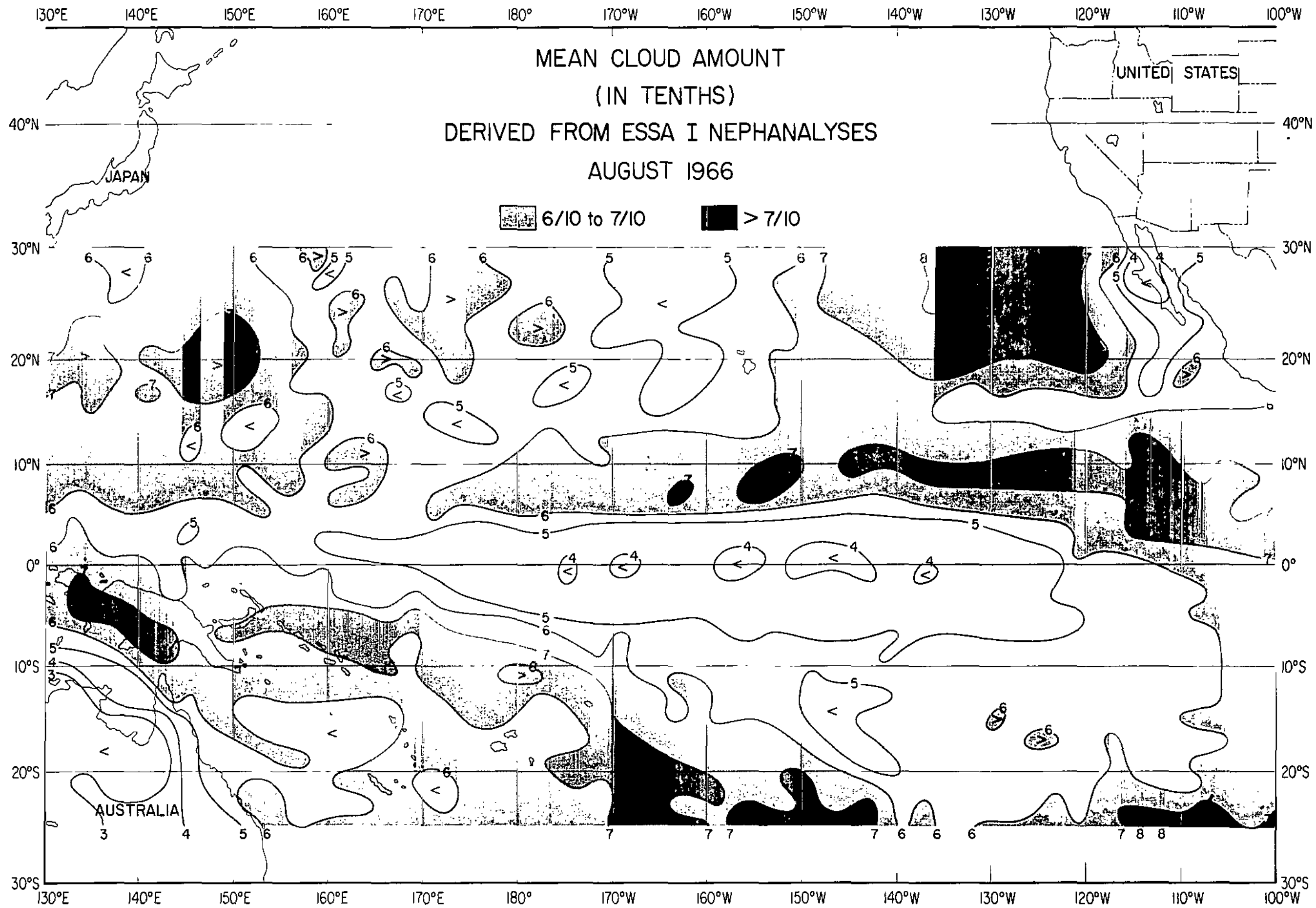

Figure A17—Mean cloud amount (in tenths) derived from ESSA I August 1966 nephanalyses.

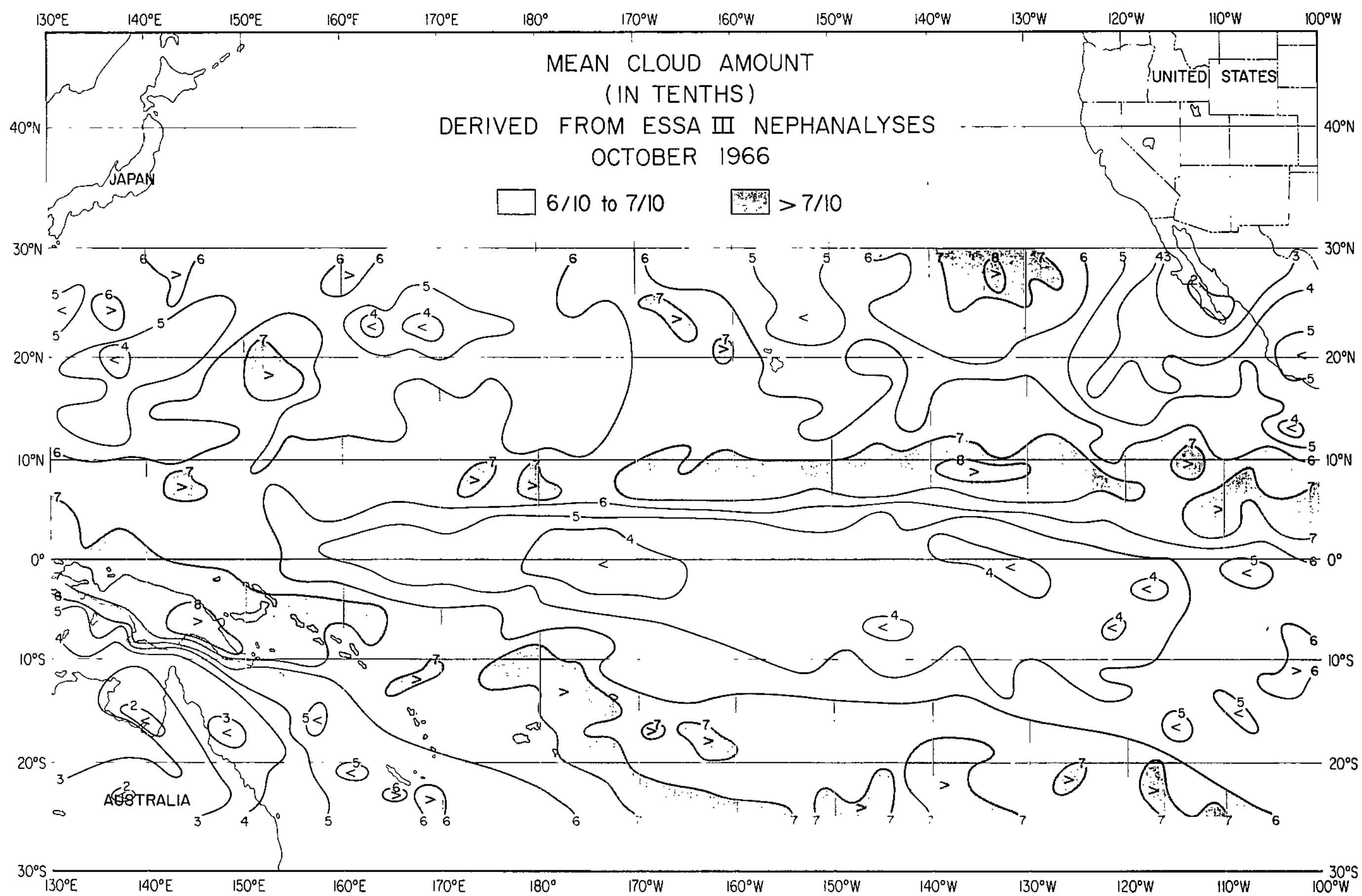

Figure A18—Mean cloud amount (in tenths) derived from ESSA III October 1966 nephanalyses.

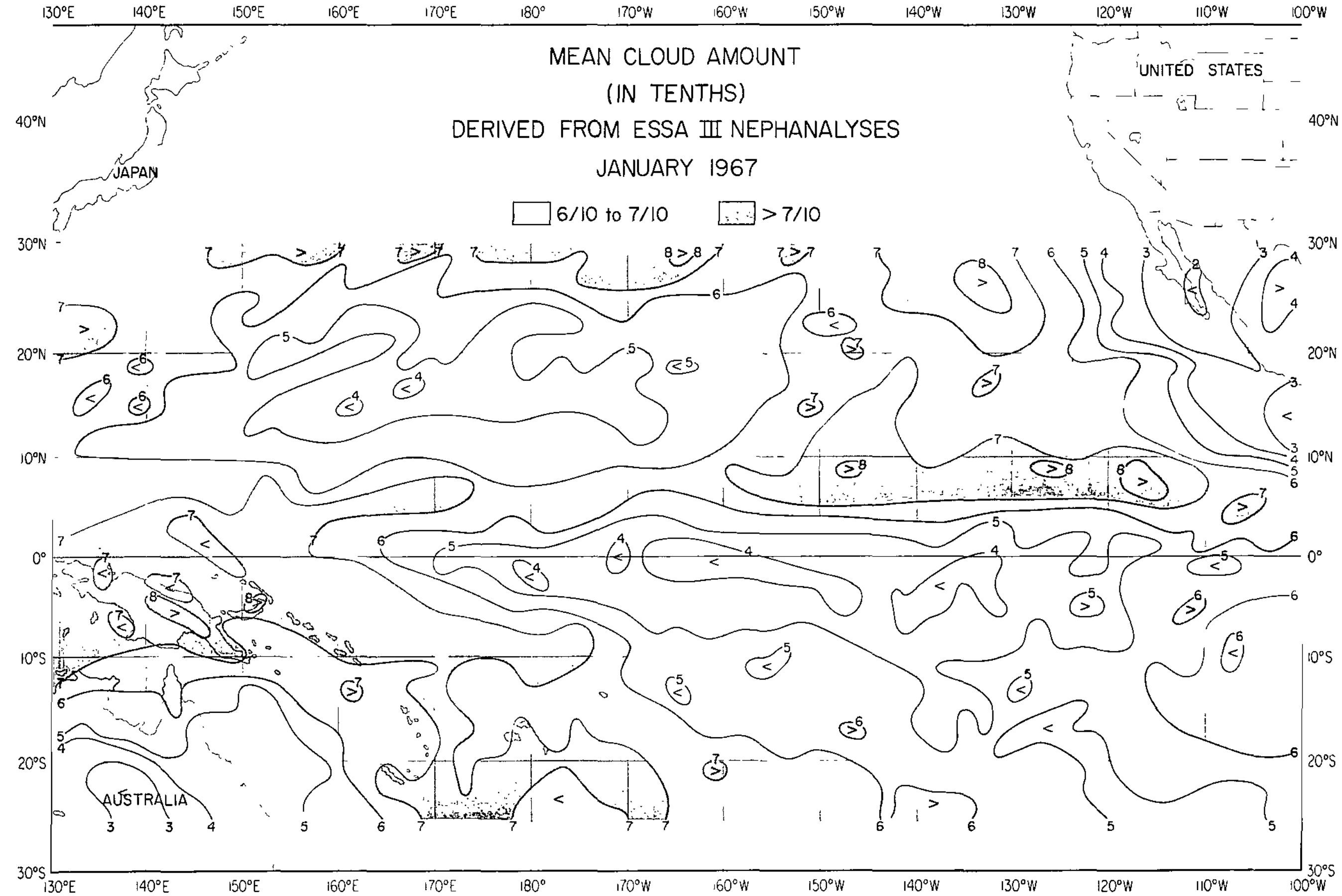

Figure A19—Mean cloud amount (in tenths) derived from ESSA III January 1967 nephanalyses.

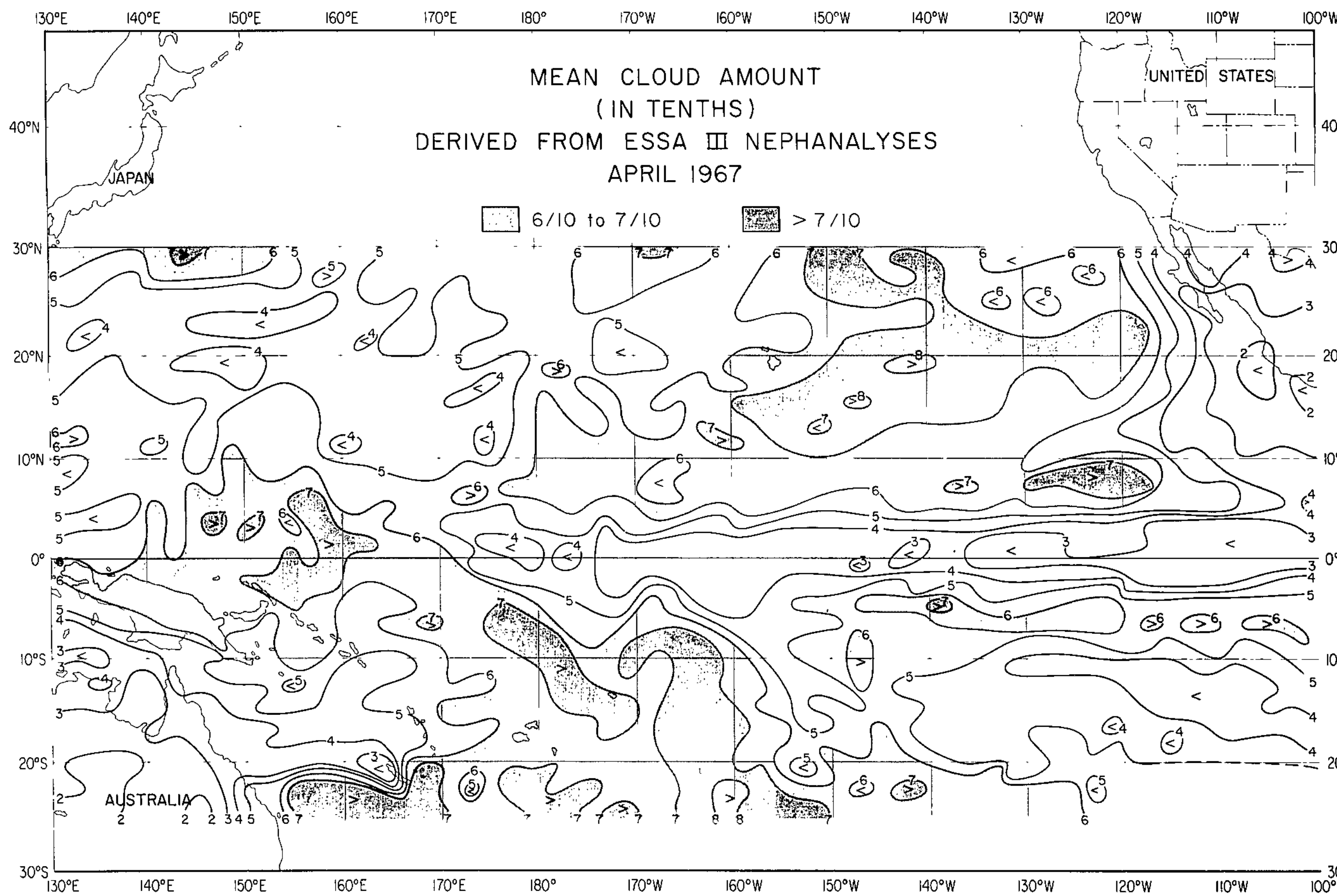

Figure A20—Mean cloud amount (in tenths) derived from ESSA III April 1967 nephanalyses.

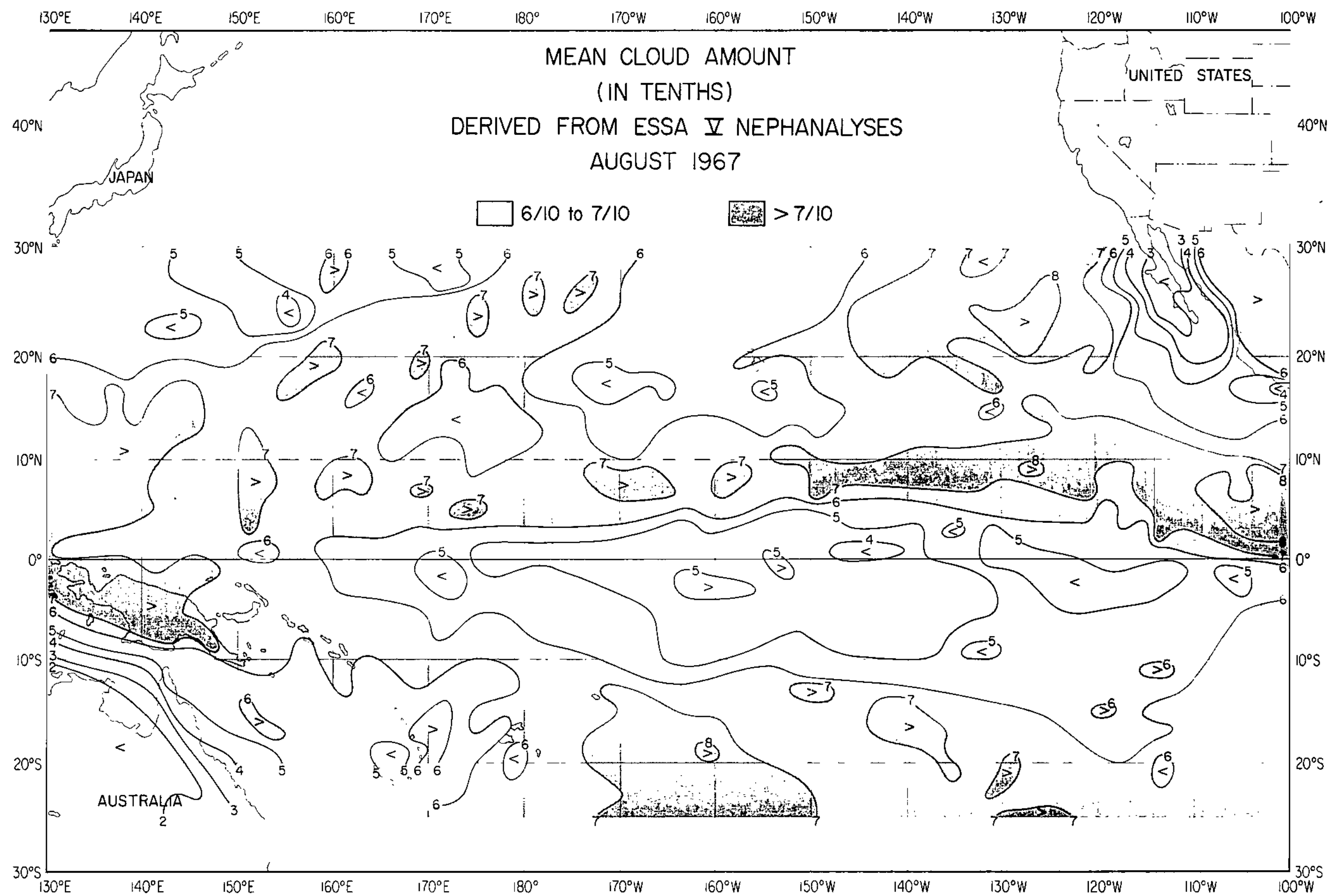

Figure A21—Mean cloud amount (in tenths) derived from ESSA V August 1967 nephanalyses.

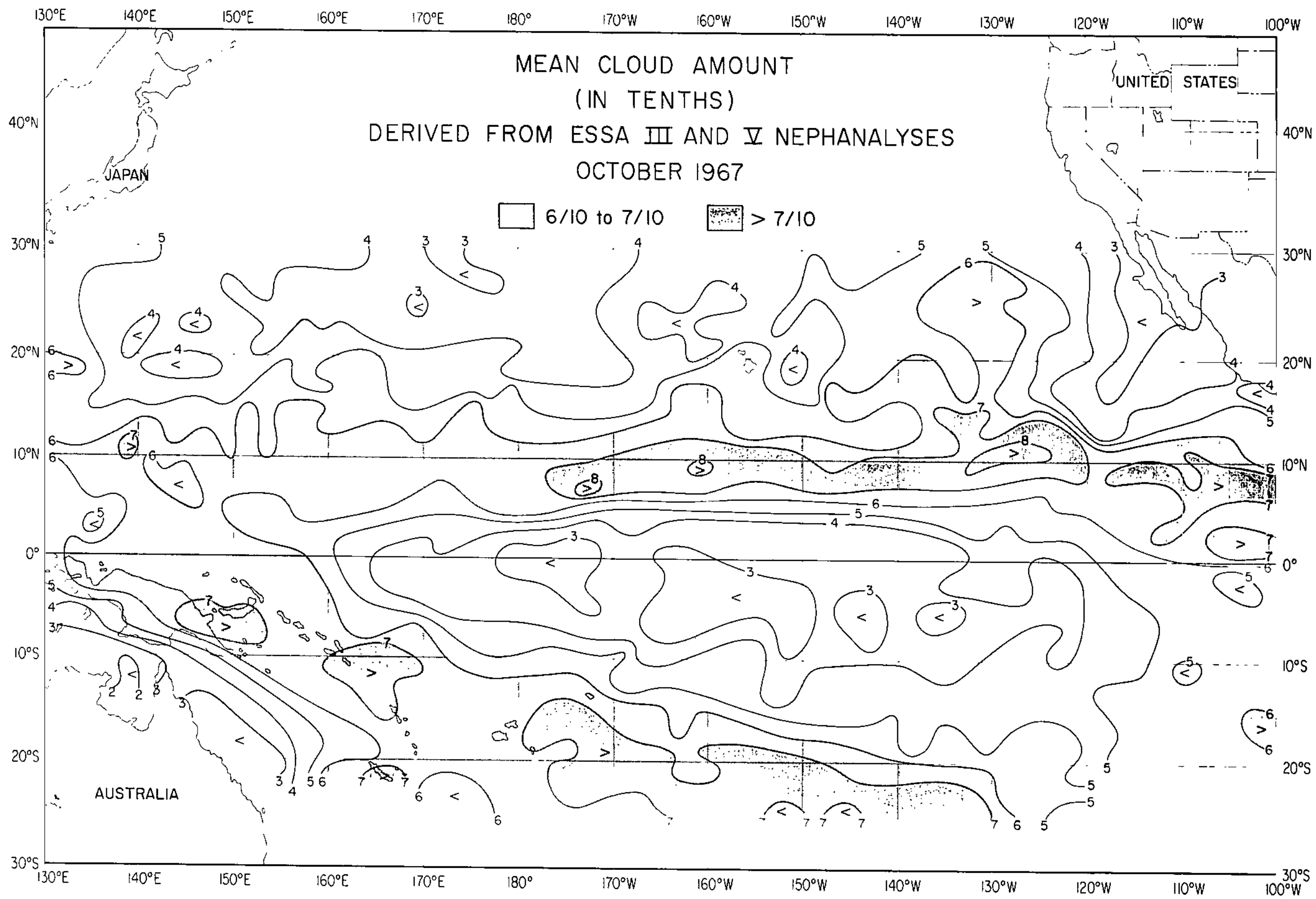

Figure A22—Mean cloud amount (in tenths) derived from ESSA III and October 1967 nephanalyses.

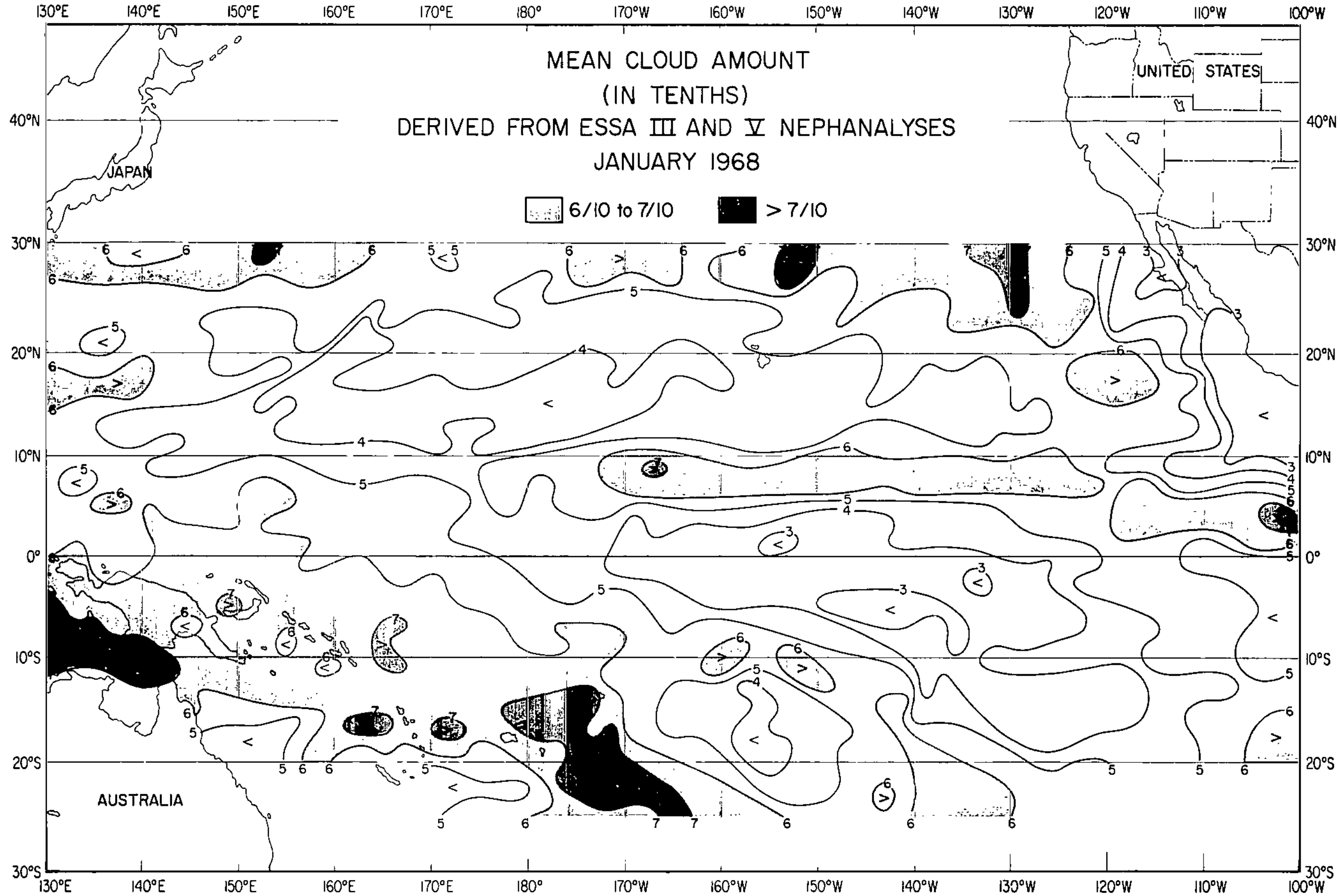

Figure A23—Mean cloud amount (in tenths) derived from ESSA III and V January 1968 nephanalyses.

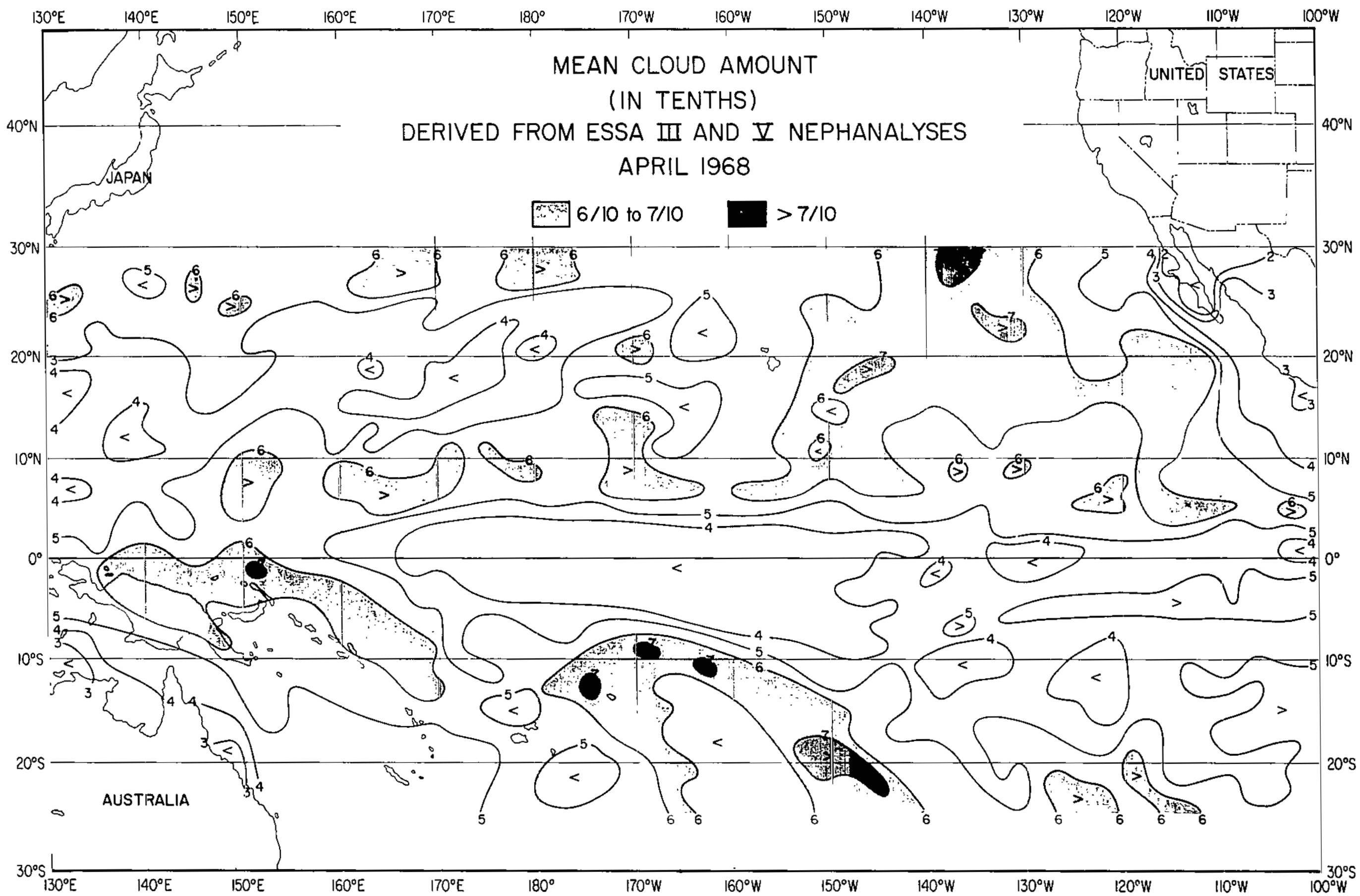

Figure A24—Mean cloud amount (in tenths) derived from ESSA III and V April 1968 nephanalyses.

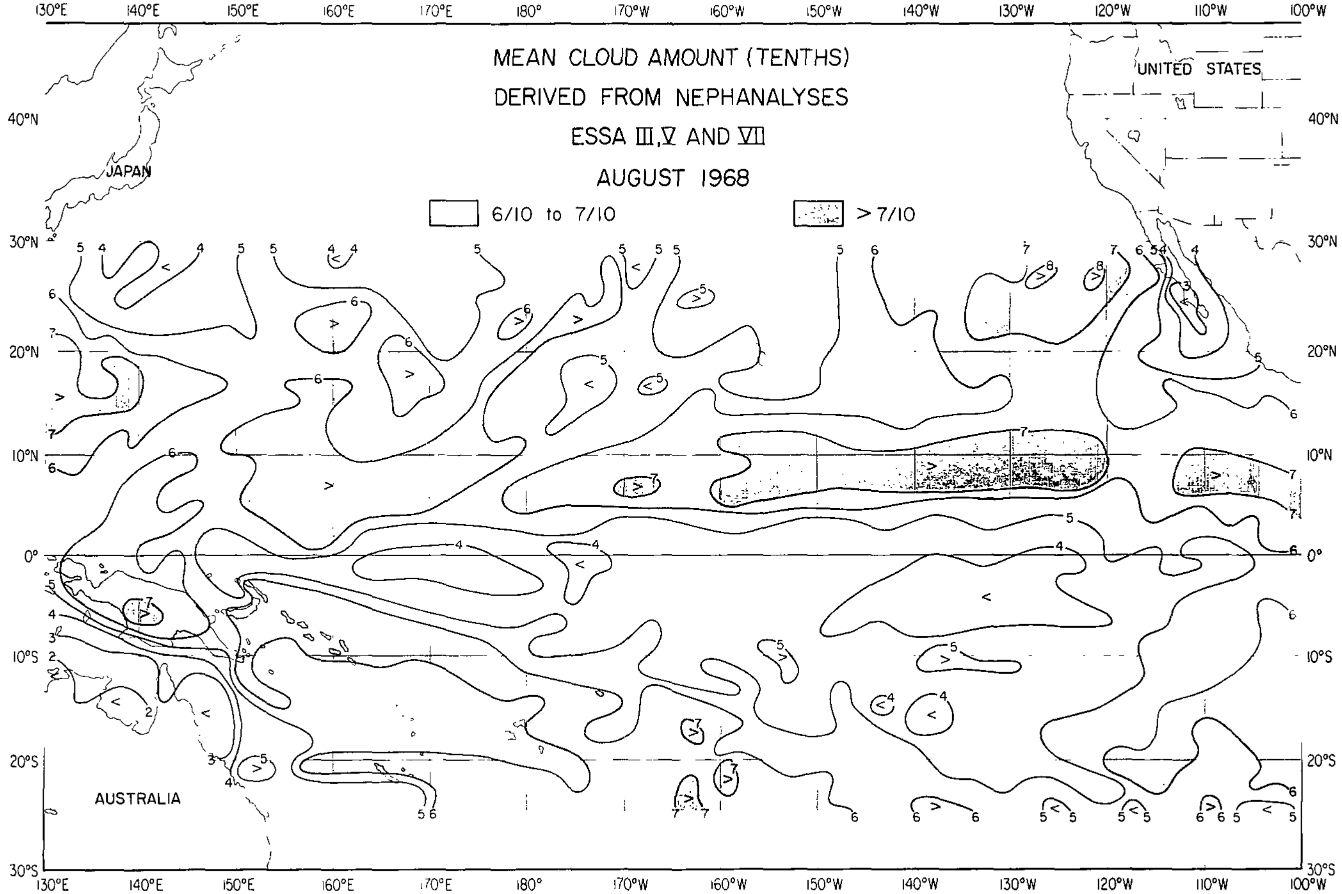

Figure A25—Mean cloud amount (in tenths) derived from ESSA III, V, and VII August 1968 nephanalyses.

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