SP-99

SPECIAL PUBLICATION

MONTHLY CHARTS OF MEAN, MINIMUM, AND MAXIMUM SEA SURFACE TEMPERATURE OF THE INDIAN OCEAN

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ABSTRACT

These charts, based on ship injection temperature data, show the monthly maximum, minimum, and mean sea surface temperatures for the Indian Ocean. The data are numerous in all but the southernmost portion of the area, and the addition of new data probably will not greatly change the analysis.

Upwelling along the coasts of the continents is evident on the charts. Of particular interest is a little-studied region off the coast of the Somali Republic, where during the southwest monsoon, the mean temperature in one 1° quadrangle drops to 4° F. less than the mean temperature in the surrounding 1° quadrangles. The maximum and minimum sea surface charts show temperature variations which are sometimes masked by the averaging of the temperatures on the mean charts, as in the Antarctic Convergence, which is best shown on the maximum charts.

The graphs of monthly variability of temperature in selected locations show that surface temperature values in the Indian Ocean north of the Equator have two maximum periods during the year, as compared to one maximum per year in the Pacific and Atlantic Oceans.

Because of the large quantity of data involved, these charts, in general, are more definitive than charts of other parameters such as salinity, except where the analysis were based on fewer than 25 observations per 1° quadrangle or in regions where the 1° quadrangle averaging disguises more complex thermal structure.

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and
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Oceanographic Analysis Division
Marine Sciences Department

FOREWORD

The charts in this publication are based on ship injection temperature data collected over more than 100 years. They are being made available as an interim convenience before a more extensive analysis of the Indian Ocean can be made and presented in Publication No. 704, "Oceanographic Atlas of the Indian Ocean, Section II, Physical Properties." It is hoped that this volume will prove useful to analysts in the interpretation of the large quantities of data collected during the recent International Indian Ocean Expedition.

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Captain, U.S. Navy
Commander
U.S. Naval Oceanographic Office

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Introduction

The Naval Oceanographic Office is currently engaged in producing a series of atlases on the oceans of the world. In these atlases the Physical Properties Section deals mainly with the distribution and variation of three basic parameters: temperature, salinity, and density. While analyses of these parameters are made as complete as present data allow, undoubtedly some modifications will be necessary with the collection of new data.

The charts and graphs of sea surface temperature in the atlases as well as in this publication, however, are based on ship injection data so numerous in many regions that little future modification may be necessary. Therefore, these charts are being published herein until a more extensive analysis can be presented in Pub. No. 704 "Oceanographic Atlas of the Indian Ocean Section II, Physical Properties." The current need for sea surface temperature charts for use in analyzing the international Indian Ocean Expedition data has prompted an earlier release of these charts.

Description of the charts

Sea surface temperatures are the most easily collected of oceanographic measurements. In addition to oceanographic and naval vessels, ships of opportunity furnish sea surface temperature data by their reports of injection temperatures.

Because injection temperatures are commonly taken below the surface and may be influenced by heat from the ship's engines or boilers, they are not individually considered as reliable as temperatures derived from bucket thermometers or Nansen casts. However, if taken in sufficient quantities by a number of ships over a prolonged period, the overall reliability of injection temperature data improves considerably.

When analyzing this type of data, the following criteria are used:

< 25 obs/1° square -- poor

25-99 obs/1° square -- good

≥ 100 obs/1° square -- excellent

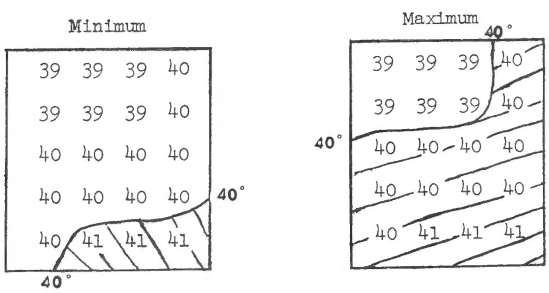
To show regions of reliability, those 1° squares containing 25 or more observations are shaded on the presented charts.

Mean, minimum, and maximum sea surface temperatures were analyzed on monthly charts. These analyses were done on charts that had been mechanically plotted by an X-Y plotter. The data on these charts consisted of injection temperatures collected by various international marine organizations and are retained in punch card form at the U. S. National Weather Records Center, Asheville, North Carolina and at the Naval Oceanographic Office. The data listed in the following table for the marine decks cover the period from 1854 until 1961.

Deck	Name	Inclusive Dates	Number of Obs.
110	Navy-Marine Obs.	1945-51	79,444
116	U.S. Merchant Marine Obs.	1949-60	353,216
117	U.S. Navy Marine Obs.	1952-61	254,626
118	Japanese Marine Obs.	1937-53	508,082
119	Japanese Marine Obs.	1953-60	386,283
184	British Marine Obs.	4/53-6/56	131,479
187	Japanese Whaling Fleet Obs.	1946-56	574
189	Dutch Marine Obs.	12/39, 9/45-6/55	183,159
192	German Marine Obs.	1859-1939	879,086
193	Netherlands Marine Obs.	1854-1938	2,585,262
194	British Marine Obs.	1856-1953	1,005,270
195	U.S. Navy Ship Logs Obs.	1942-45	81,177
197	Danish Marine Obs.	1860-1956	455
281	U.S. Navy Monthly Aerological Record	1920-45	19,236
		TOTAL	6,467,349

On the mean charts the machine utilized all available data, whereas on the minimum and maximum charts the machine was instructed to omit data for squares containing fewer than 10 observations. Because of the inherent error in injection temperature data, minimum temperature was taken as the first temperature class interval for which frequencies equal or exceed 2.5 percent of the data, while maximum temperature was taken as the first class interval that equals or exceeds 97.5 percent of the data.

As the temperature values on the minimum and maximum charts were plotted for class intervals of 1°F. each, and therefore as whole numbers, the analysis was necessarily different from that of the mean charts, where the plotted values were carried to one decimal place. The method of analysis was intended to show the maximum intrusion of extreme temperatures. The minimum isoline was drawn on the **warmer** border of the temperature class interval, whereas the maximum isoline was drawn on the **colder** border of the temperature class interval, as shown in the following example:



In addition to the horizontal charts, graphs of monthly sea surface temperature variation for selected locations are shown. In this presentation the percentage distribution of sea surface temperature in 1°F. class intervals was plotted for each month, and curves of 1, 2.5, 25, 50, 75, 97.5, and 99 percent were constructed.

The choice of locations for these graphs was governed by the desire to demonstrate the degree of variability which occurs between various regions in this ocean, while attempting to select those locations with a sufficiently high number of observations to allow reasonable analysis.

In comparing the analyzed charts, several features are noticeable. For example, the upwelling of cold water along the coasts of continents is evident. Of particular interest is the little-studied area off the east coast of the Somali Republic. During the southwest monsoon the persistence of the wind produces general upwelling along this coast. This is most evident off Ras Hafun (10°25'N., 51°16'E.), where the July mean temperature in the appropriate 1° square is nearly 4°F. less than the July mean temperature in the surrounding 1° squares. In the graphs of monthly variability the double maximum-minimum characteristics of the Indian Ocean's north equatorial waters is strongly accentuated off Ras Hafun. Here, the minimum during July - August may be compared to the warmer minimum temperatures occurring at the same time in nearby regions. In addition to the temperatures shown off Ras Hafun, a low of 55°F. has recently been reported by the Scripps ship ARGO during the International Indian Ocean Expedition.

The 1° square spacing of these charts, as well as the monthly treatment of data, may hide small local or temporary temperature conditions, especially on the mean charts, where the averaging of values may oversimplify the temperature variations of a complex region. These fluctuations may be better determined by referring to the maximum or minimum charts. For example, the Antarctic Convergence Zone, poorly discernible on the mean charts, is well defined on the maximum charts. Major current systems of the Indian Ocean, such as the North Equatorial Current and the Equatorial Countercurrent, are also best defined on the charts of maximum temperatures. In turn, currents of cool water are best defined on the minimum chart, as for example the intrusion of cool water in the South China Sea in February.

Because of the large quantity of data involved, it is believed that these charts are, in general, more definitive than oceanographic charts of other parameters such as salinity, for which data are sparse. Although these charts may not be considered accurately descriptive where the analysis was based on fewer than 25 observations per 1° square, or in areas where the 1° square averaging disguises more complex thermal structure, they are useful tools for the ocean scientist, especially where other types of data do not exist or are in poor distribution.

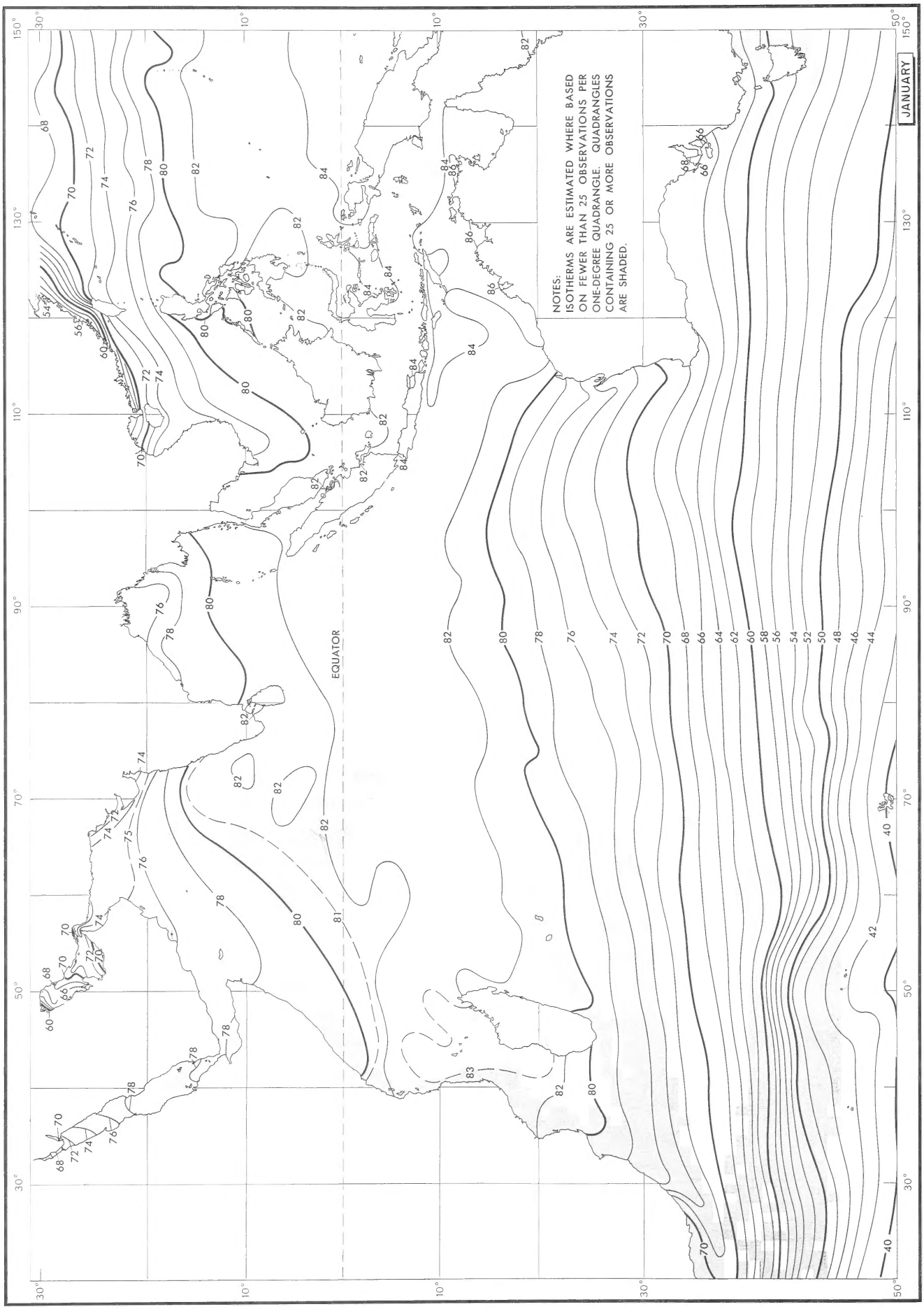


FIGURE 1 MEAN SEA SURFACE TEMPERATURE (°F.), JANUARY

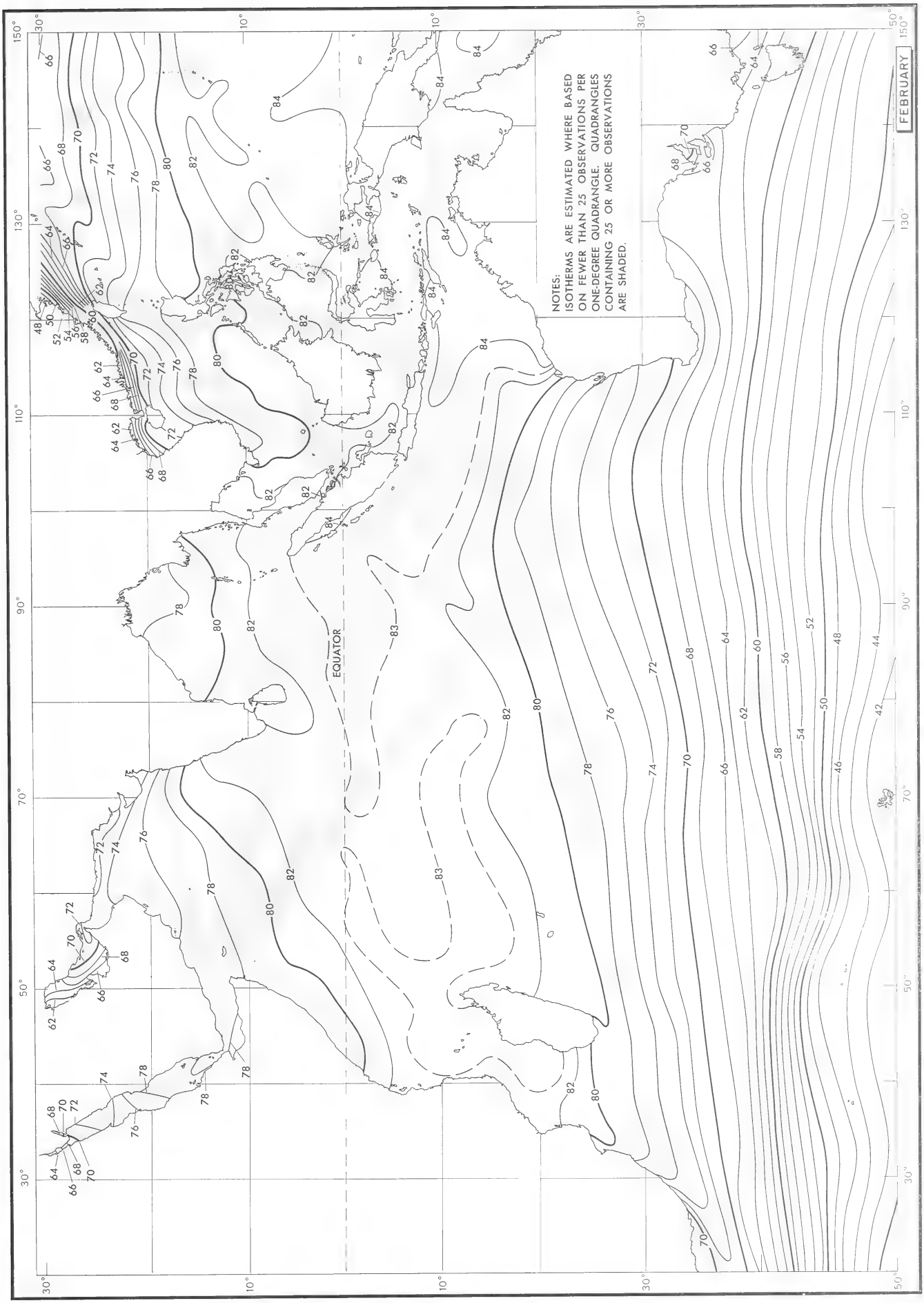


FIGURE 2 MEAN SEA SURFACE TEMPERATURE (°F.), FEBRUARY

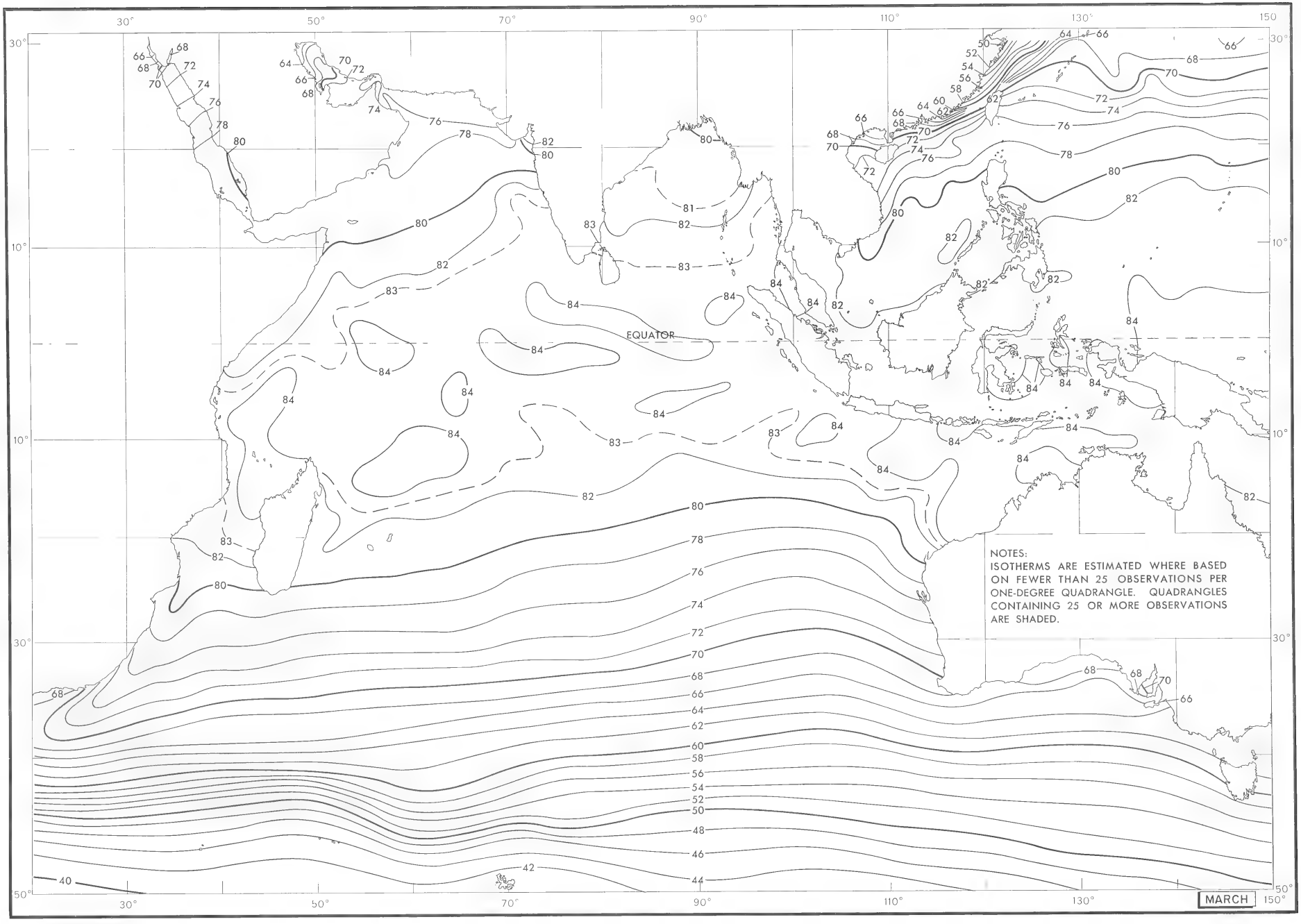


FIGURE 3 MEAN SEA SURFACE TEMPERATURE (°F.), MARCH

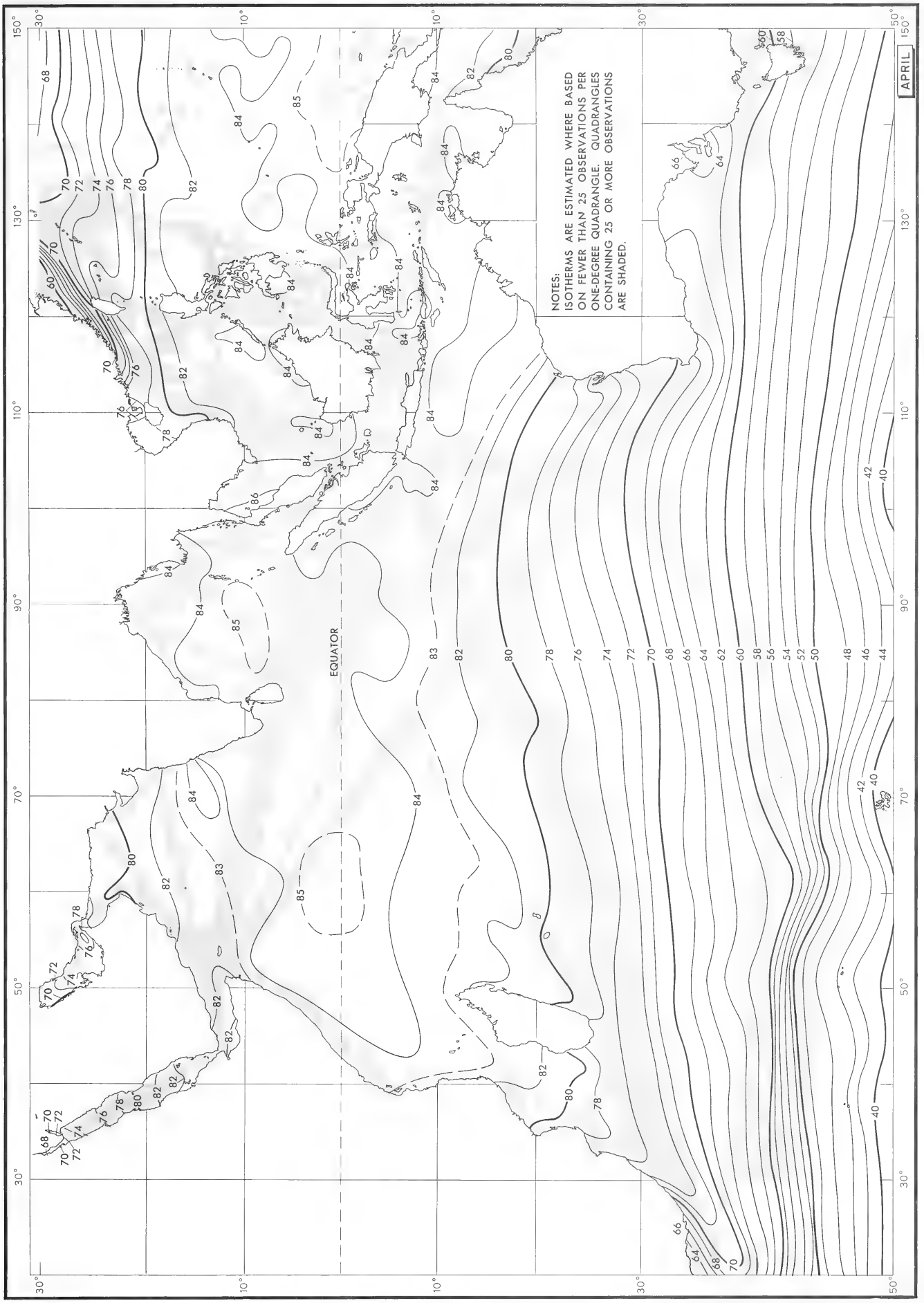


FIGURE 4 MEAN SEA SURFACE TEMPERATURE (°F.), APRIL

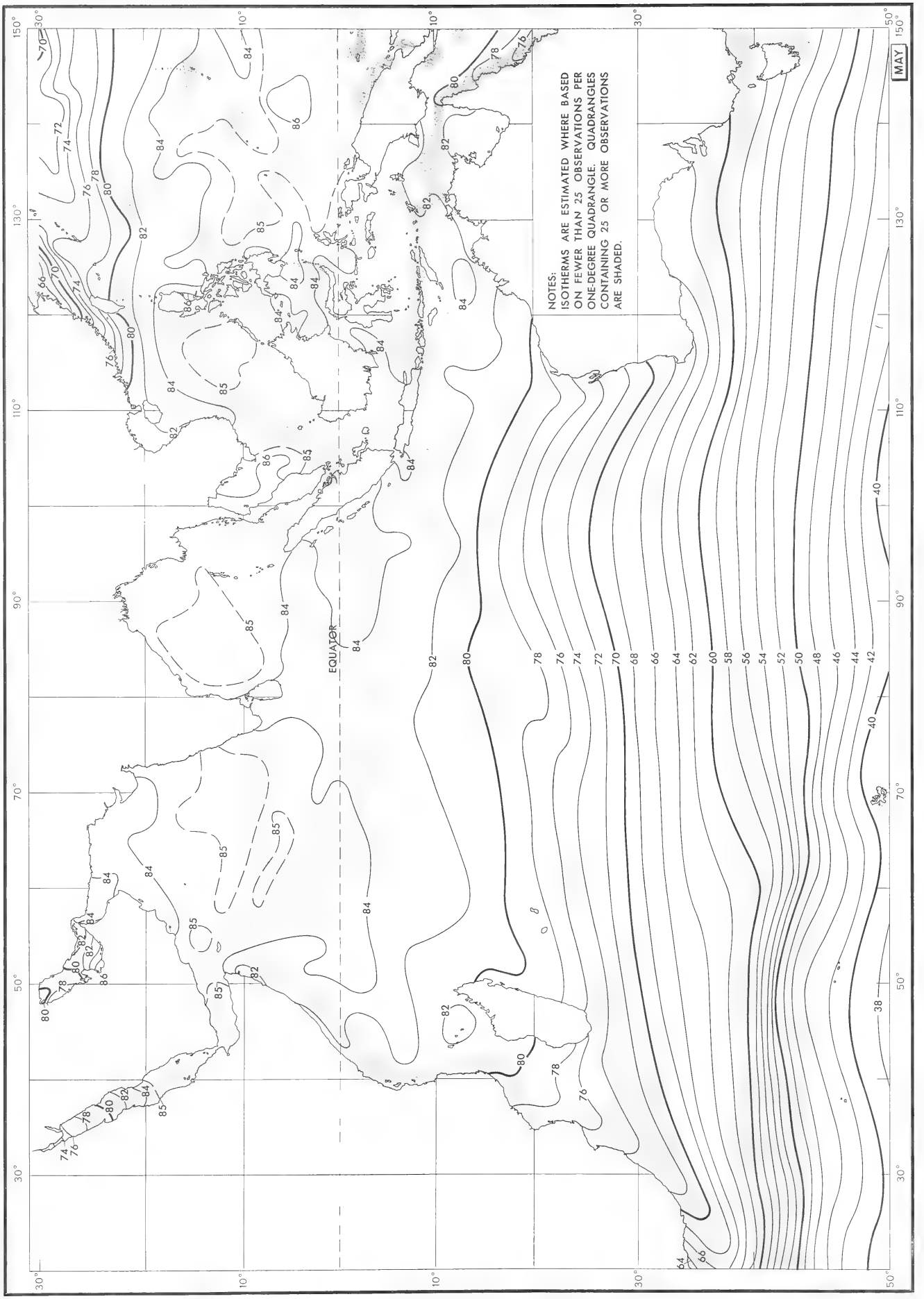


FIGURE 5 MEAN SEA SURFACE TEMPERATURE (°F.), MAY

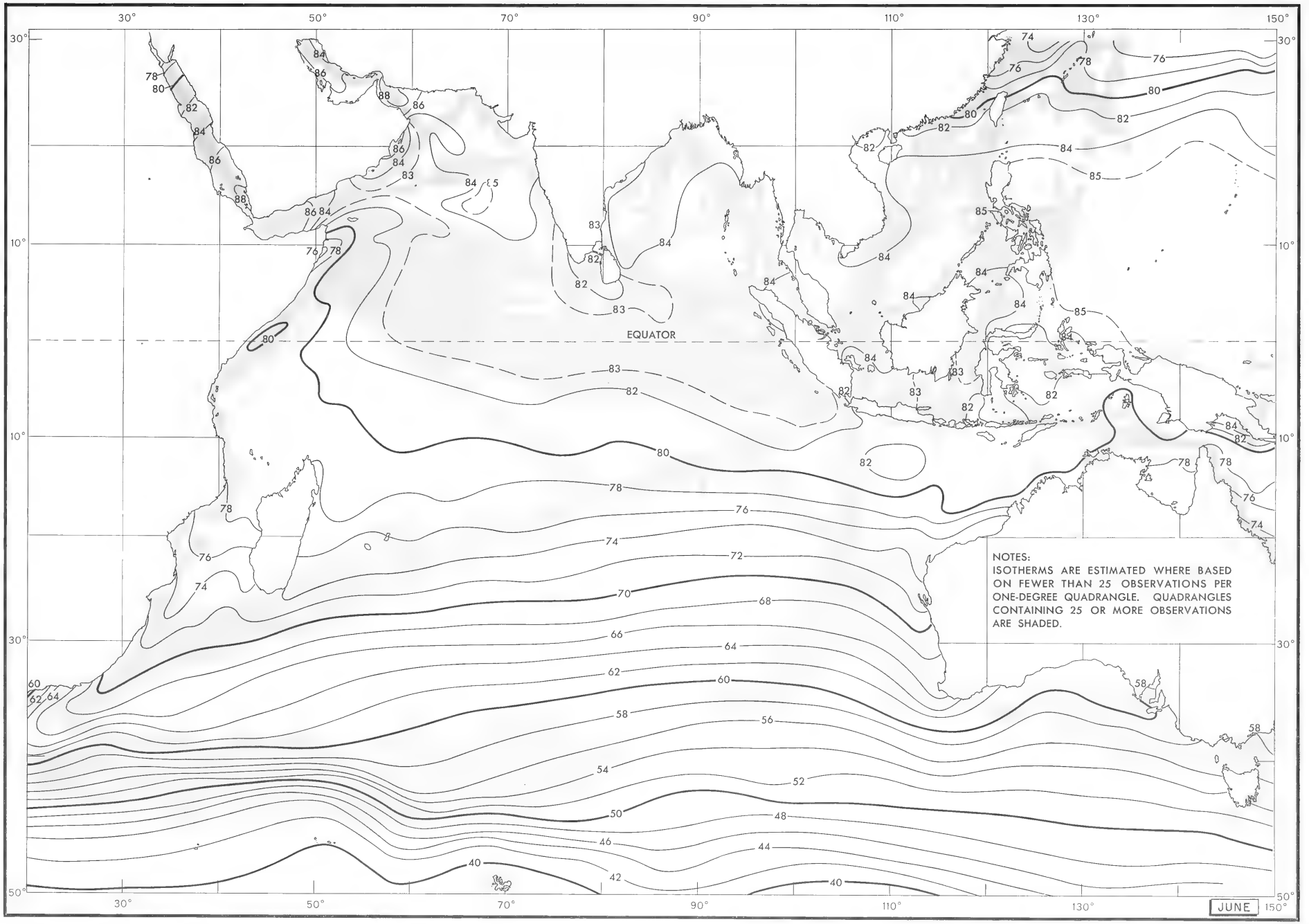


FIGURE 6 MEAN SEA SURFACE TEMPERATURE (°F.), JUNE

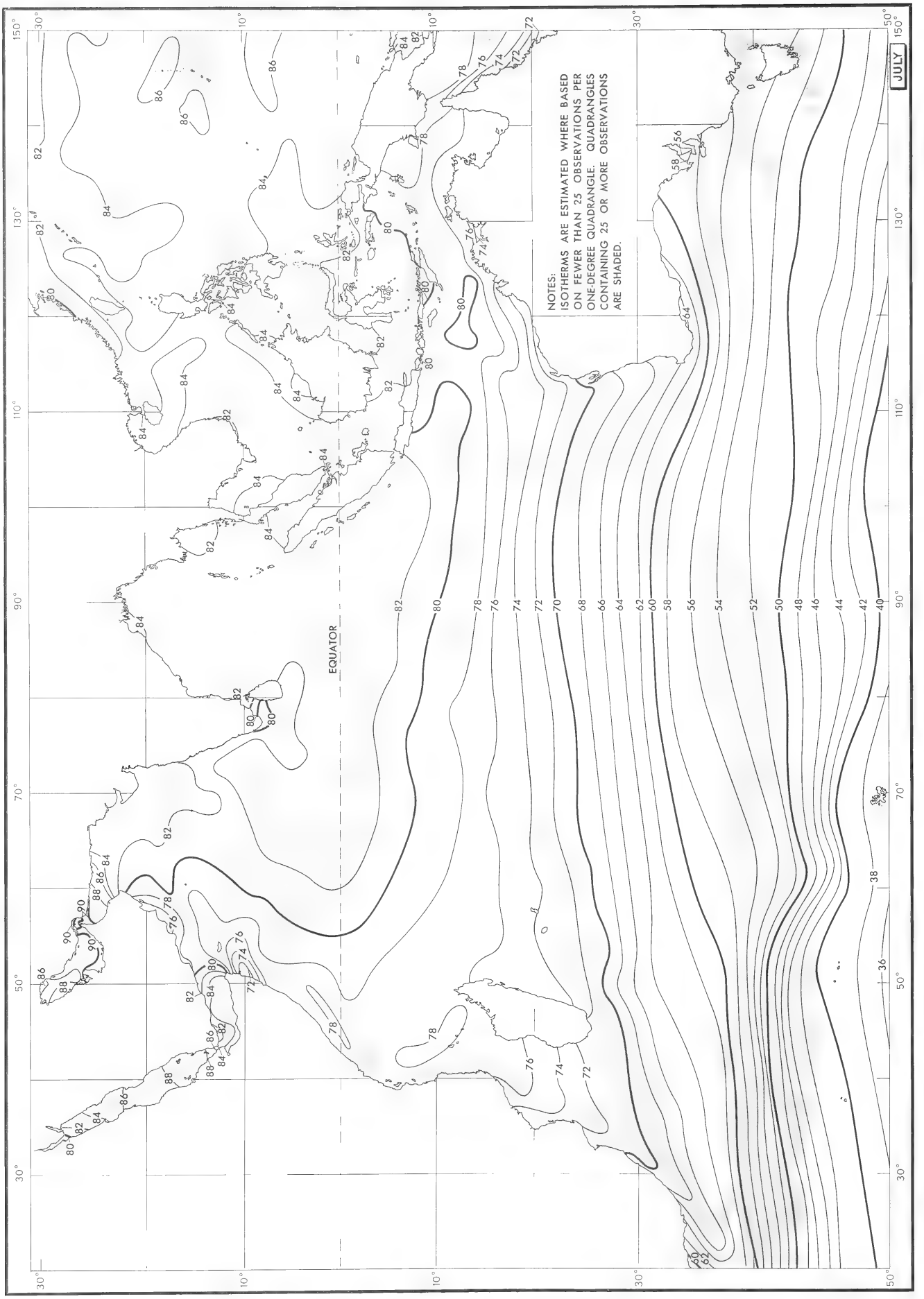


FIGURE 7 MEAN SEA SURFACE TEMPERATURE (°F.), JULY

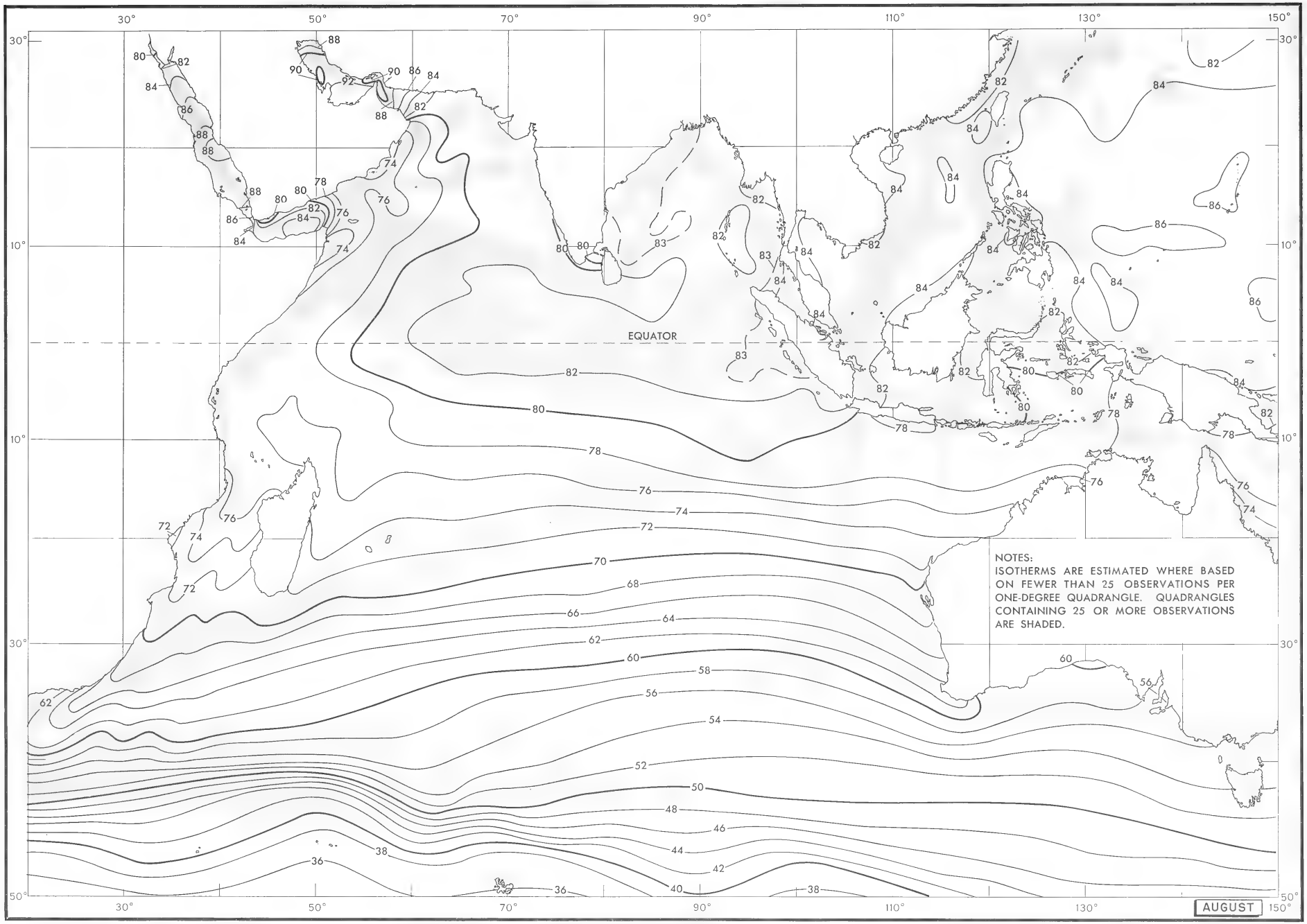


FIGURE 8 MEAN SEA SURFACE TEMPERATURE (°F.), AUGUST

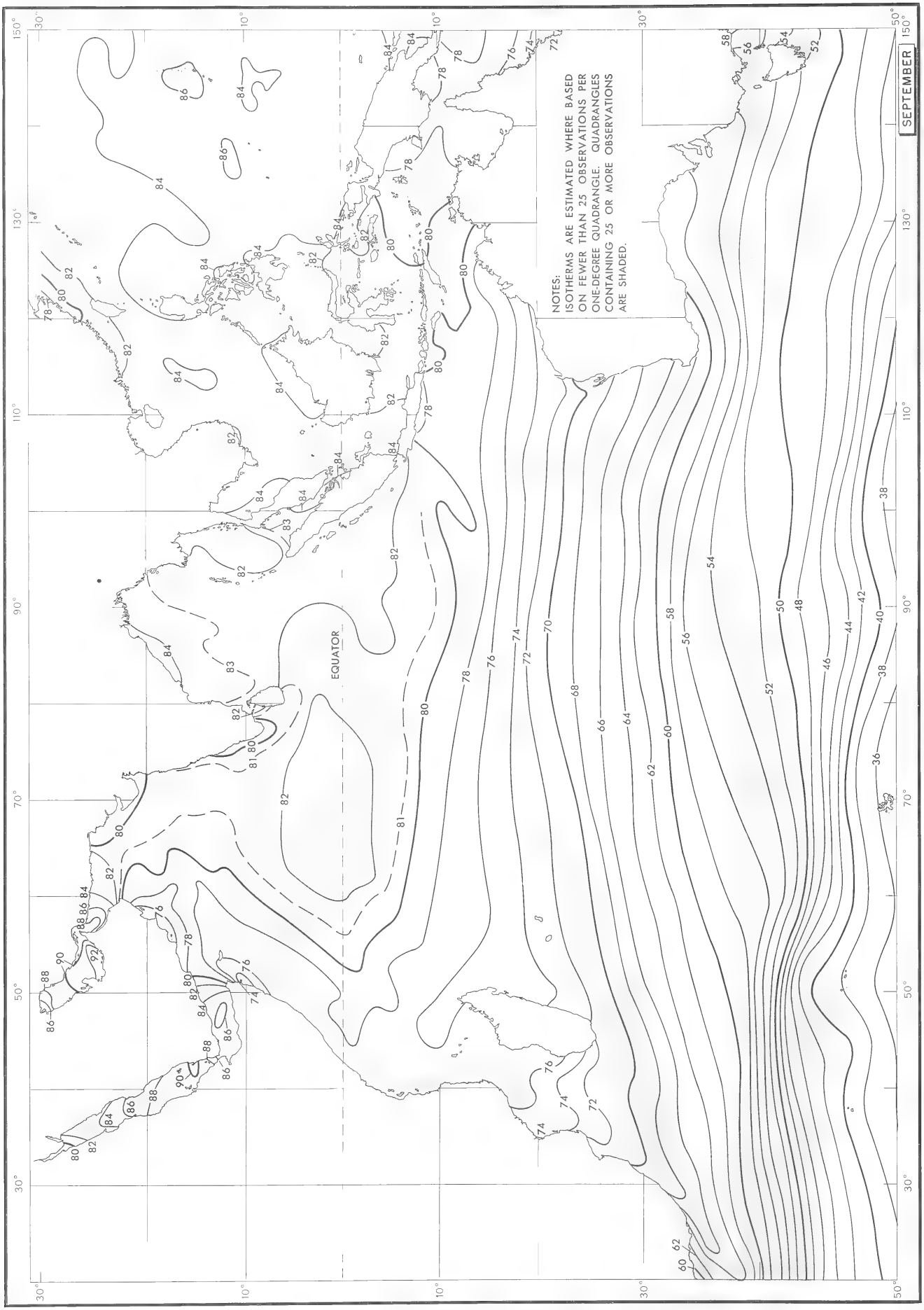


FIGURE 9 MEAN SEA SURFACE TEMPERATURE (°F.), SEPTEMBER

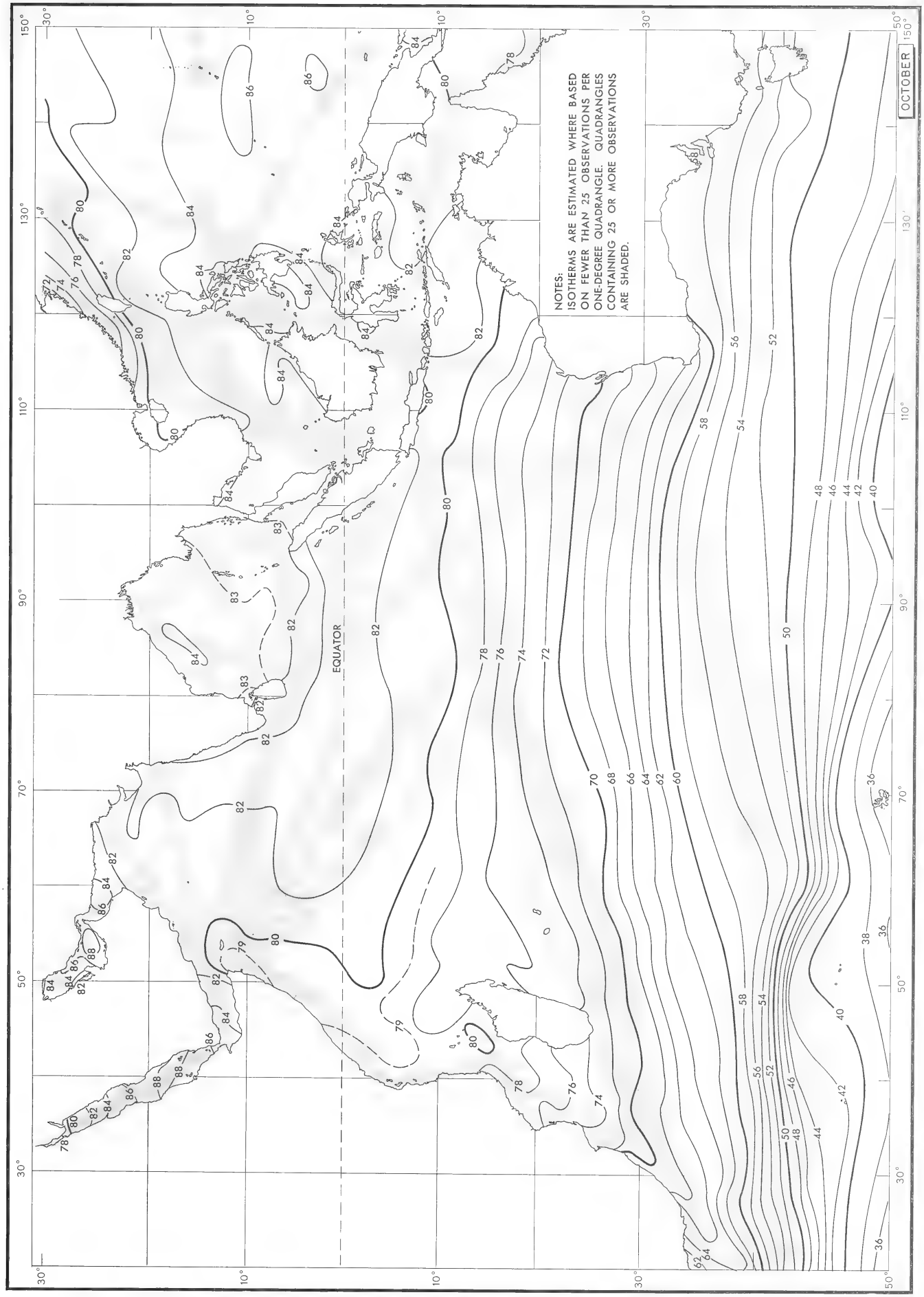


FIGURE 10 MEAN SEA SURFACE TEMPERATURE (°F.), OCTOBER

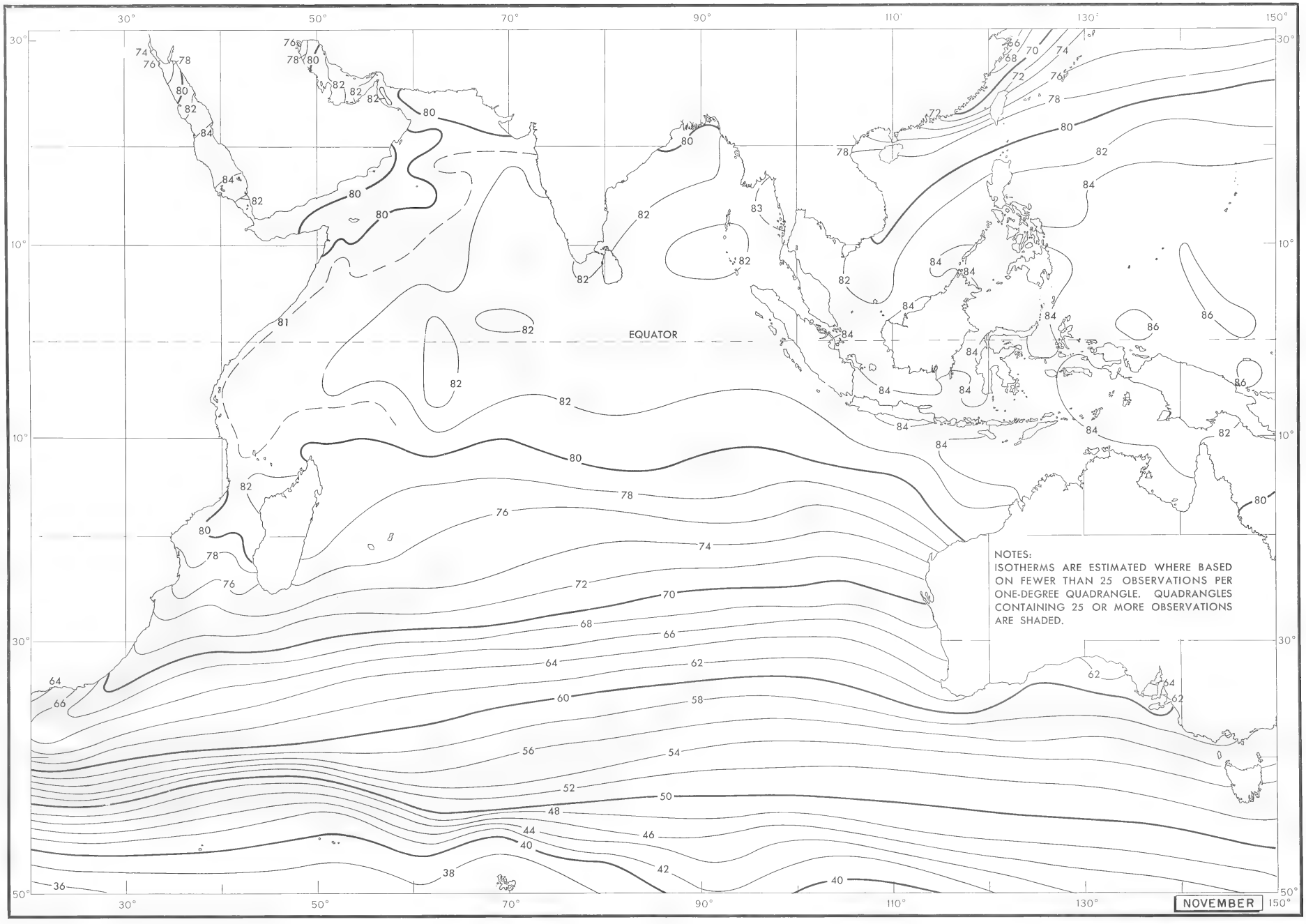


FIGURE 11 MEAN SEA SURFACE TEMPERATURE (°F.), NOVEMBER

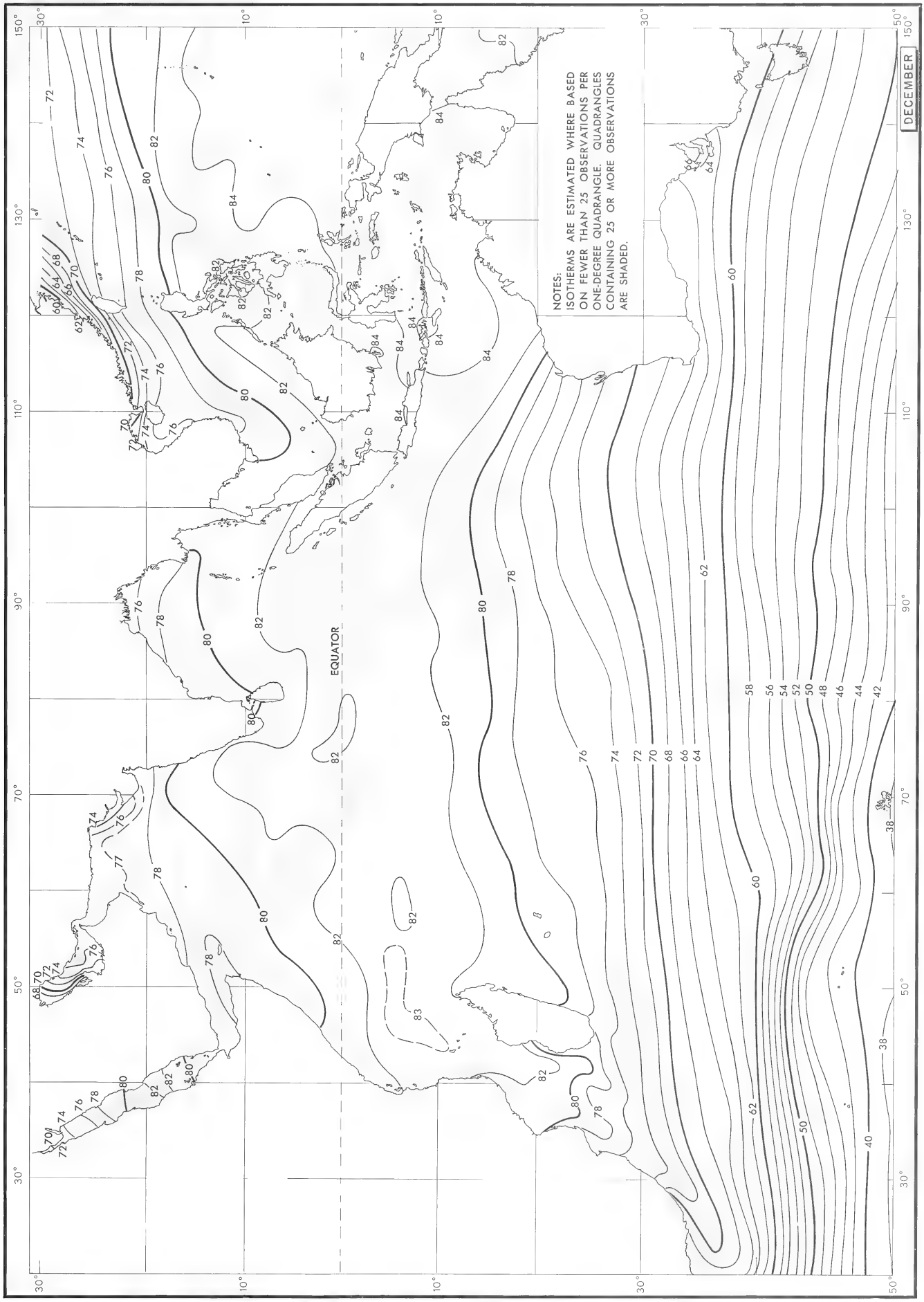


FIGURE 12 MEAN SEA SURFACE TEMPERATURE (°F.), DECEMBER

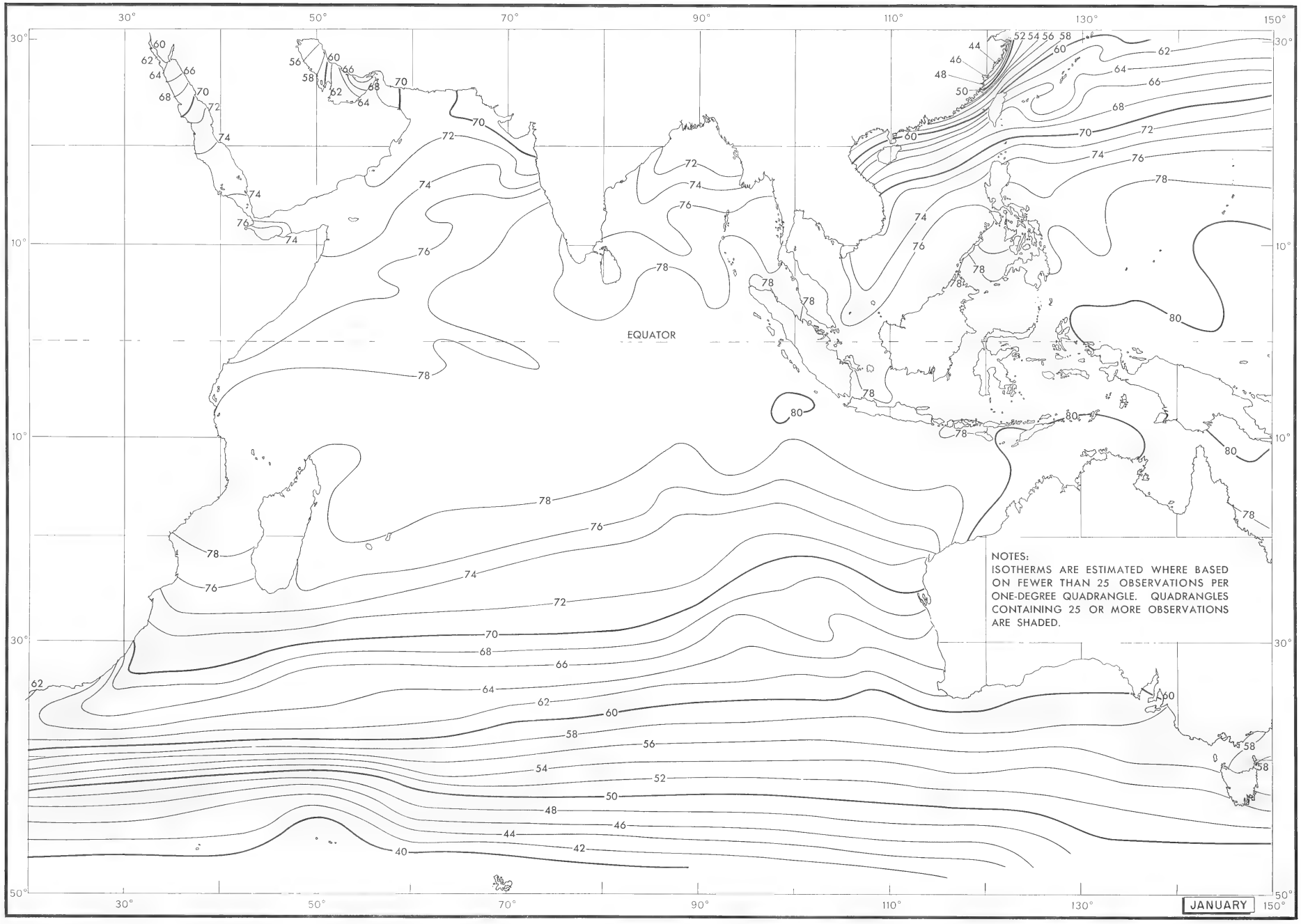


FIGURE 13 MINIMUM SEA SURFACE TEMPERATURE (°F.), JANUARY

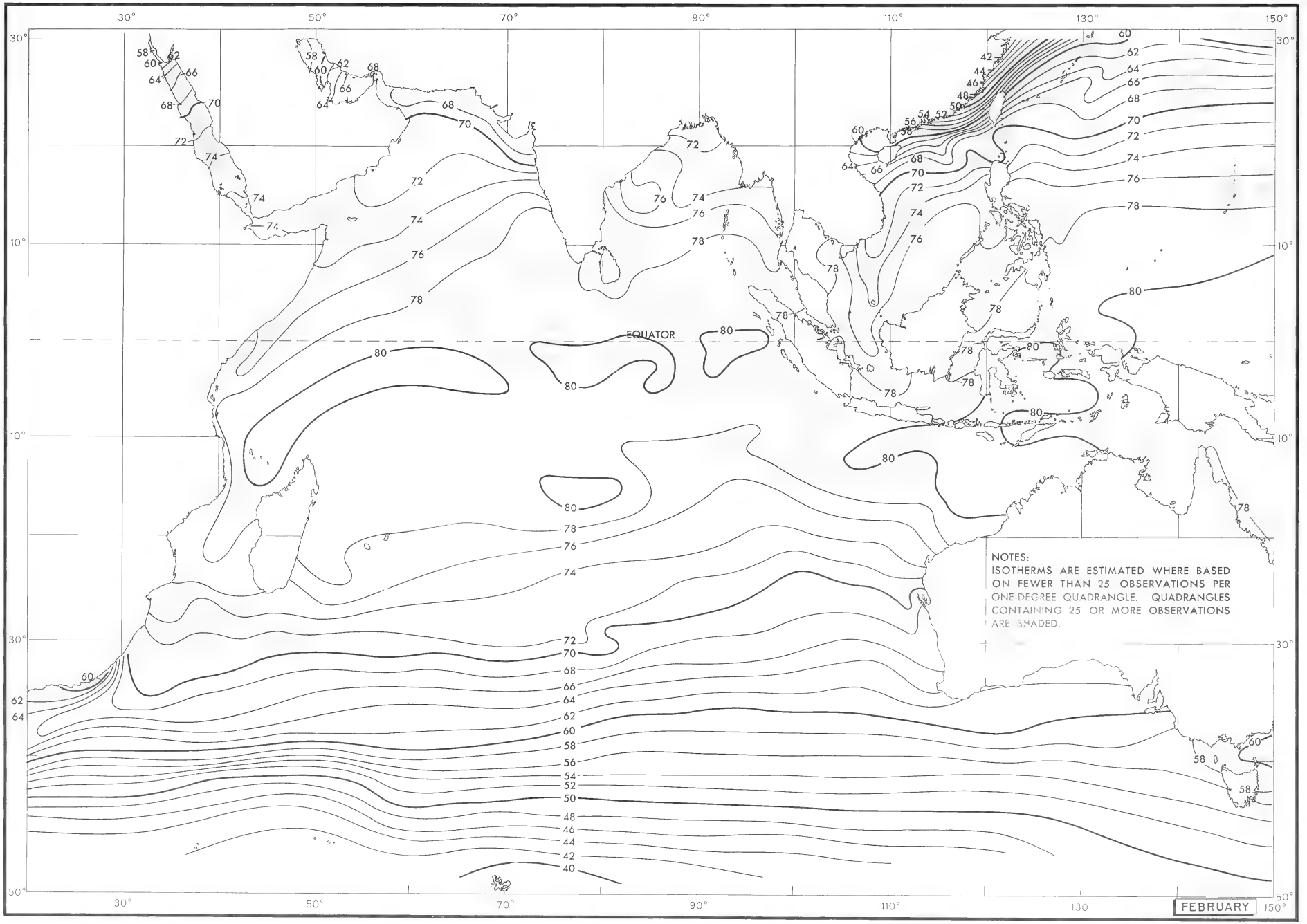


FIGURE 14 MINIMUM SEA SURFACE TEMPERATURE (°F.), FEBRUARY

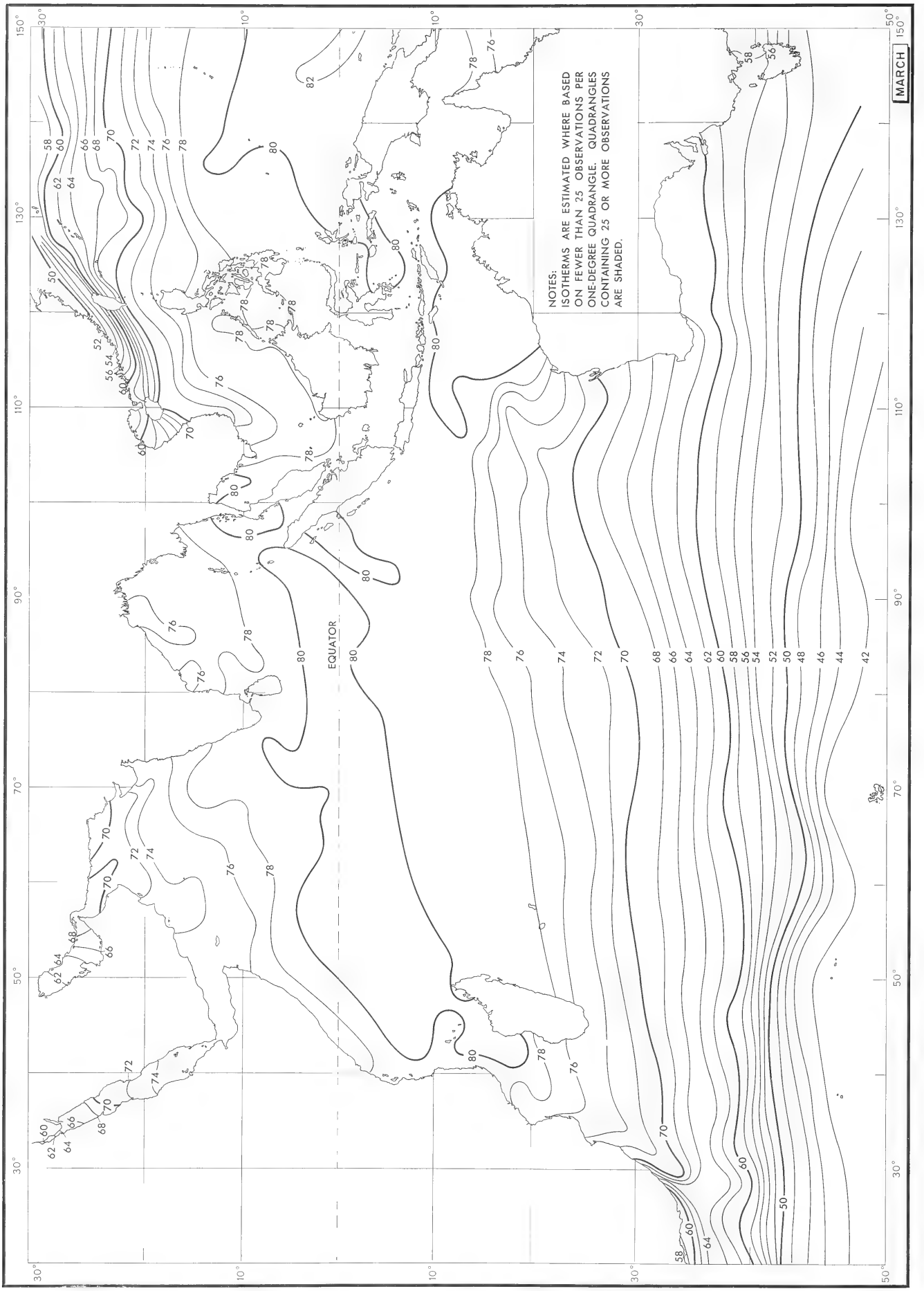


FIGURE 15 MINIMUM SEA SURFACE TEMPERATURE (°F.), MARCH

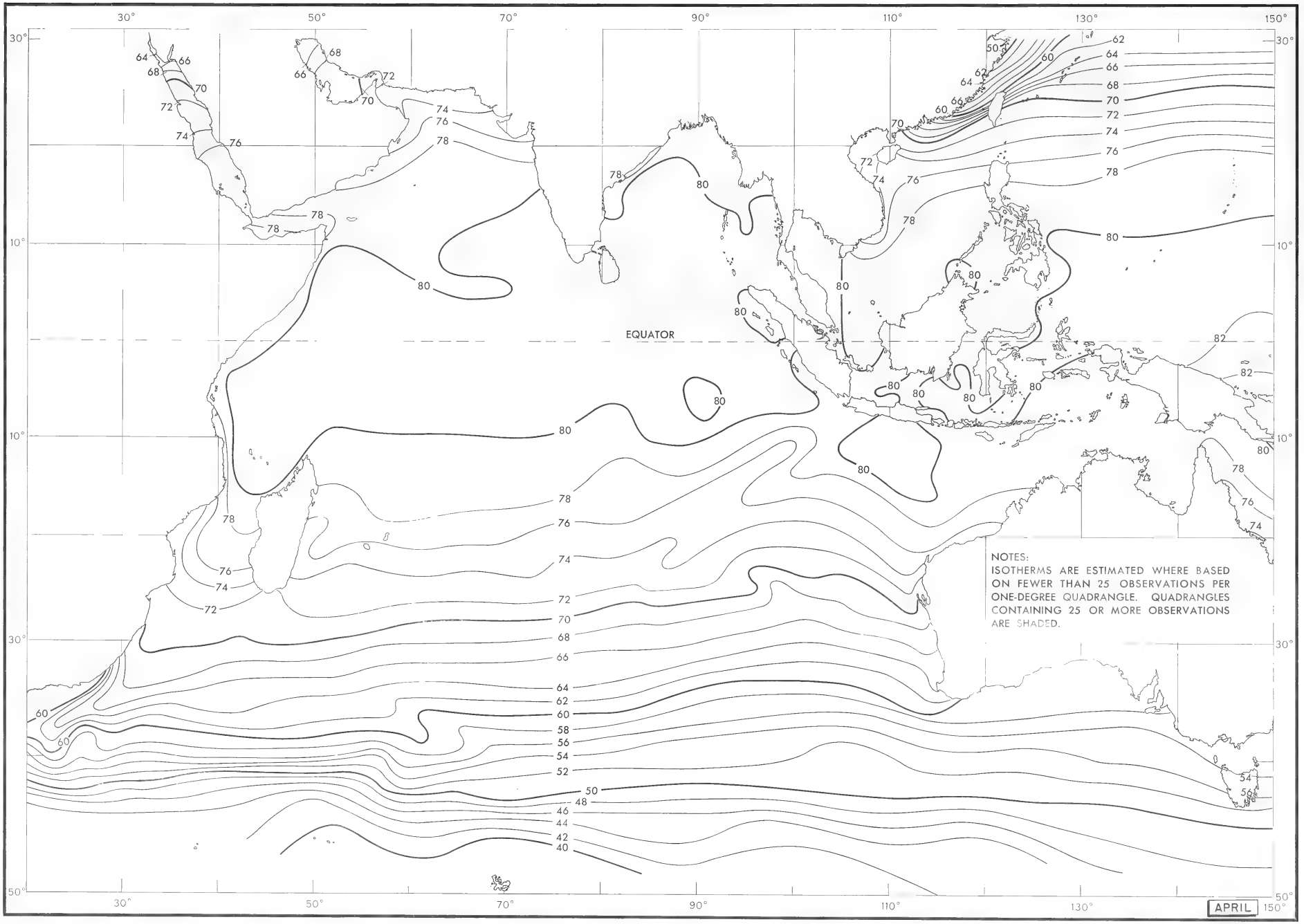


FIGURE 16 MINIMUM SEA SURFACE TEMPERATURE (°F.), APRIL

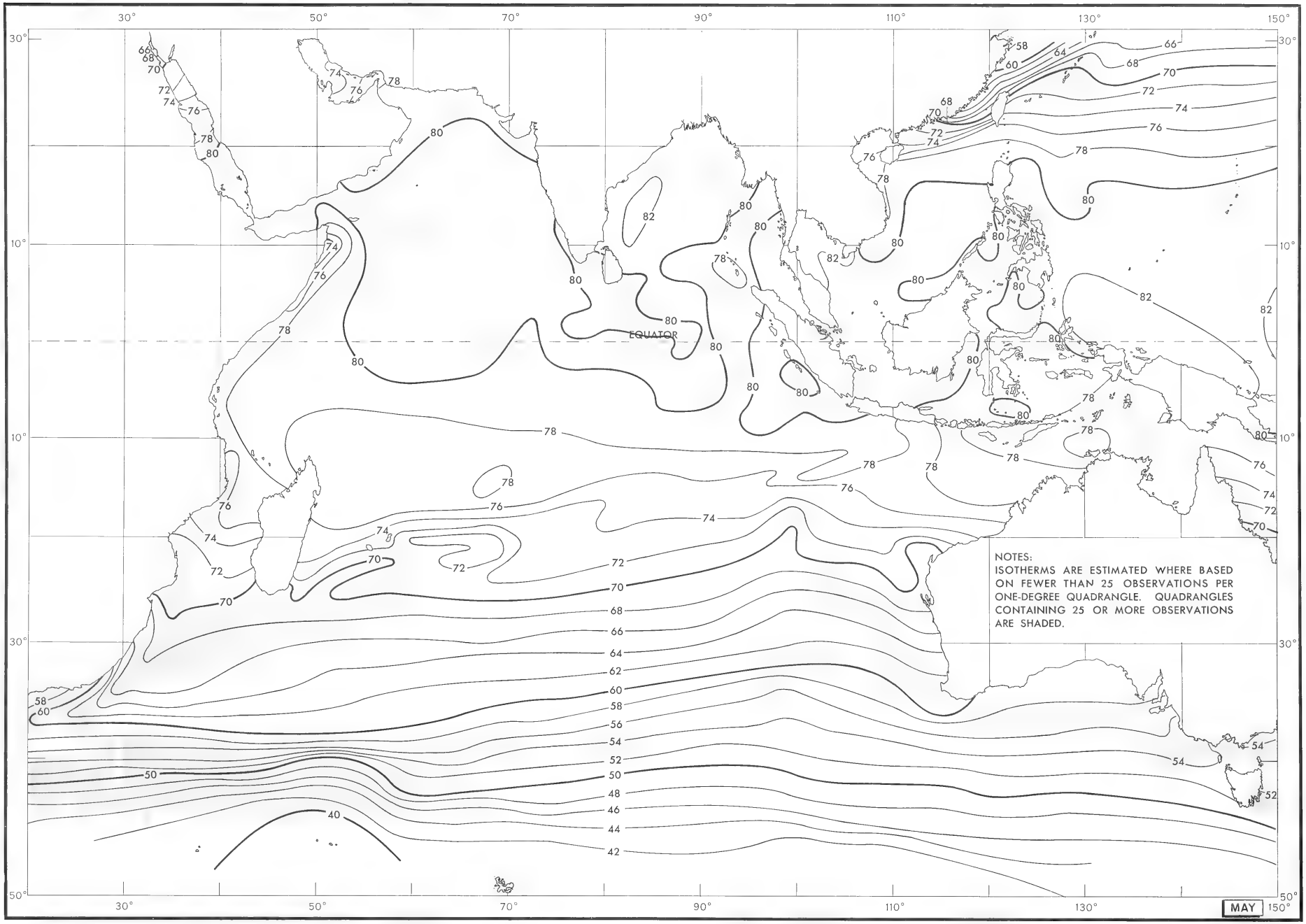


FIGURE 17 MINIMUM SEA SURFACE TEMPERATURE (°F.), MAY

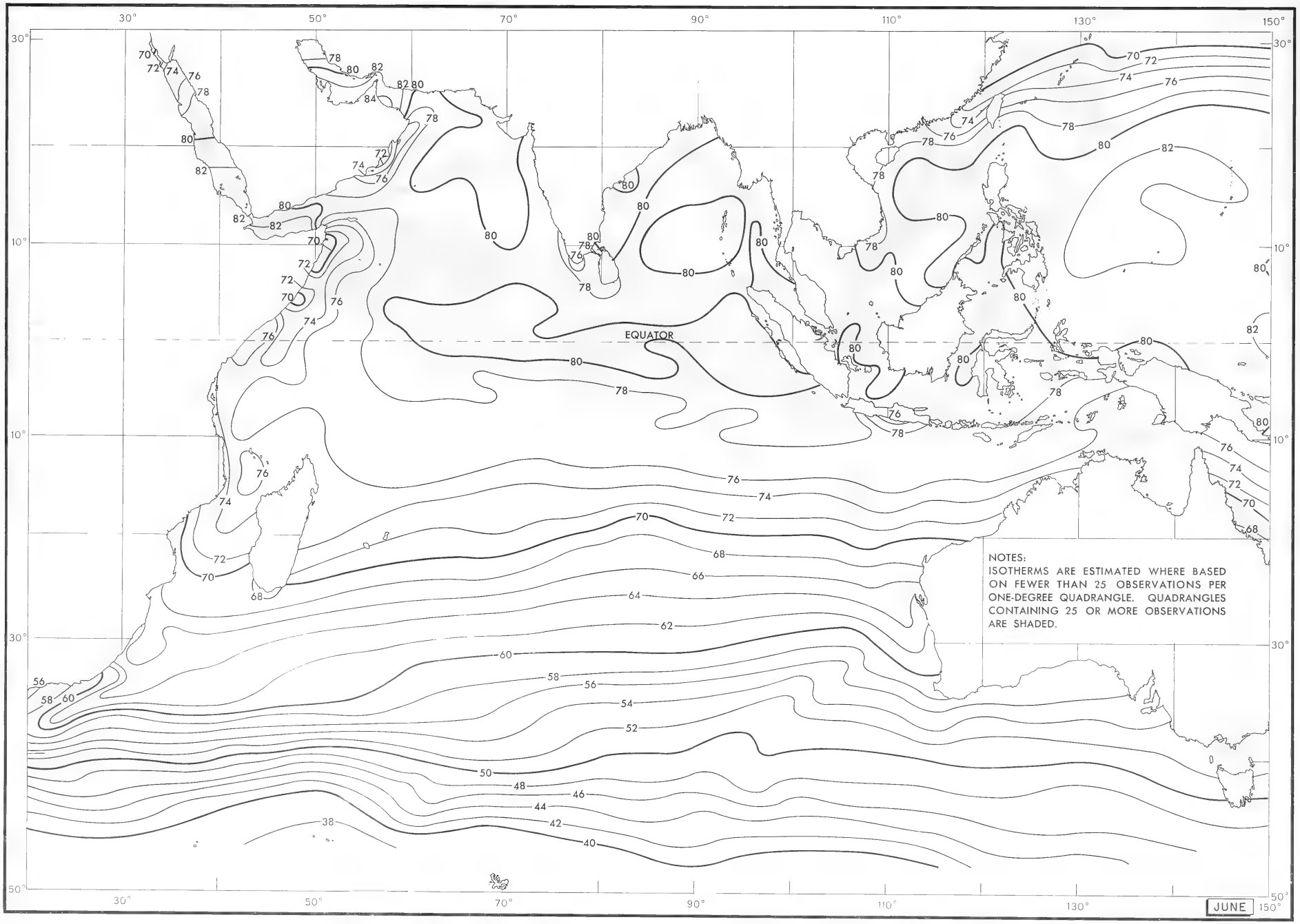


FIGURE 18 MINIMUM SEA SURFACE TEMPERATURE (°F.), JUNE

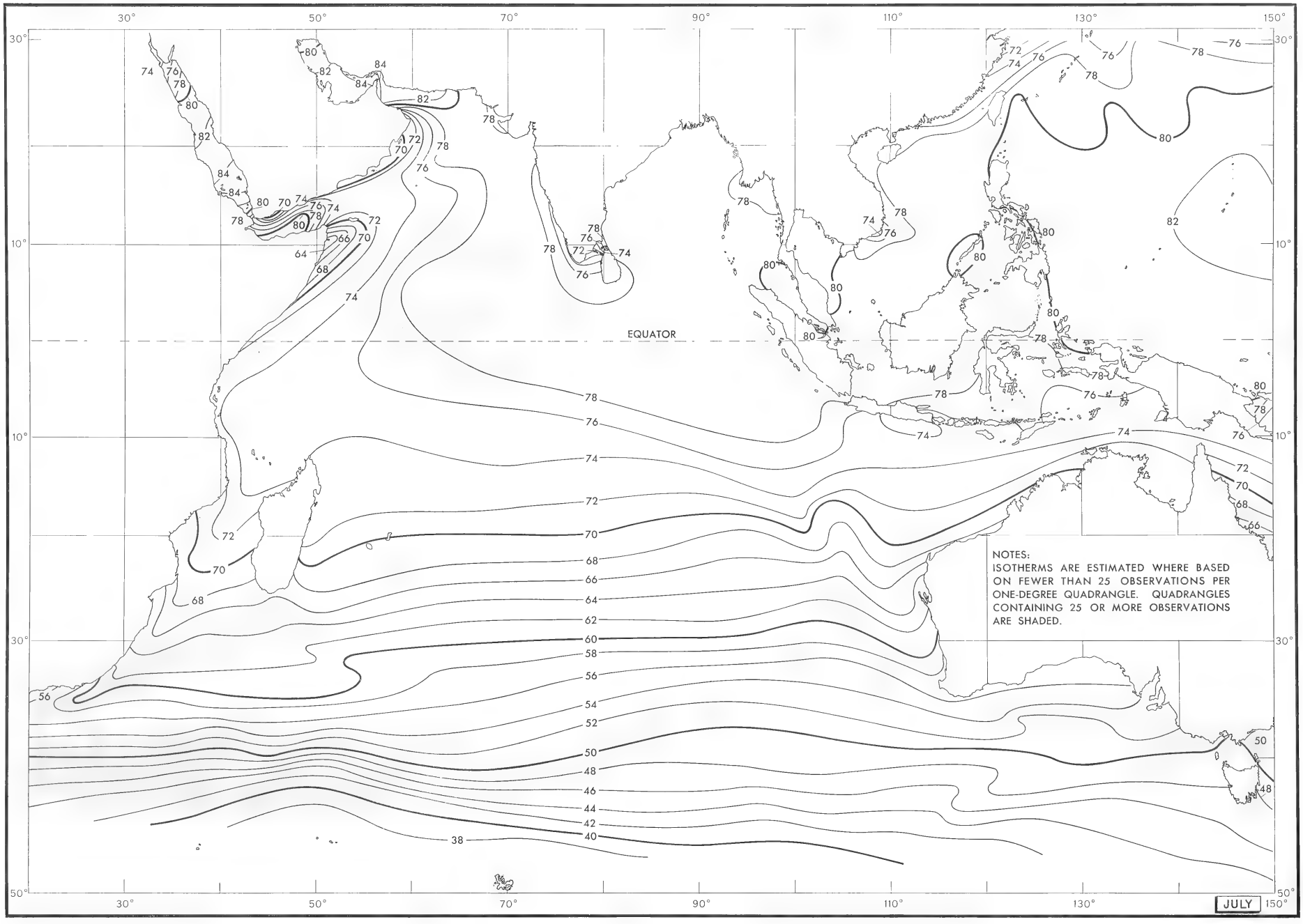


FIGURE 19 MINIMUM SEA SURFACE TEMPERATURE (°F.), JULY

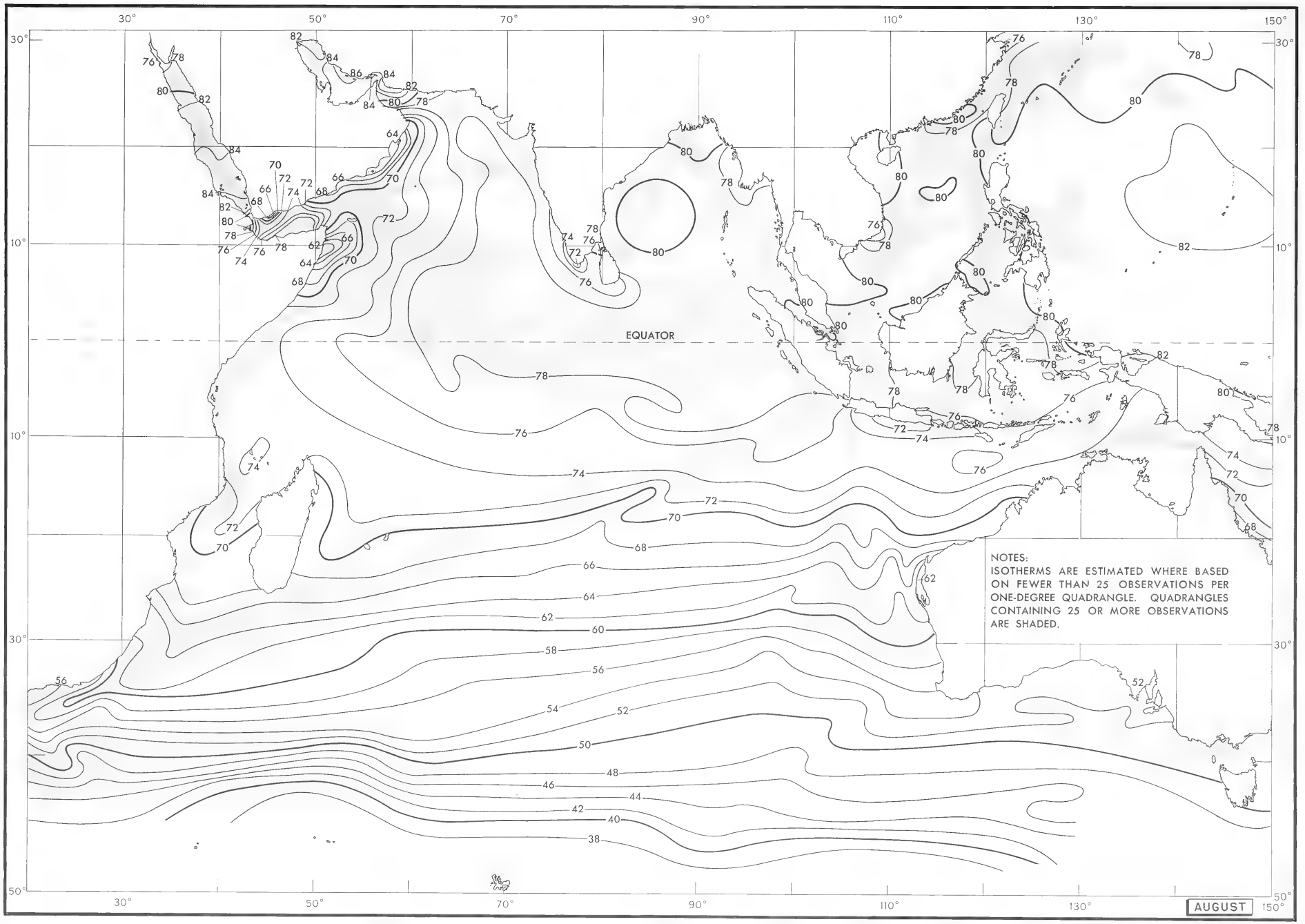


FIGURE 20 MINIMUM SEA SURFACE TEMPERATURE (°F.), AUGUST

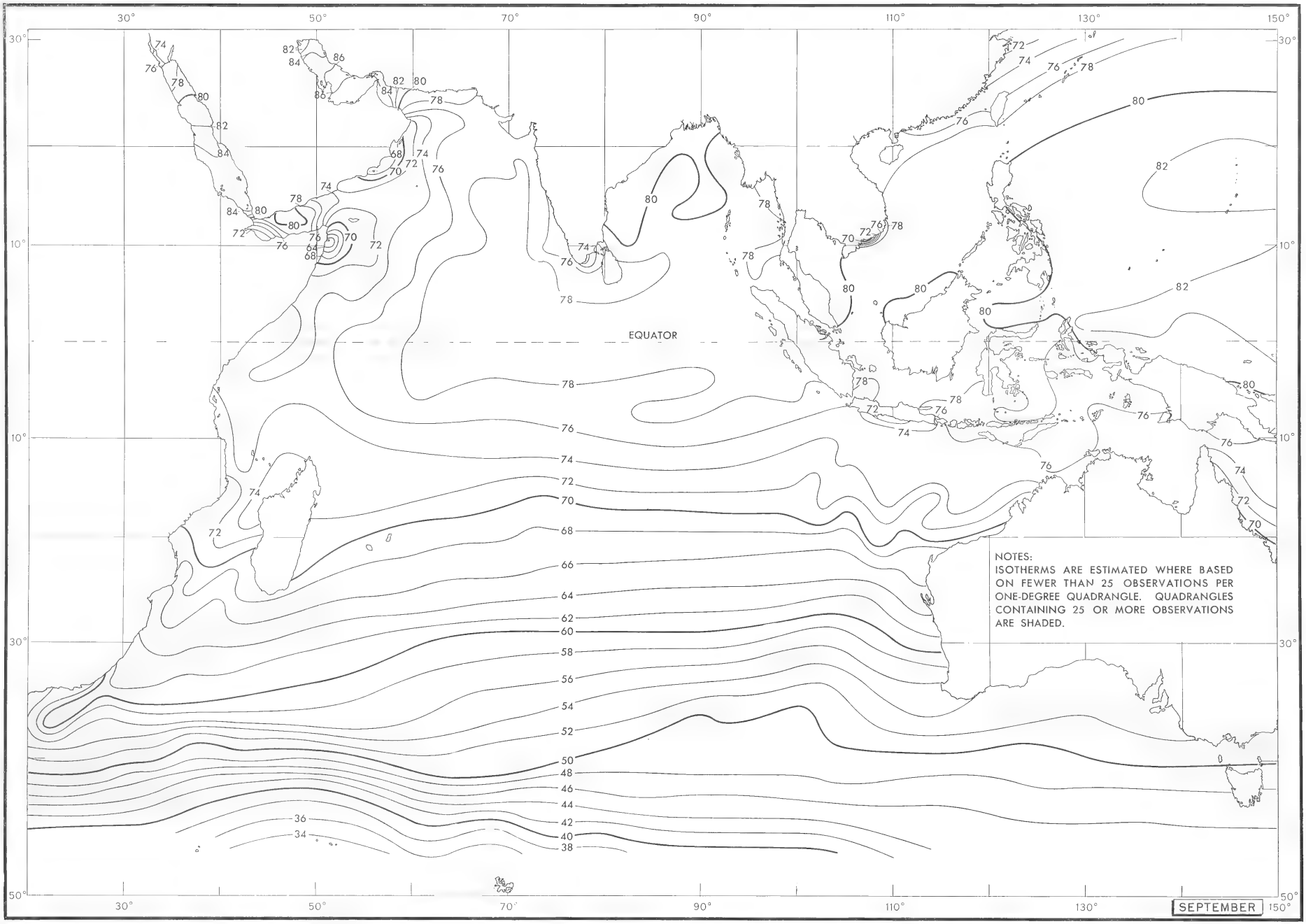


FIGURE 21 MINIMUM SEA SURFACE TEMPERATURE (°F.), SEPTEMBER

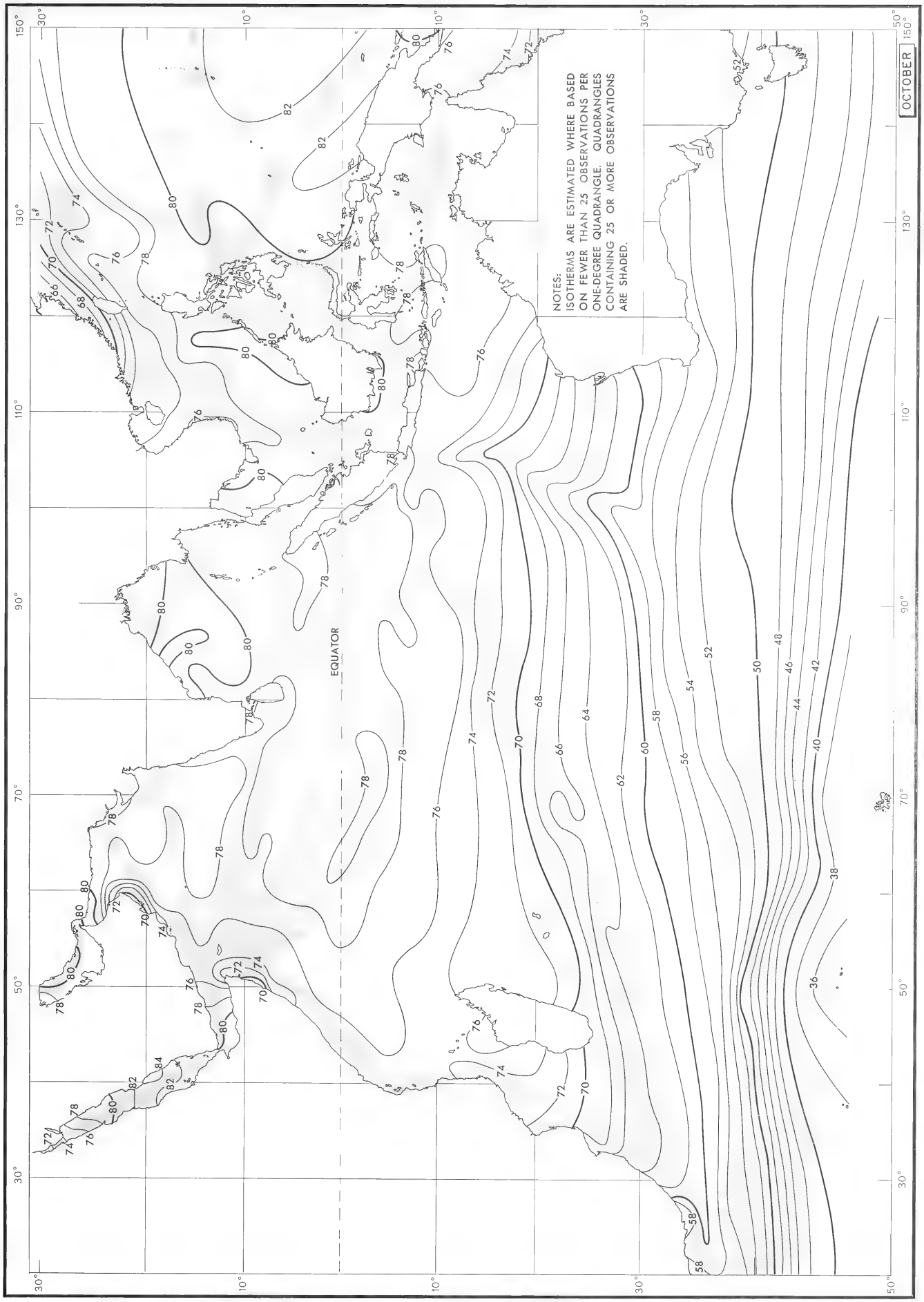


FIGURE 22 MINIMUM SEA SURFACE TEMPERATURE (°F.), OCTOBER

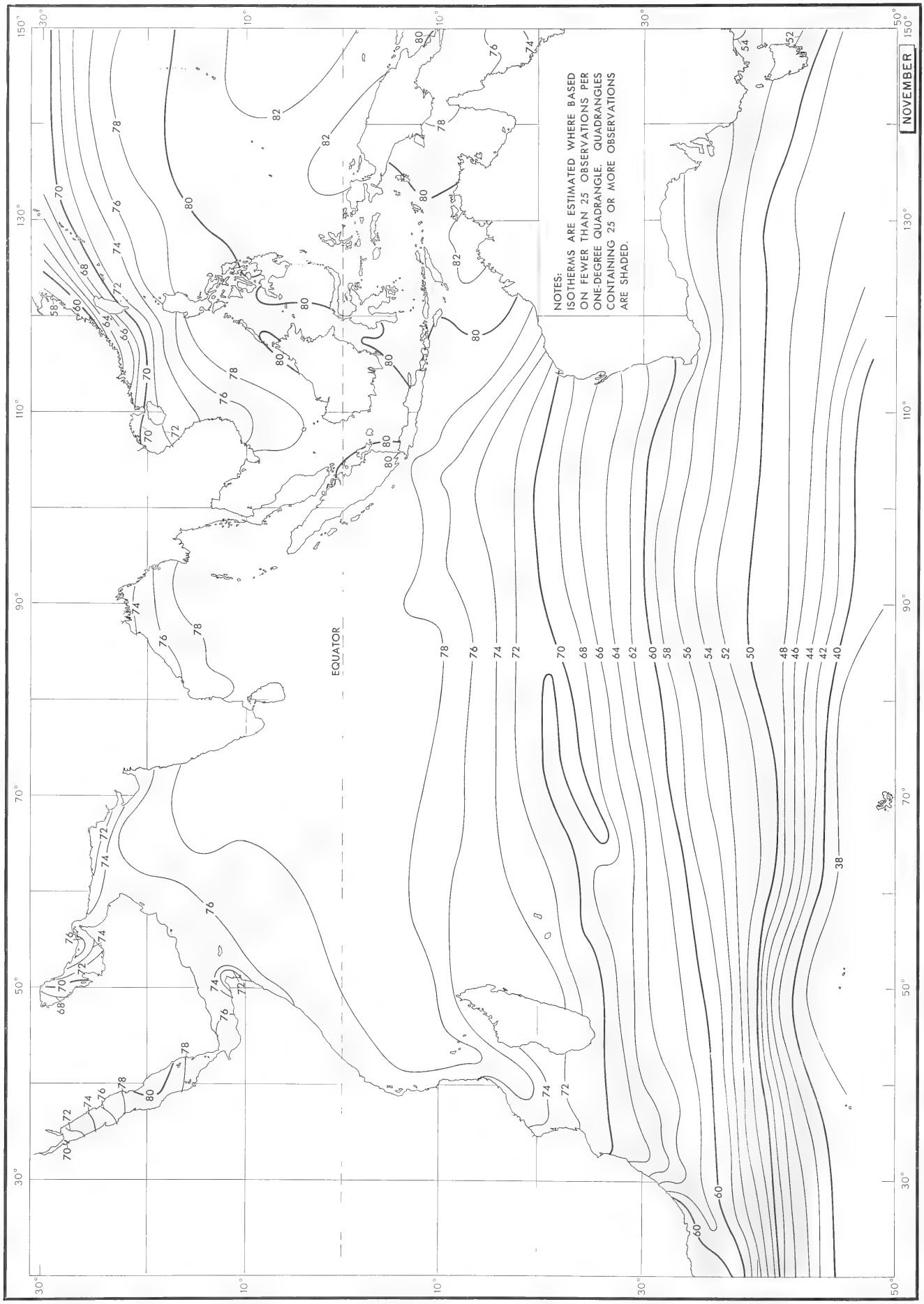


FIGURE 23 MINIMUM SEA SURFACE TEMPERATURE (°F.), NOVEMBER

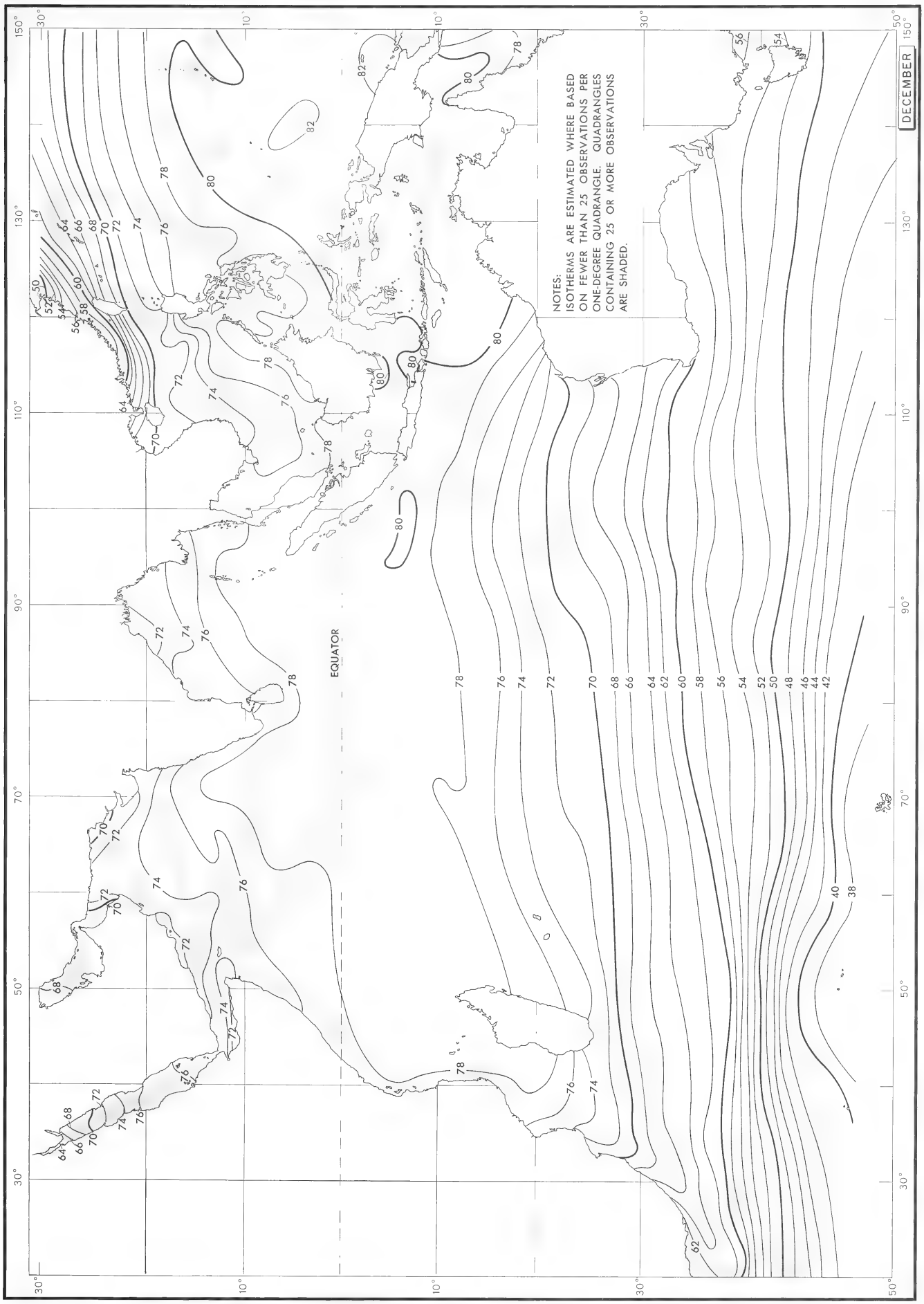


FIGURE 24 MINIMUM SEA SURFACE TEMPERATURE (°F.), DECEMBER

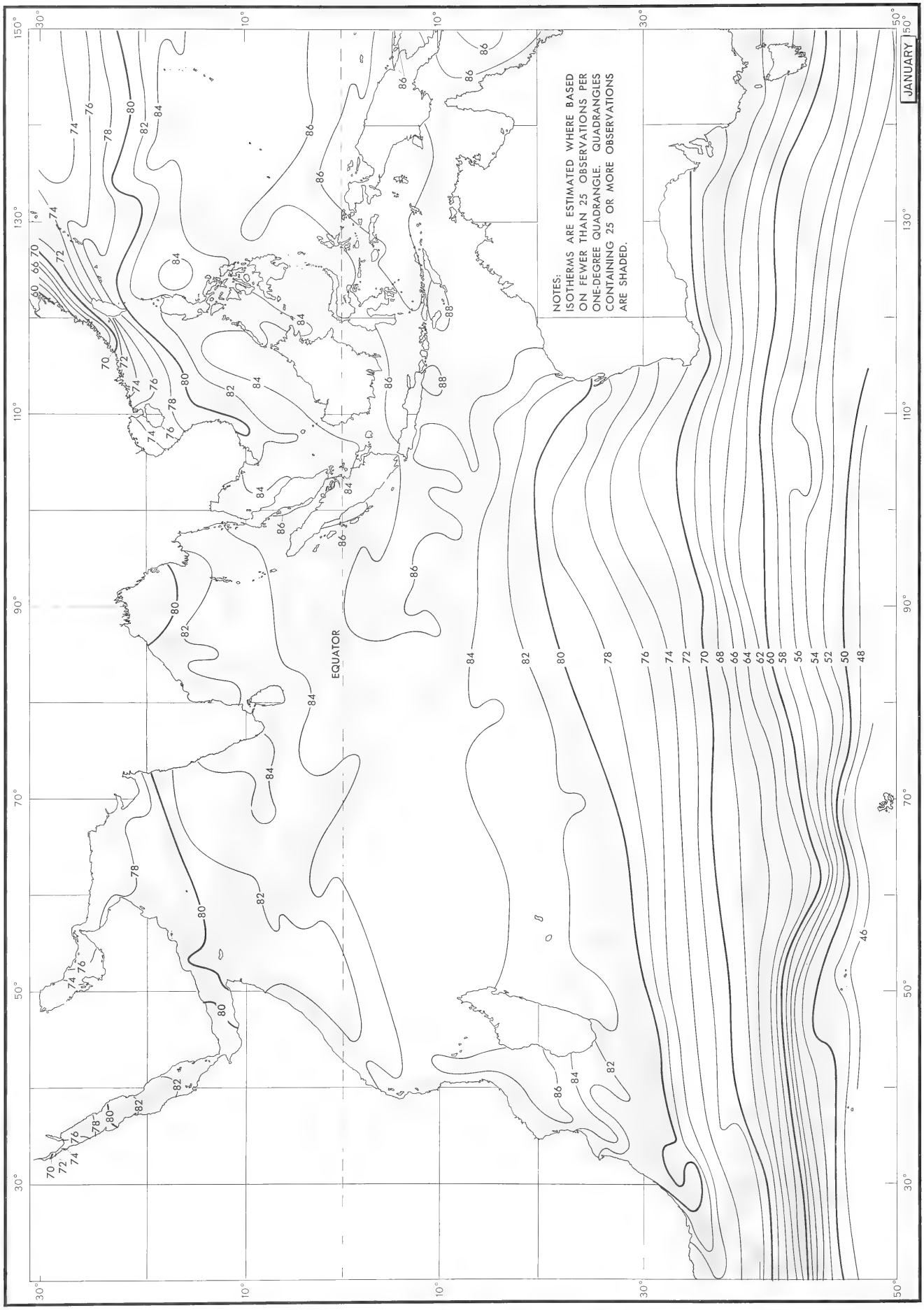


FIGURE 25 MAXIMUM SEA SURFACE TEMPERATURE (°F.), JANUARY

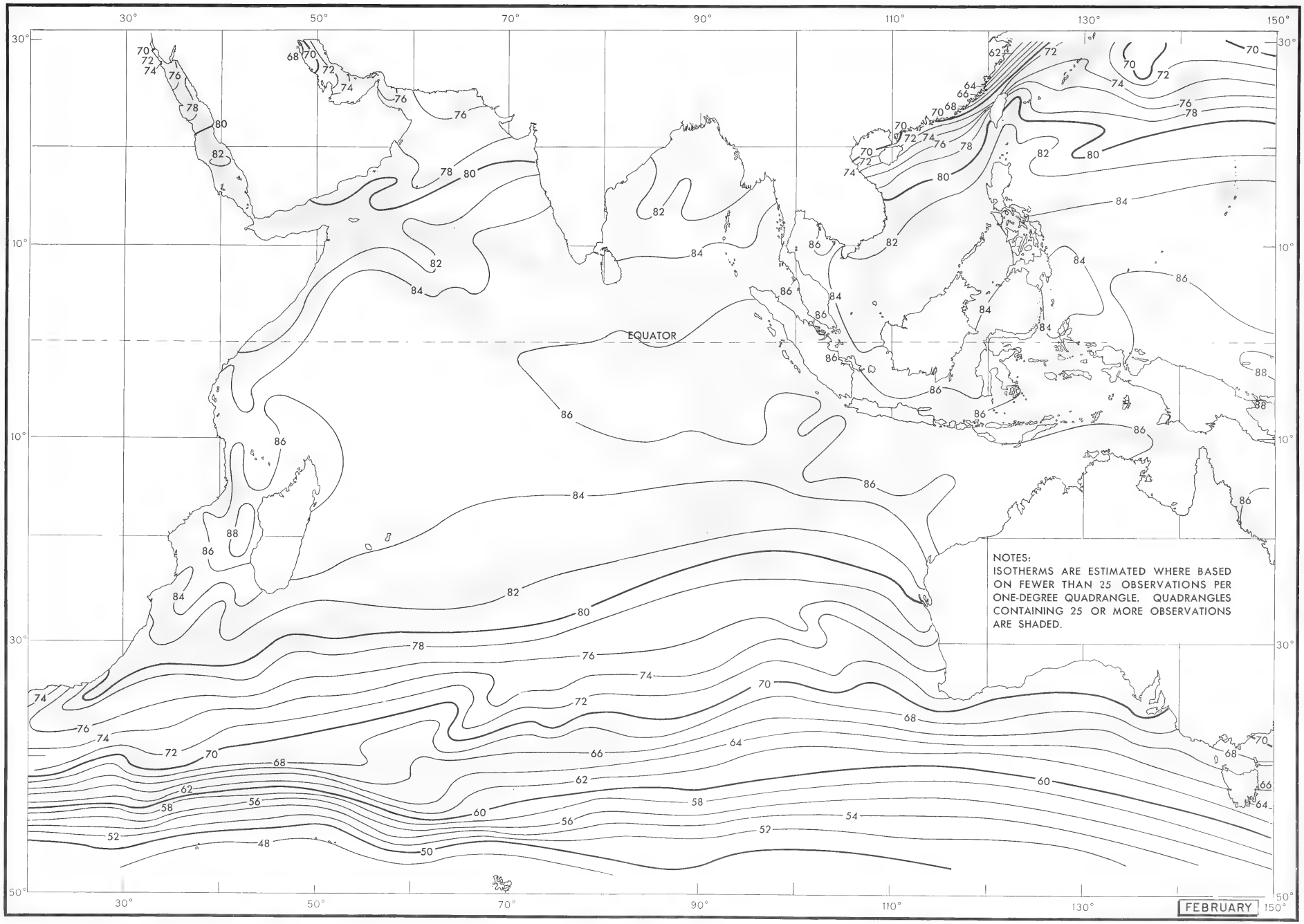


FIGURE 26 MAXIMUM SEA SURFACE TEMPERATURE (°F.), FEBRUARY

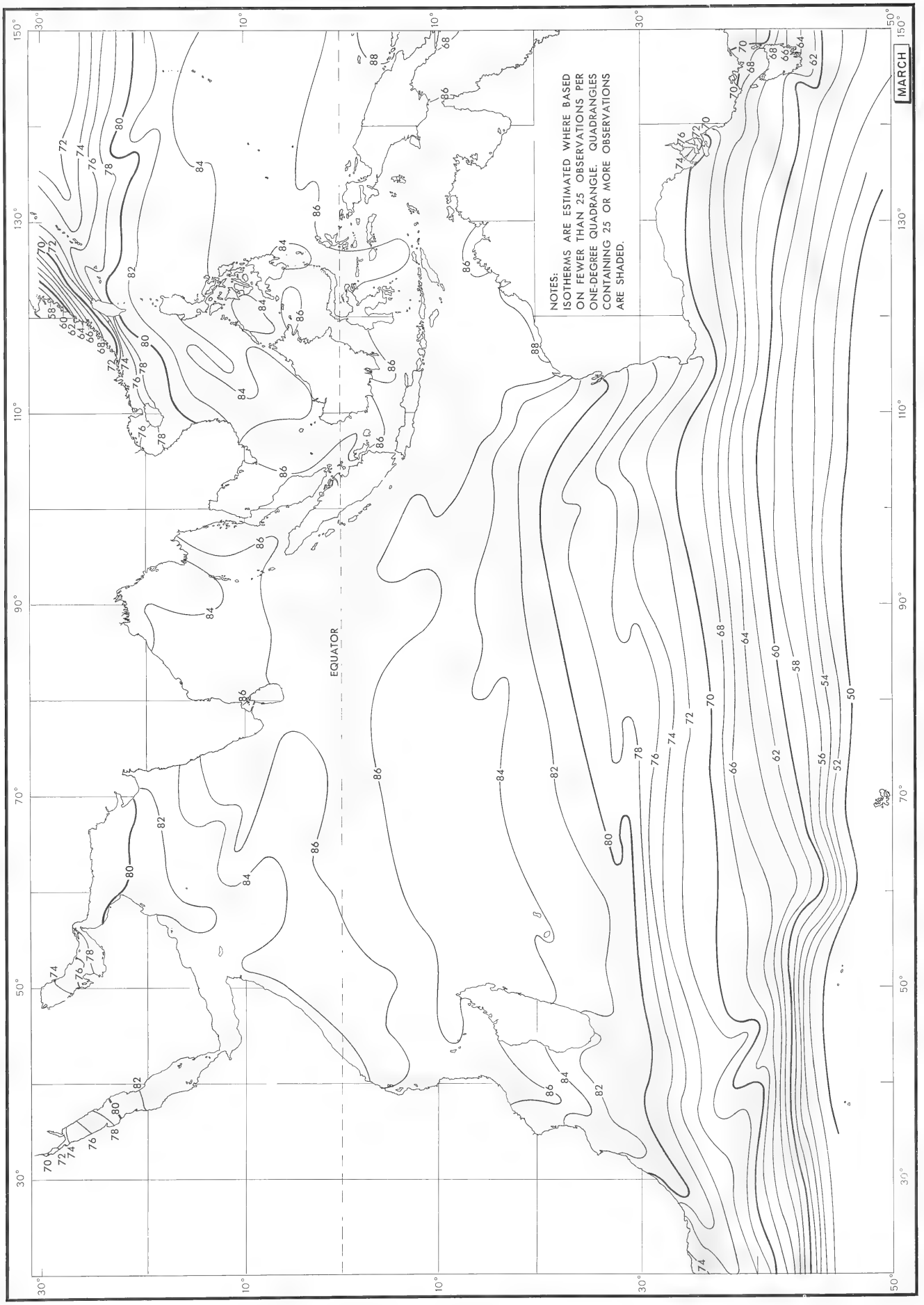


FIGURE 27 MAXIMUM SEA SURFACE TEMPERATURE (°F.), MARCH

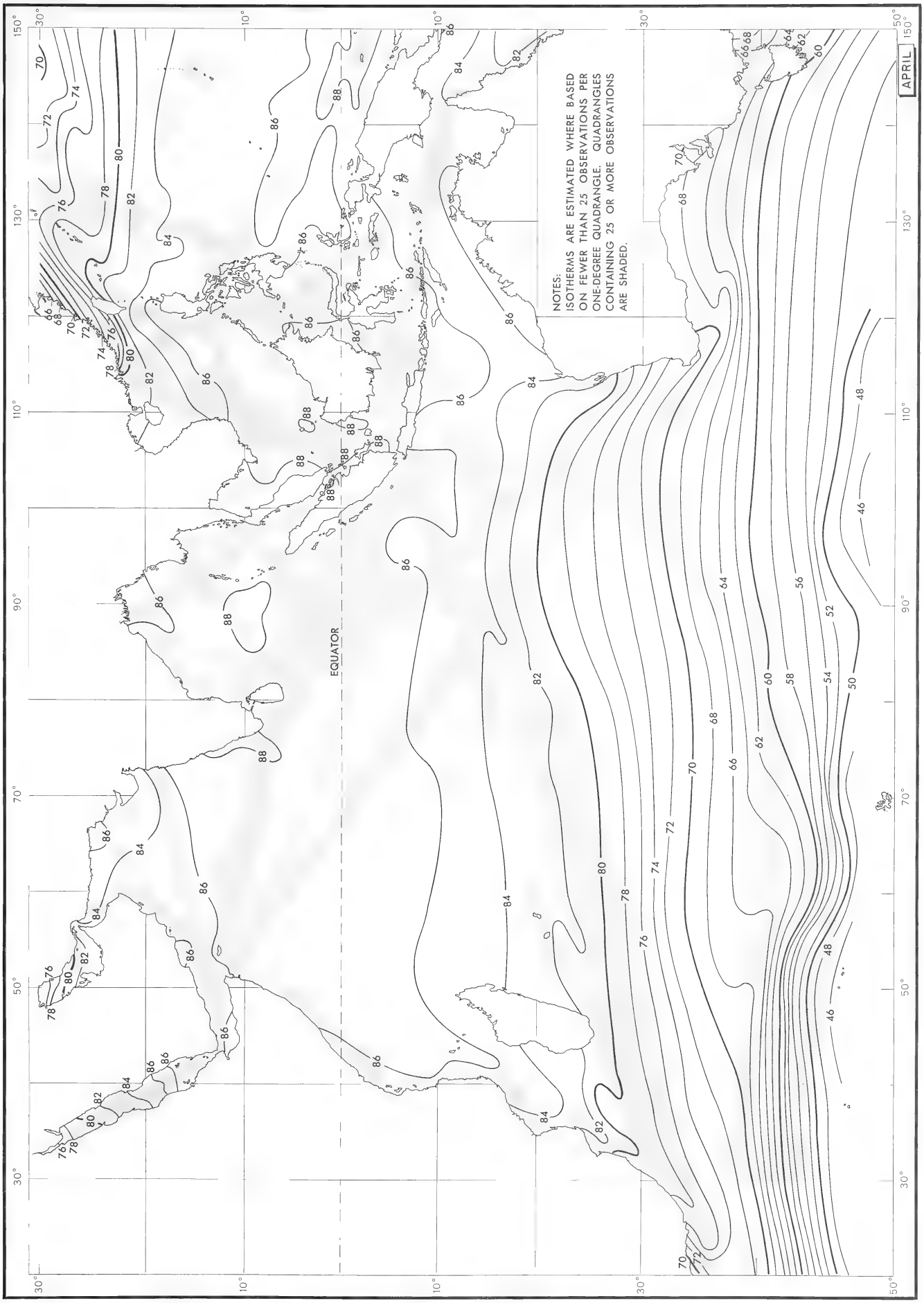


FIGURE 28 MAXIMUM SEA SURFACE TEMPERATURE (°F.), APRIL

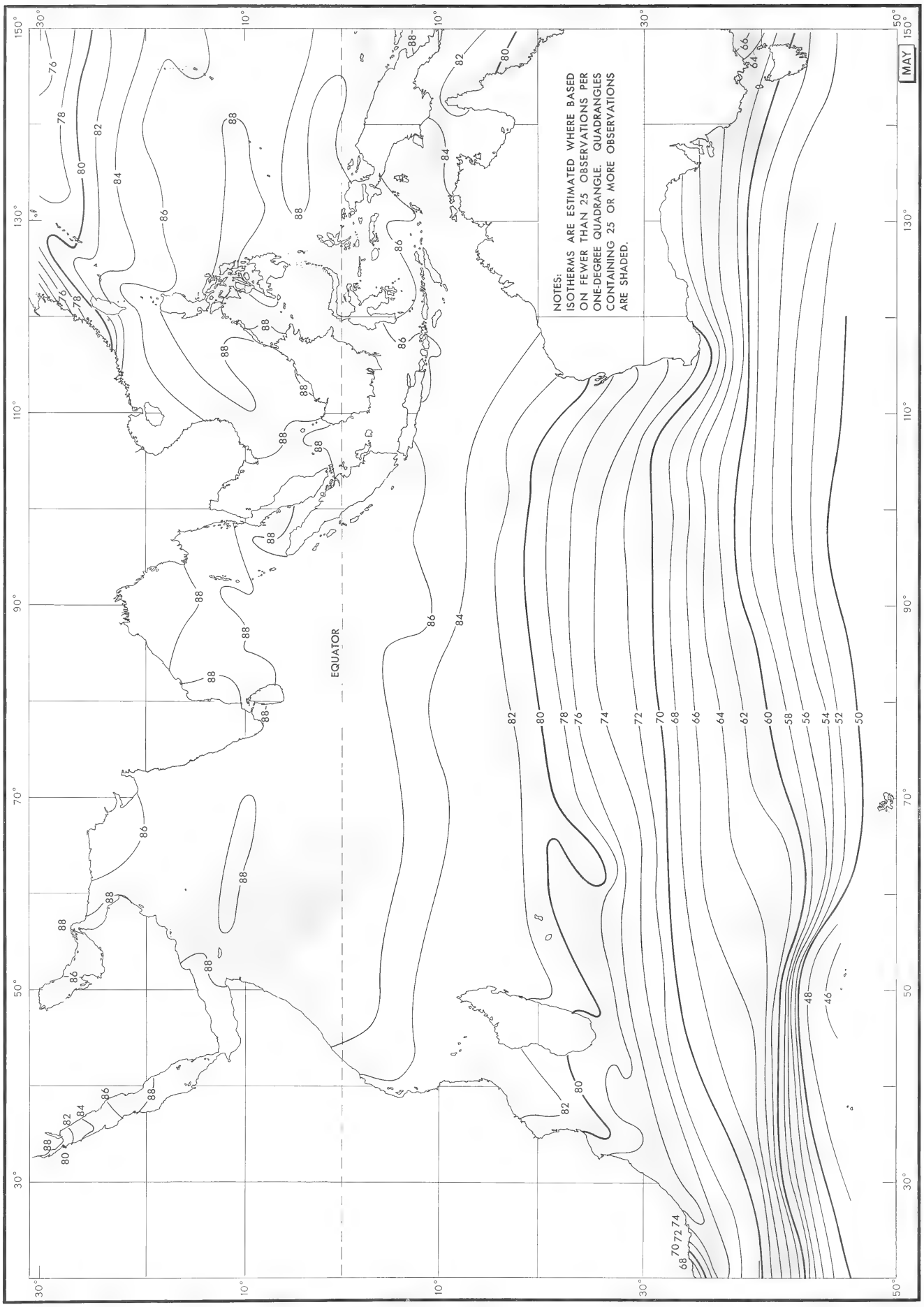


FIGURE 29 MAXIMUM SEA SURFACE TEMPERATURE (°F.), MAY

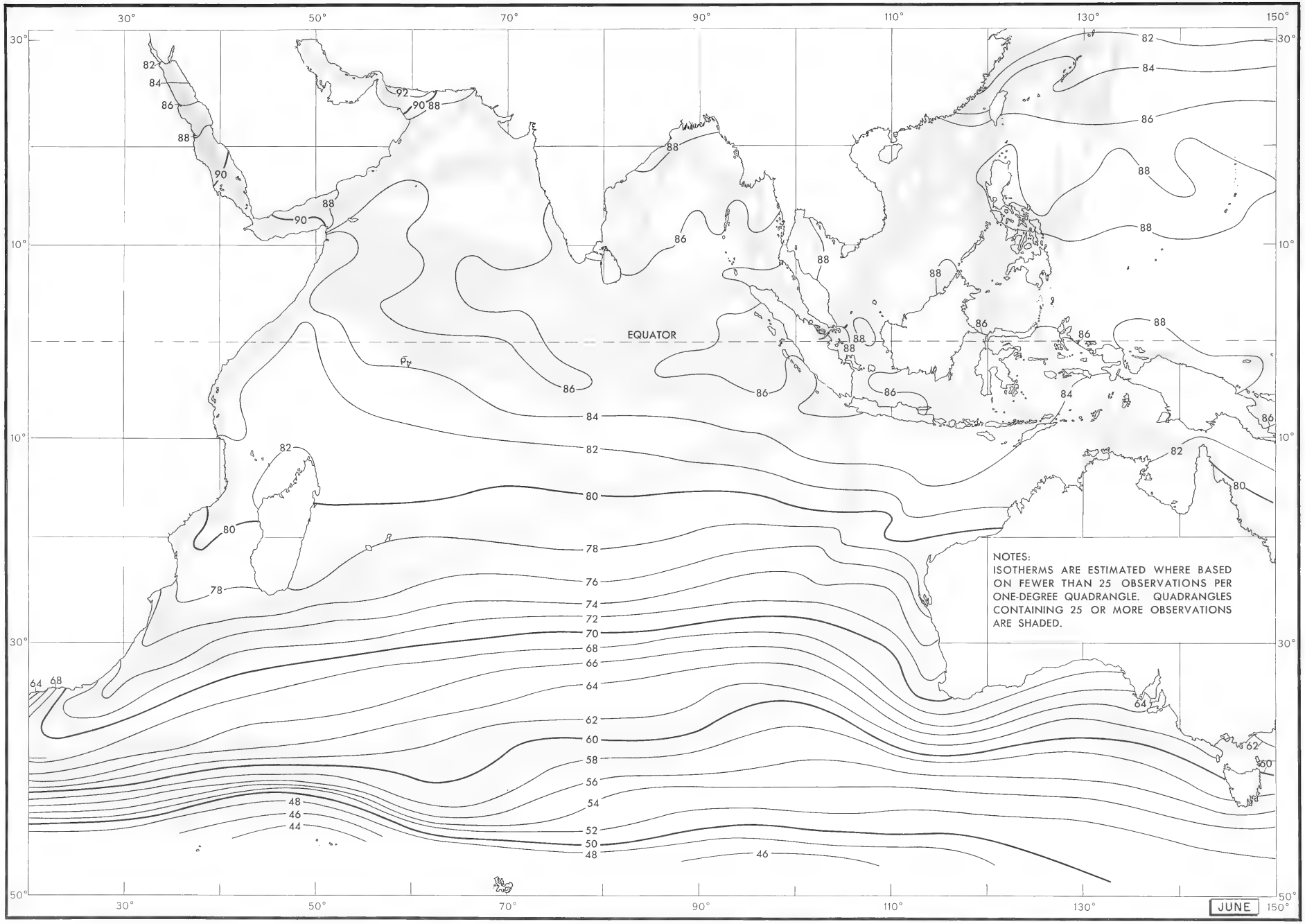


FIGURE 30 MAXIMUM SEA SURFACE TEMPERATURE (°F.), JUNE

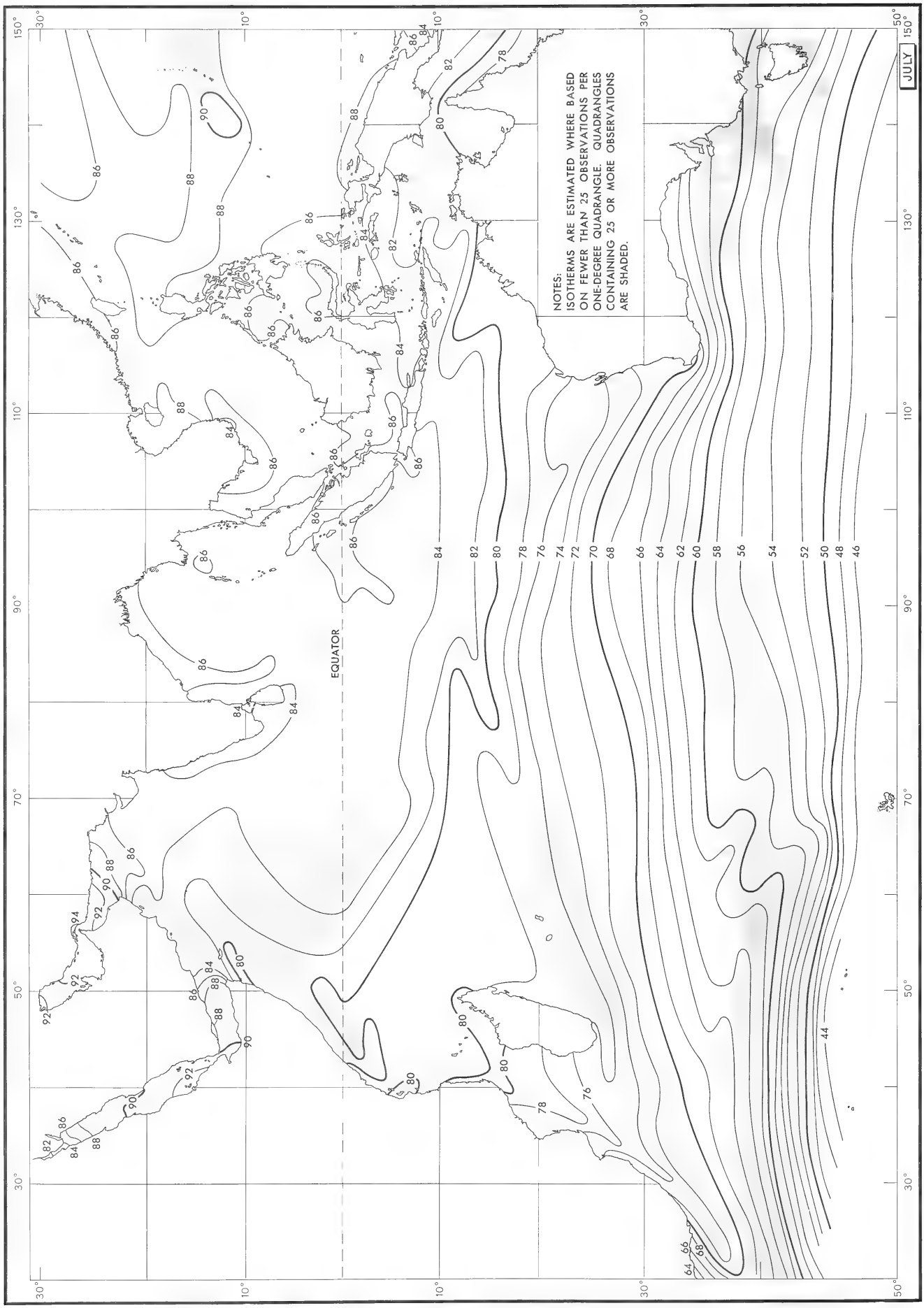


FIGURE 31 MAXIMUM SEA SURFACE TEMPERATURE (°F.), JULY

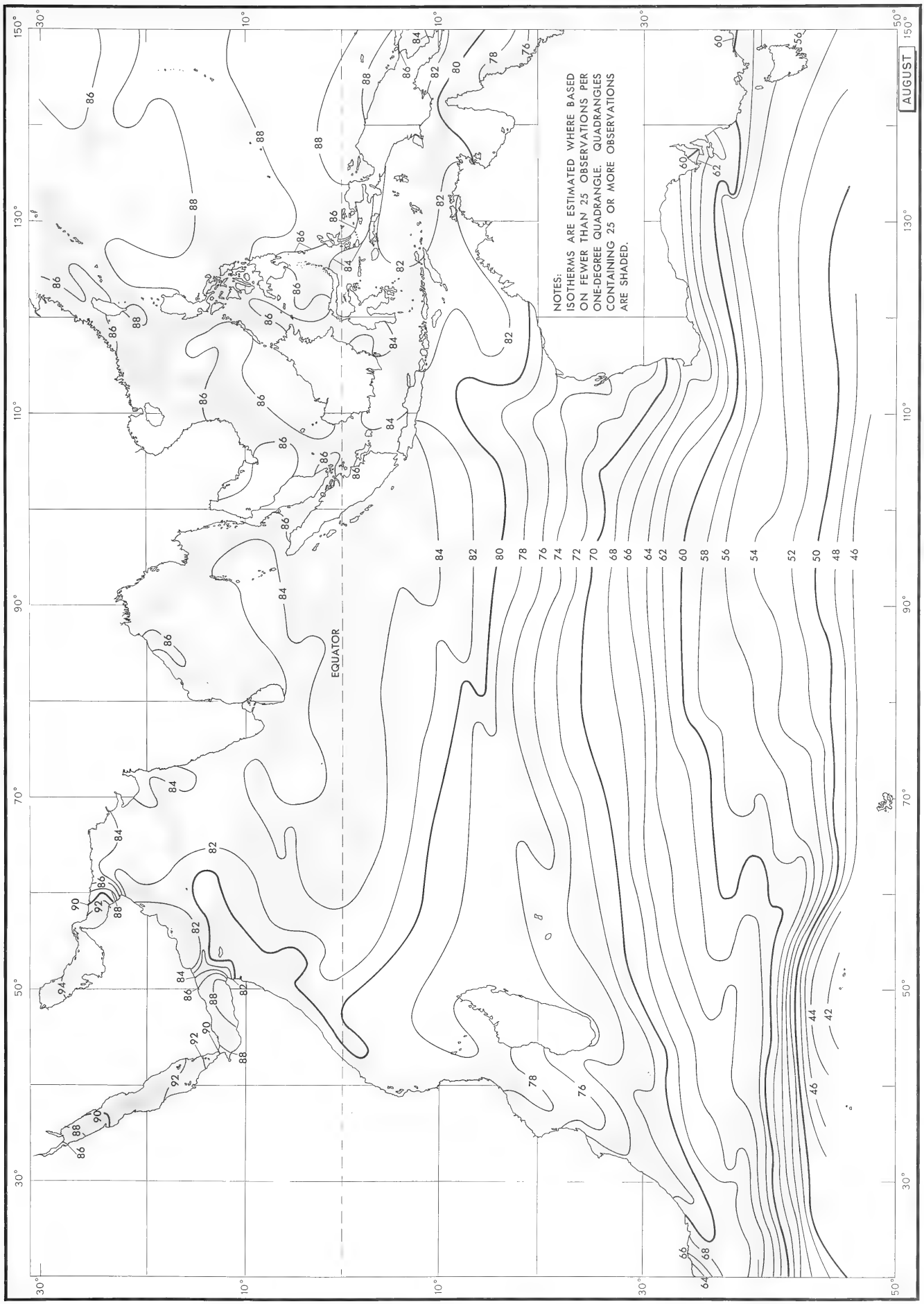


FIGURE 32 MAXIMUM SEA SURFACE TEMPERATURE (°F.), AUGUST

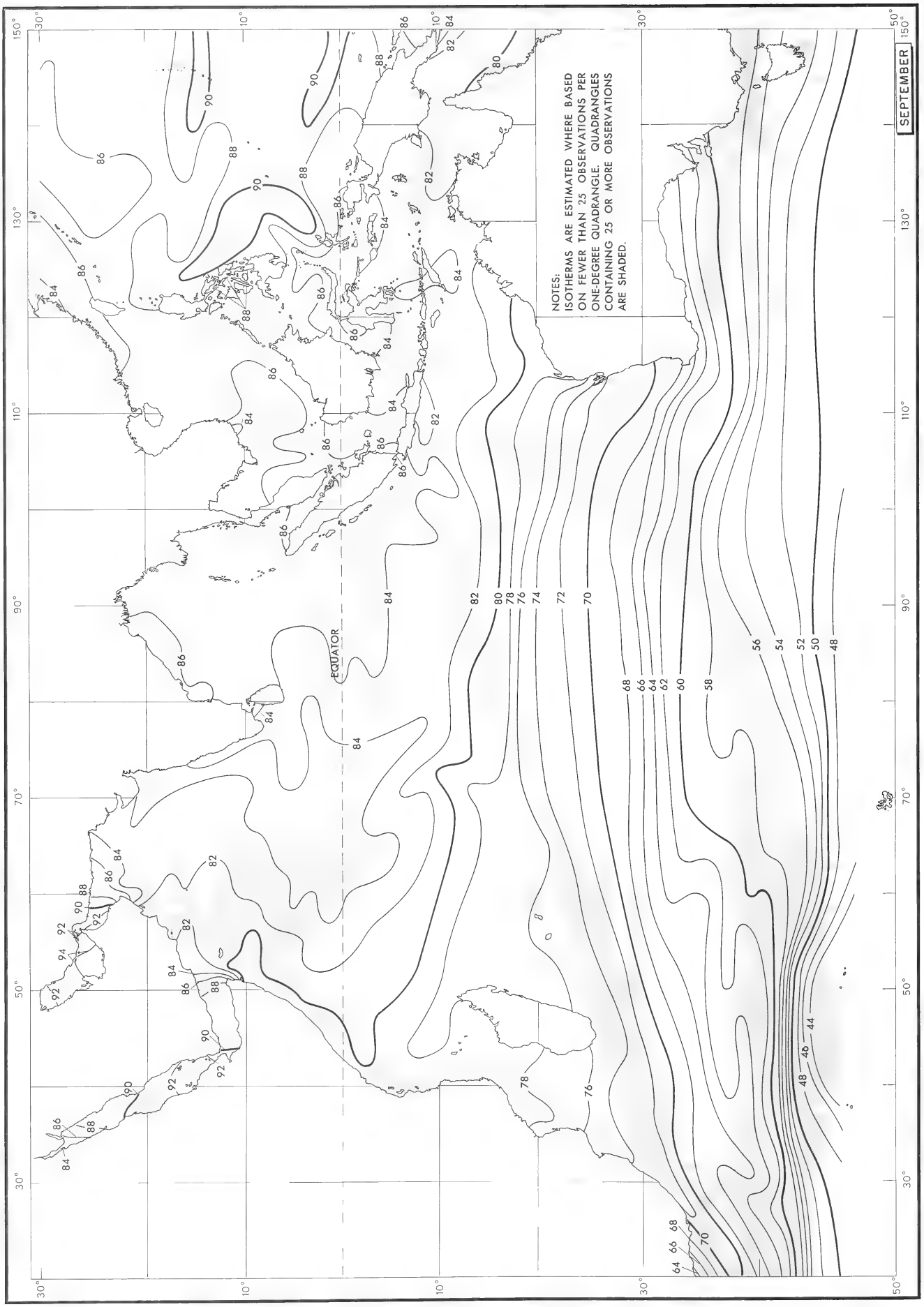


FIGURE 33 MAXIMUM SEA SURFACE TEMPERATURE (°F.), SEPTEMBER

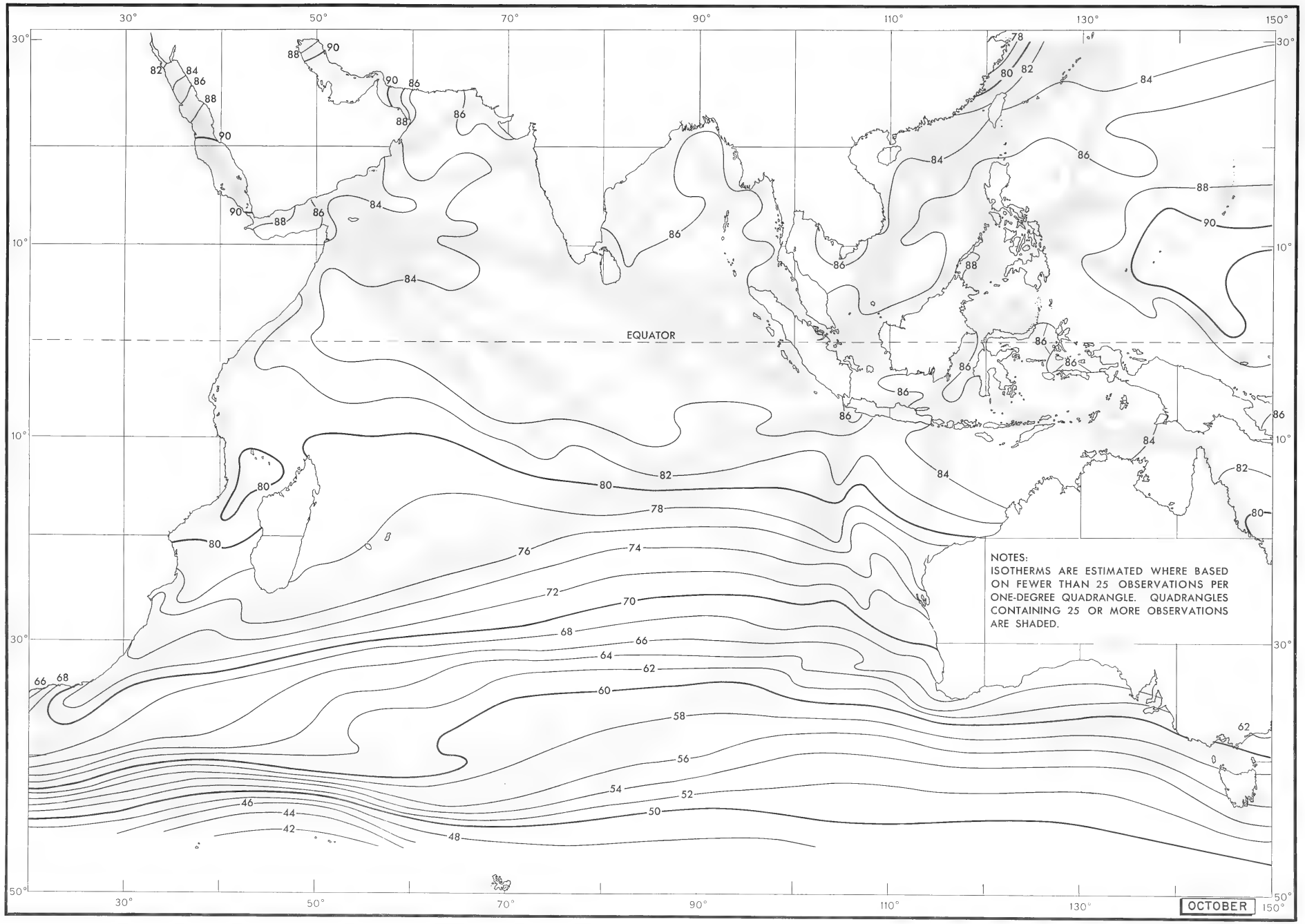


FIGURE 34 MAXIMUM SEA SURFACE TEMPERATURE (°F.), OCTOBER

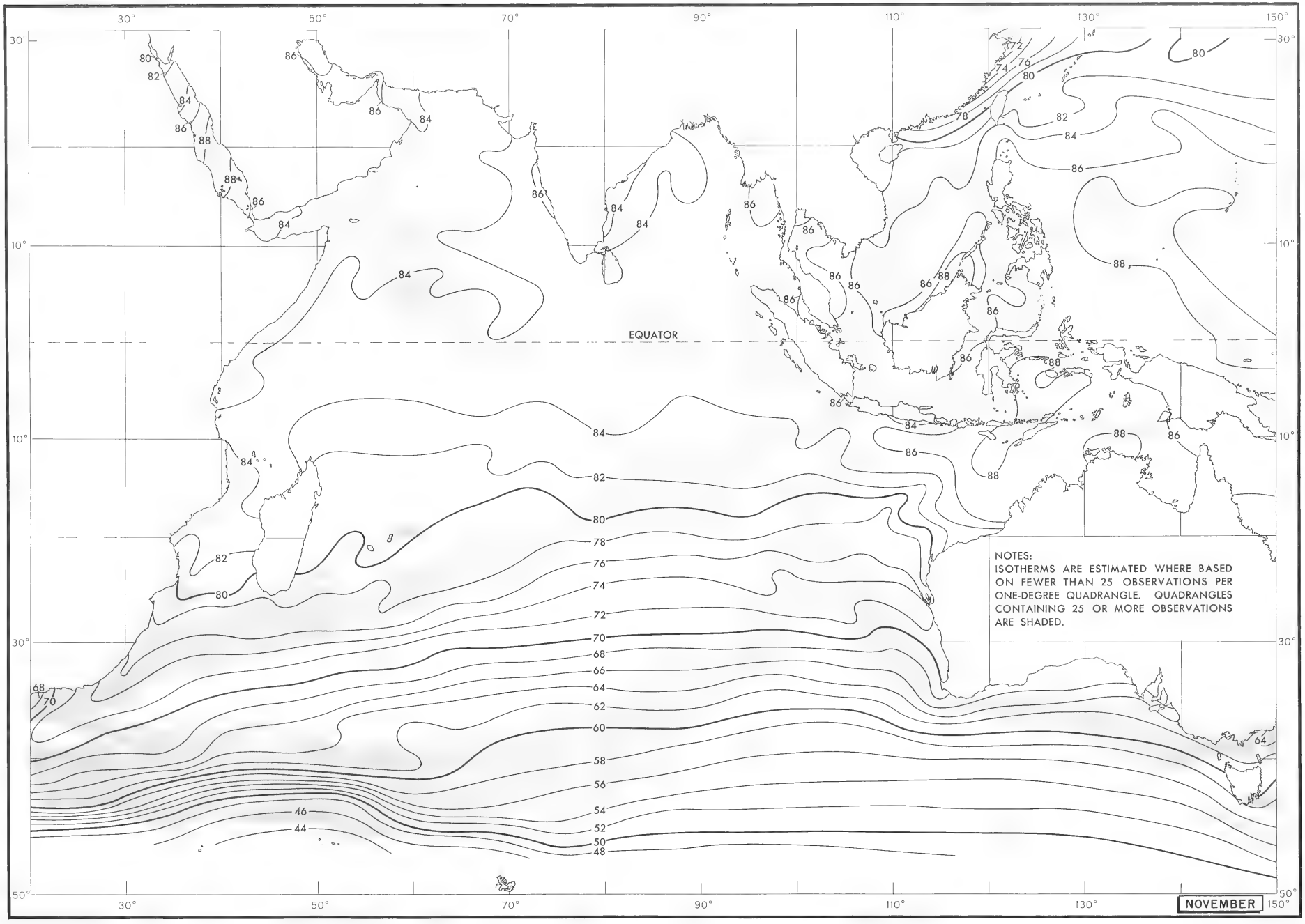


FIGURE 35 MAXIMUM SEA SURFACE TEMPERATURE (°F.), NOVEMBER

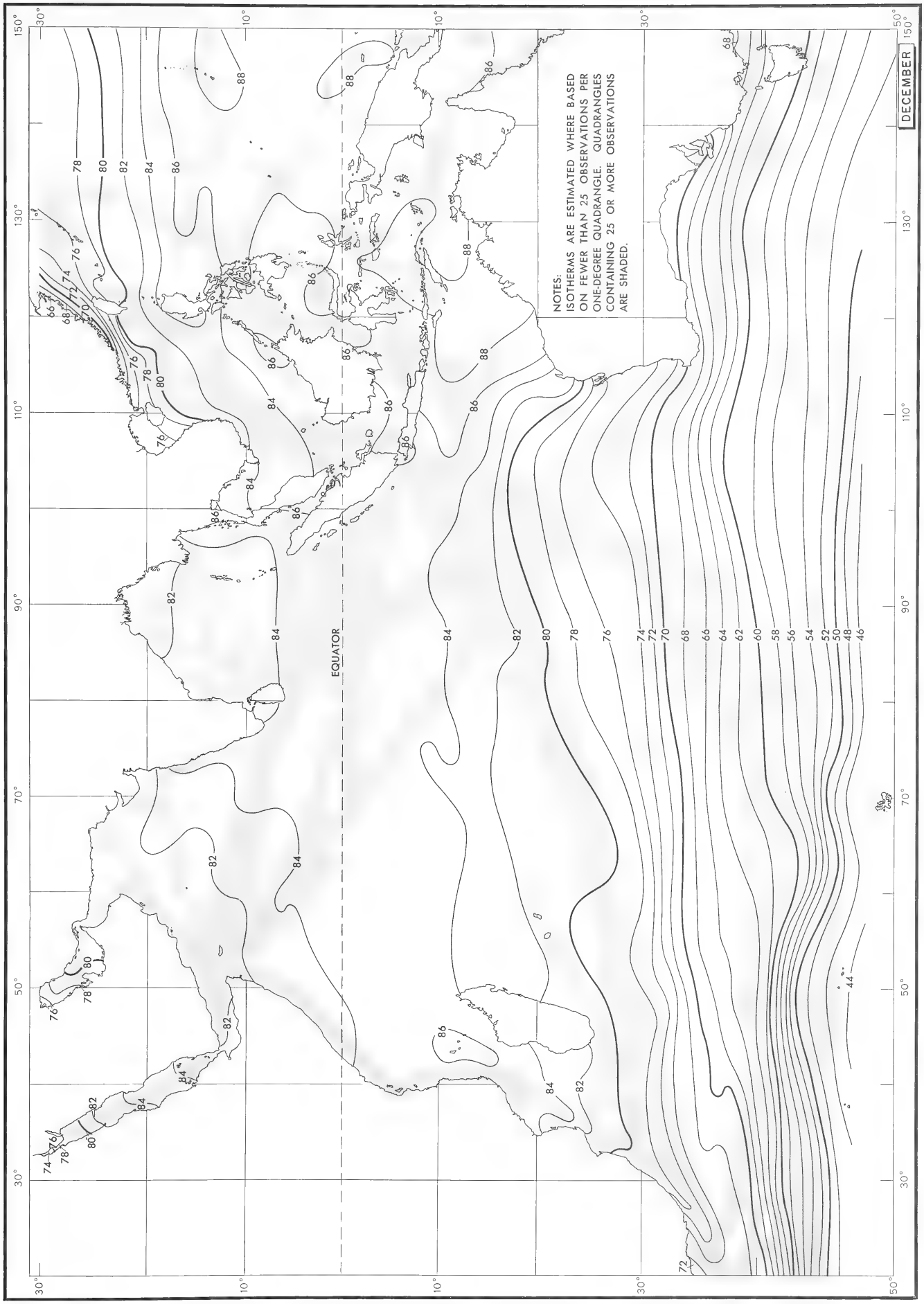


FIGURE 36 MAXIMUM SEA SURFACE TEMPERATURE (°F.), DECEMBER

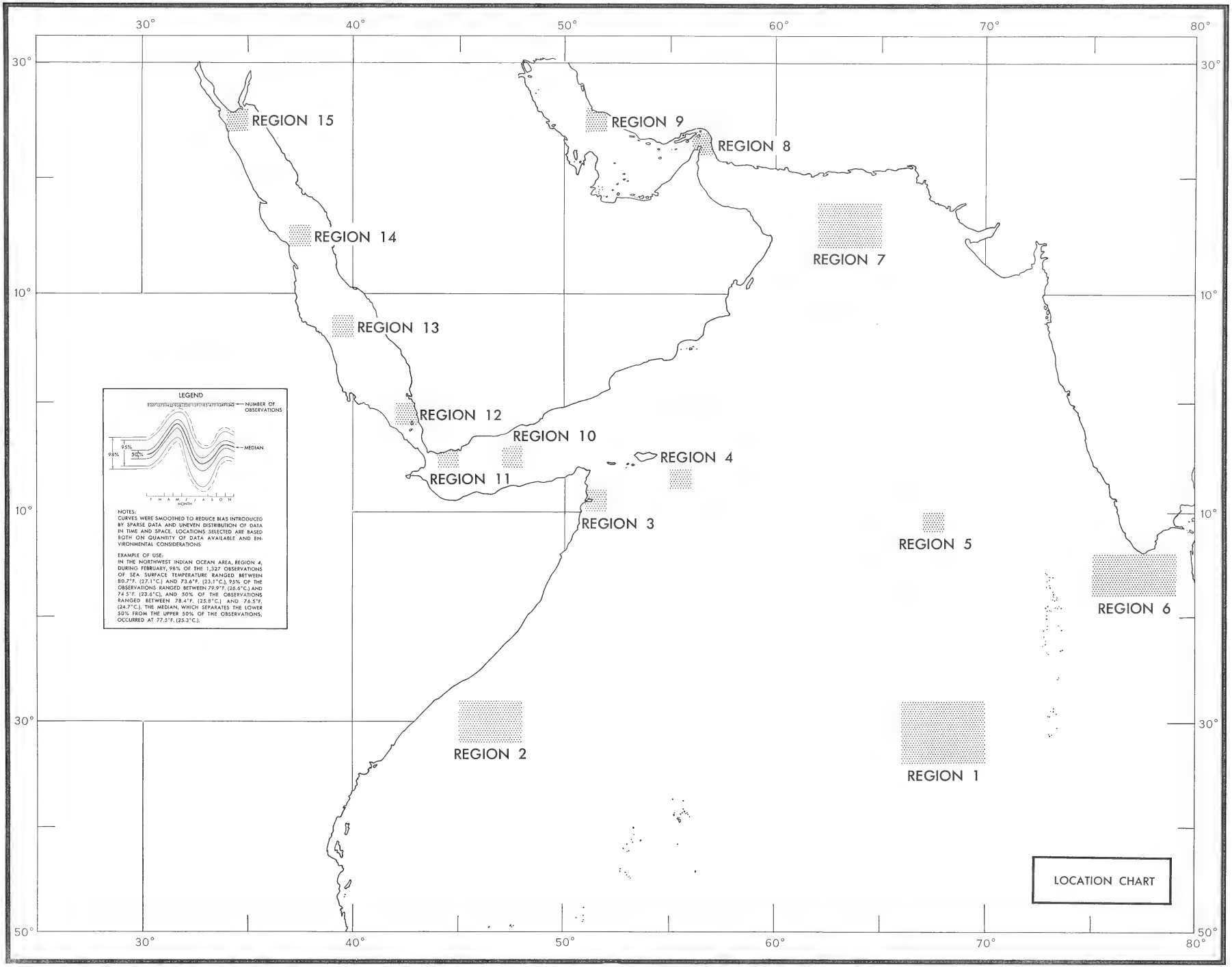


FIGURE 37 MONTHLY VARIABILITY OF SEA SURFACE TEMPERATURE IN SELECTED REGIONS—NORTHWEST INDIAN OCEAN

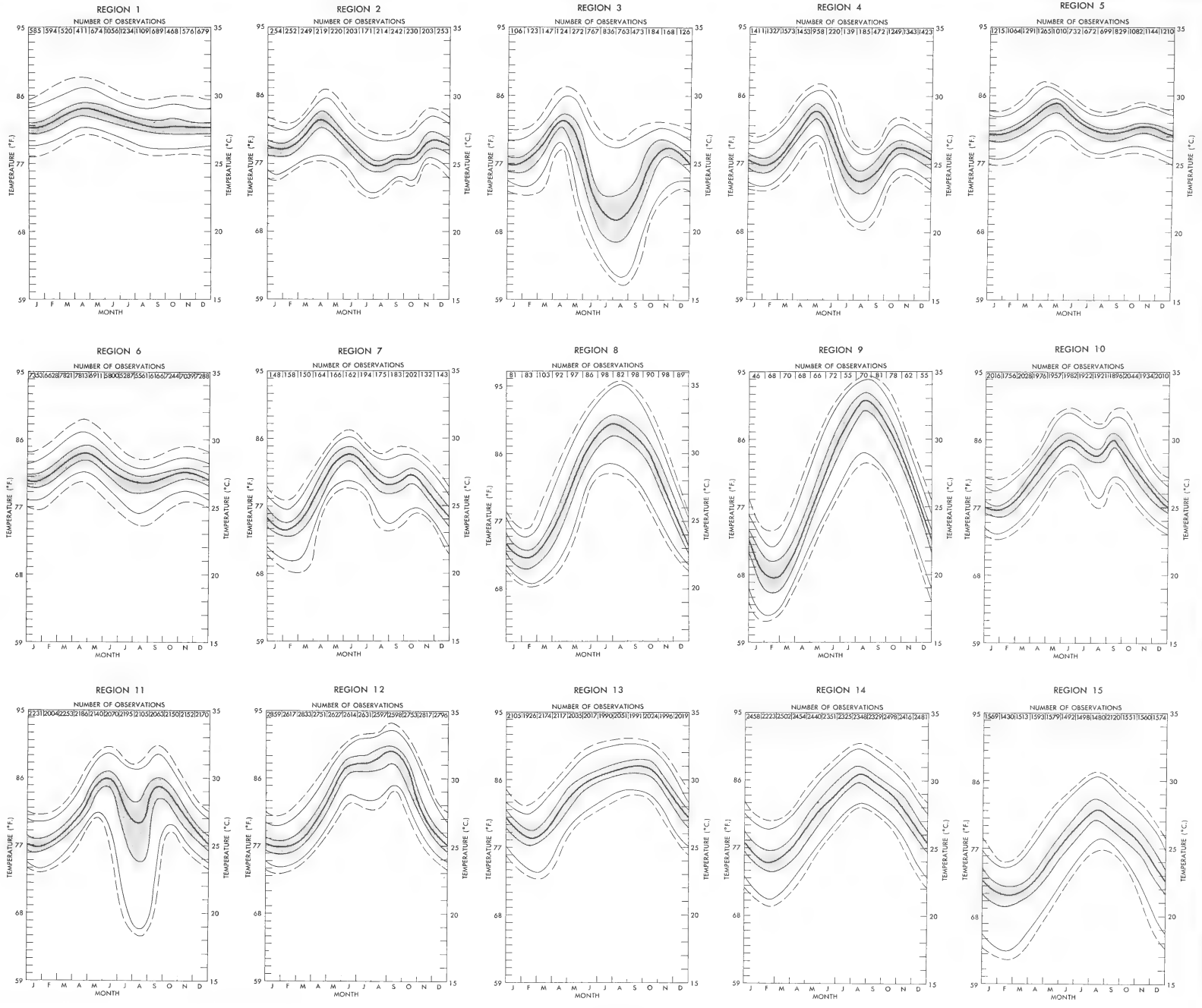
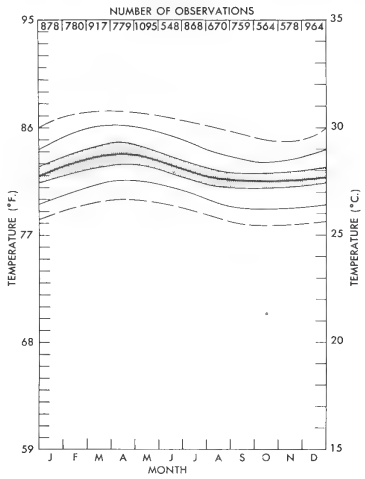

REGION 1
NUMBER OF OBSERVATIONS
585 594 520 411 674 1056 1234 1109 689 468 576 679
REGION 2
NUMBER OF OBSERVATIONS
254 252 249 219 220 203 171 214 242 230 203 253
REGION 3
NUMBER OF OBSERVATIONS
106 123 147 124 272 767 836 763 473 184 168 126
REGION 4
NUMBER OF OBSERVATIONS
141 1327 1573 1453 958 220 139 185 472 1249 343 423
REGION 5
NUMBER OF OBSERVATIONS
1215 1064 1291 1265 1010 732 672 699 829 1082 1144 1210
REGION 6
NUMBER OF OBSERVATIONS
7353 6602 7821 7813 6911 5800 5287 5561 6166 7244 7039 7288
REGION 7
NUMBER OF OBSERVATIONS
148 158 150 164 166 162 194 175 183 202 132 143
REGION 8
NUMBER OF OBSERVATIONS
81 83 103 92 97 86 98 82 98 90 98 89
REGION 9
NUMBER OF OBSERVATIONS
46 68 70 68 66 72 55 70 81 78 62 55
REGION 10
NUMBER OF OBSERVATIONS
2016 1756 2028 1976 1957 1982 1922 1921 1896 2044 1934 2010
REGION 11
NUMBER OF OBSERVATIONS
2231 2004 2253 2186 2140 2070 2195 2105 2063 2150 2152 2170
REGION 12
NUMBER OF OBSERVATIONS
2859 2617 2833 2751 2627 2614 2631 2597 2598 2753 2817 2790
REGION 13
NUMBER OF OBSERVATIONS
2105 1926 2174 2117 2035 2017 1990 2051 1991 2024 1996 2019
REGION 14
NUMBER OF OBSERVATIONS
2458 2223 2502 2454 2440 2351 2325 2348 2329 2498 2416 2481
REGION 15
NUMBER OF OBSERVATIONS
1569 1430 1513 1593 1579 1492 1498 1480 1521 1551 1560 1574
TEMPERATURE (°F.)
TEMPERATURE (°C.)
MONTH
J F M A M J J A S O N D
95
86
77
68
59
35
30
25
20
15

FIGURE 38 MONTHLY VARIABILITY OF SEA SURFACE TEMPERATURE IN SELECTED REGIONS—NORTHEAST INDIAN OCEAN

REGION 1



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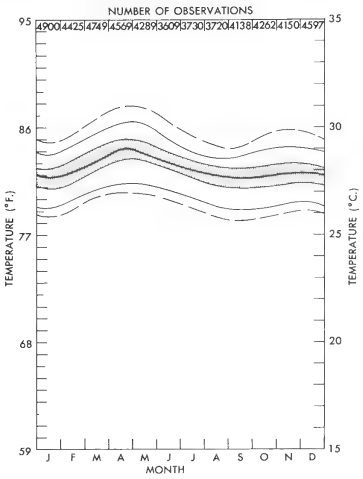

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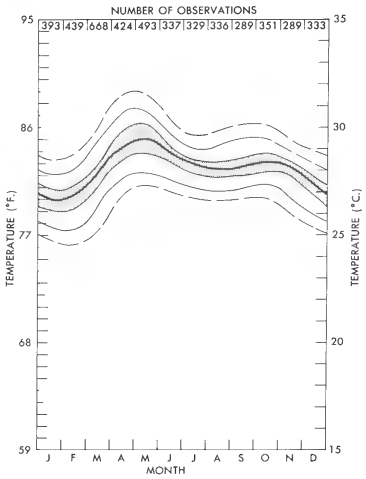

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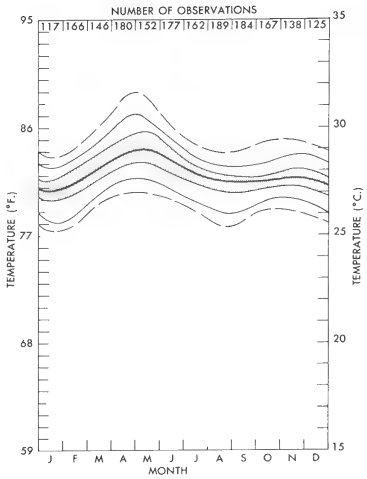

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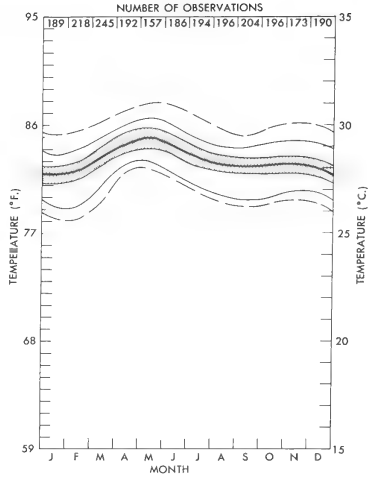

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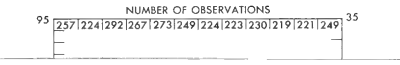

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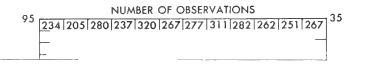

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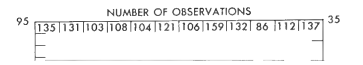

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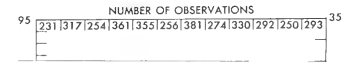

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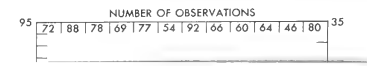

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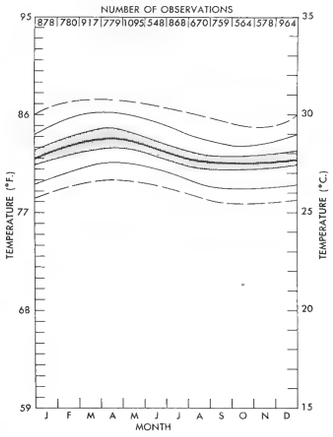

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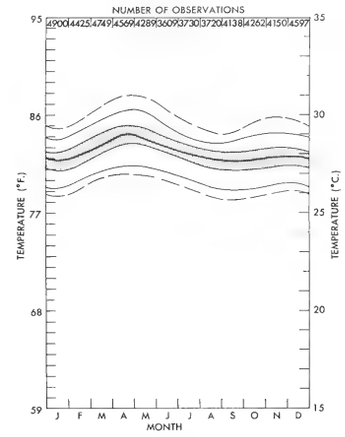

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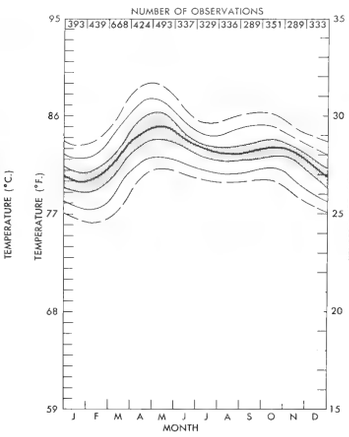

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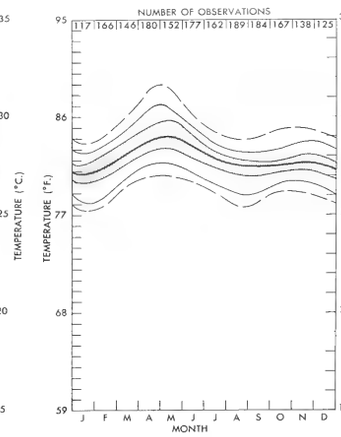

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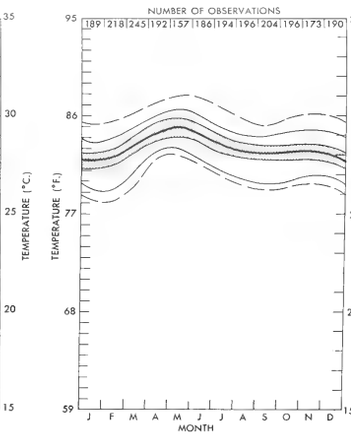

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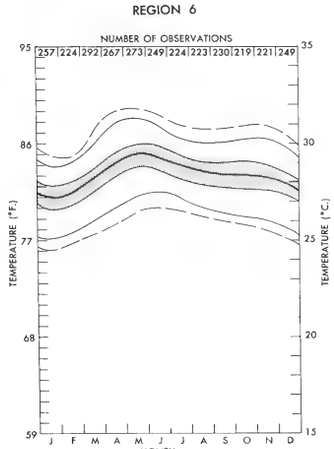

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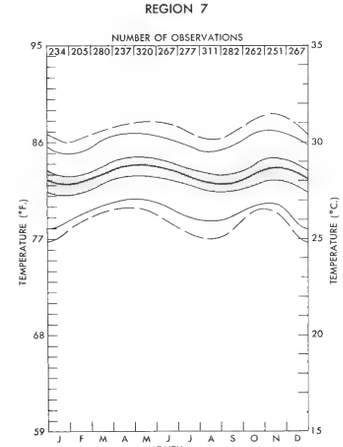

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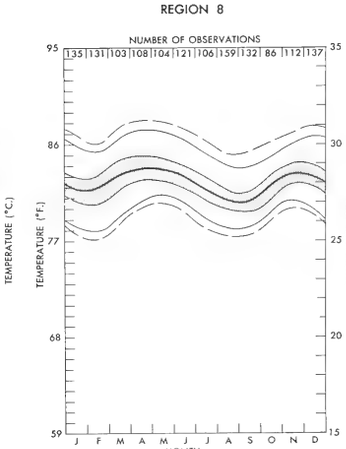

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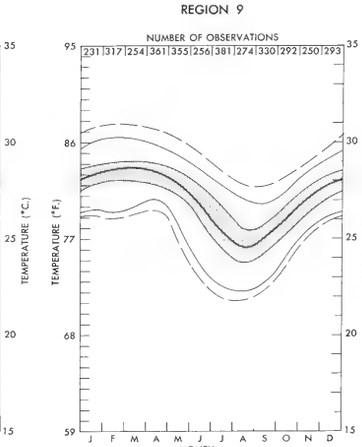

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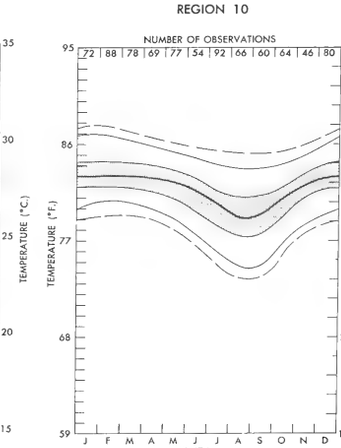

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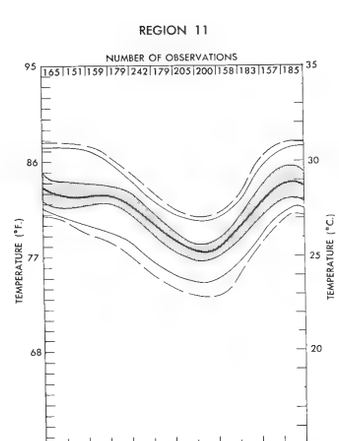

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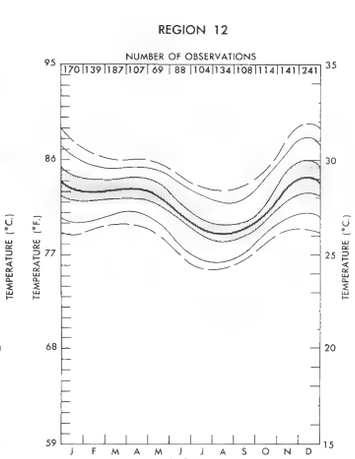

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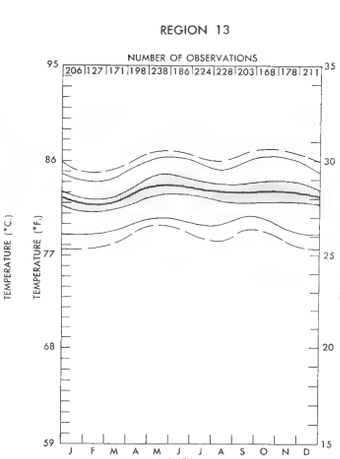

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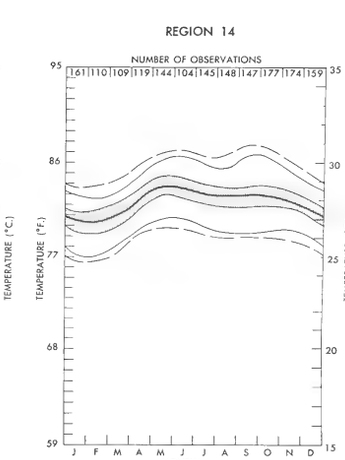

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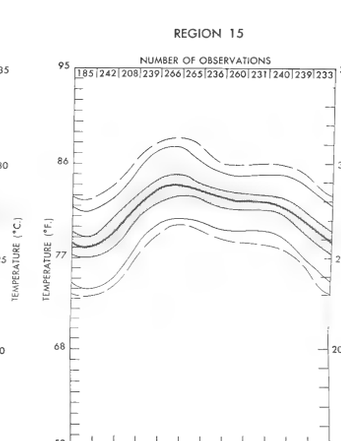

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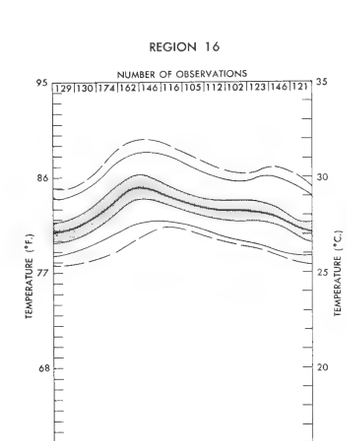

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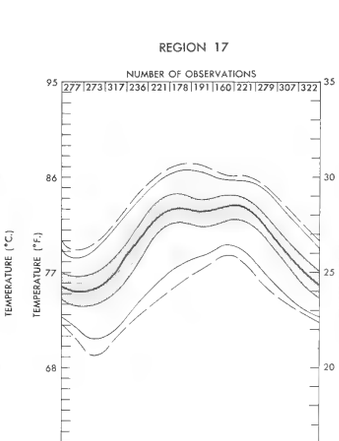

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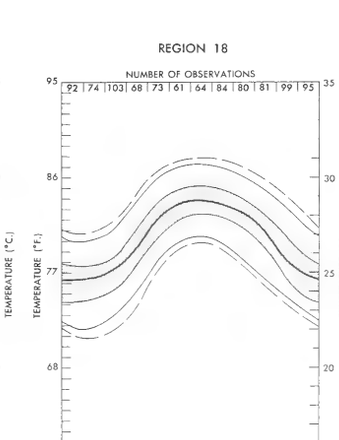


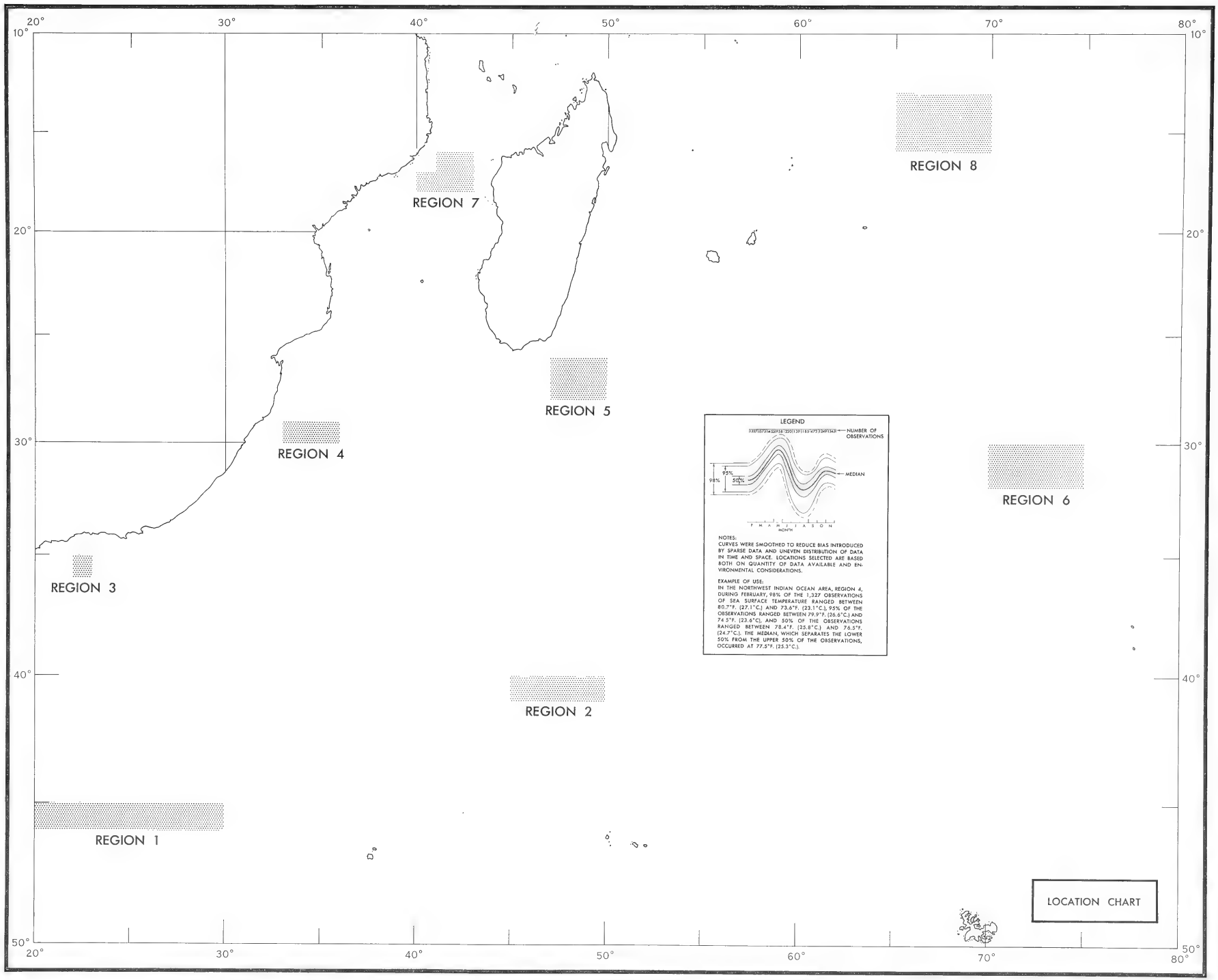
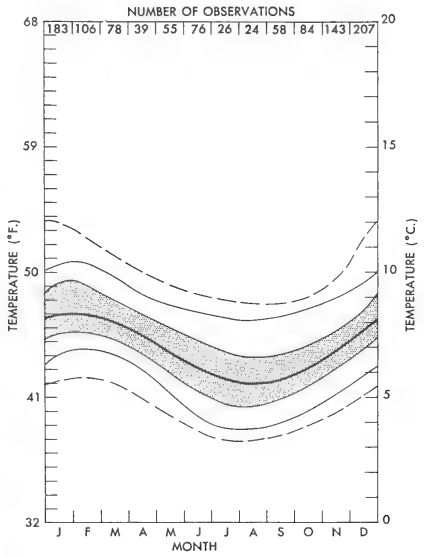


FIGURE 39 MONTHLY VARIABILITY OF SEA SURFACE TEMPERATURE IN SELECTED REGIONS—SOUTHWEST INDIAN OCEAN

REGION 1



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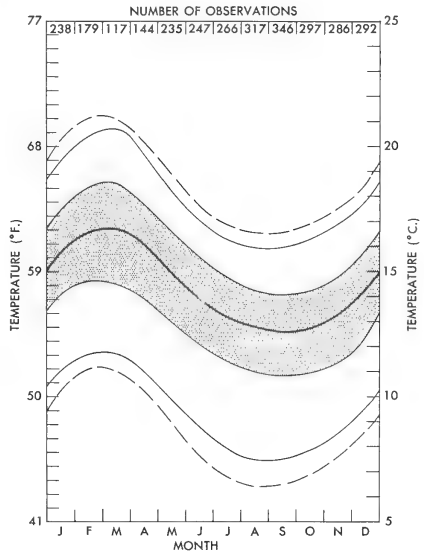

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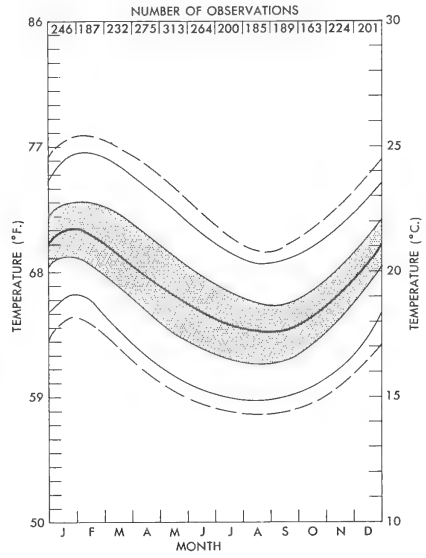

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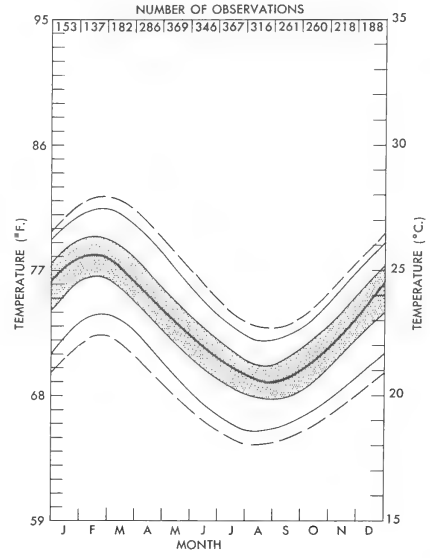

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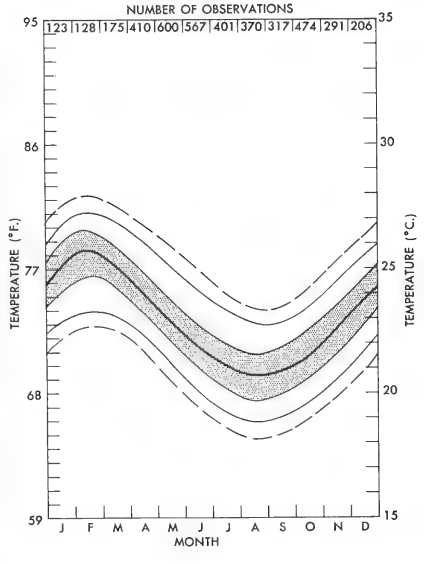

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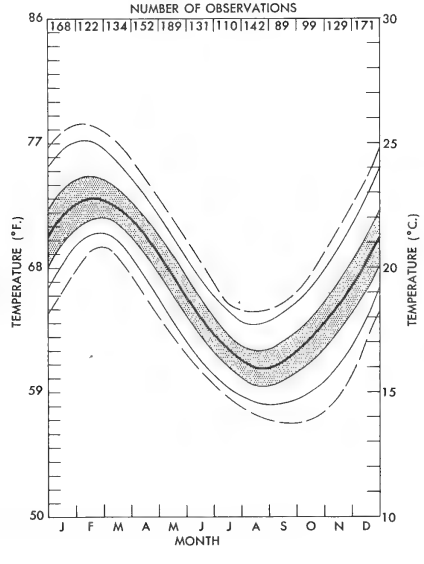

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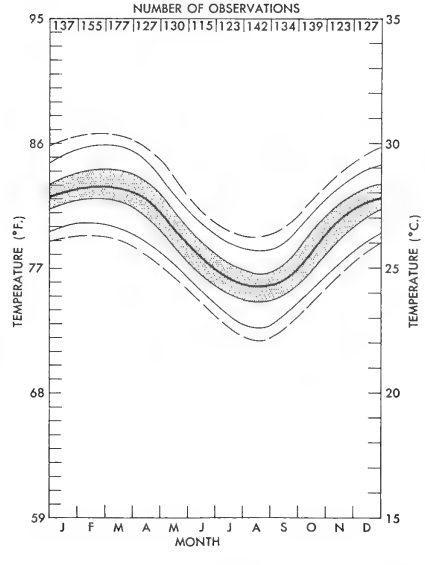

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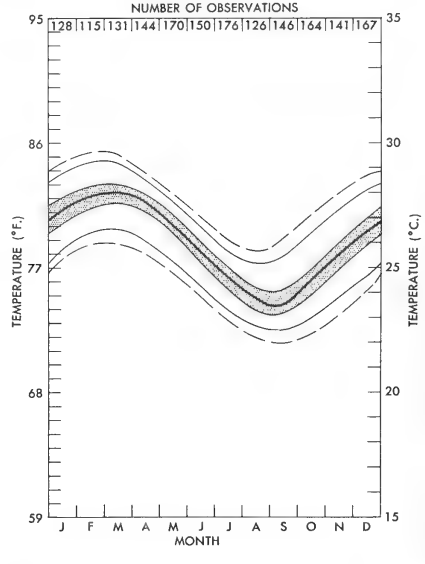


SOUTHWEST INDIAN OCEAN

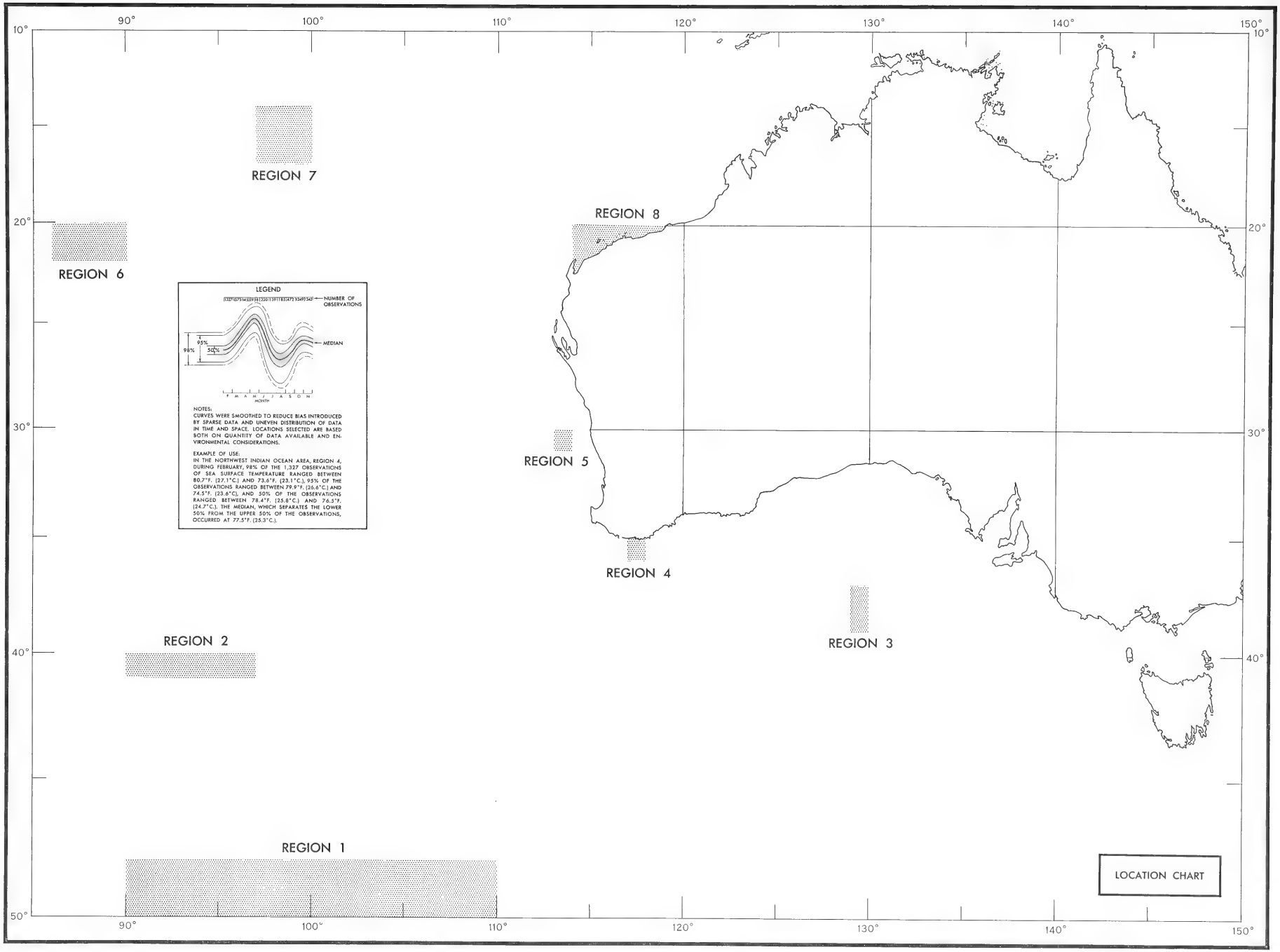
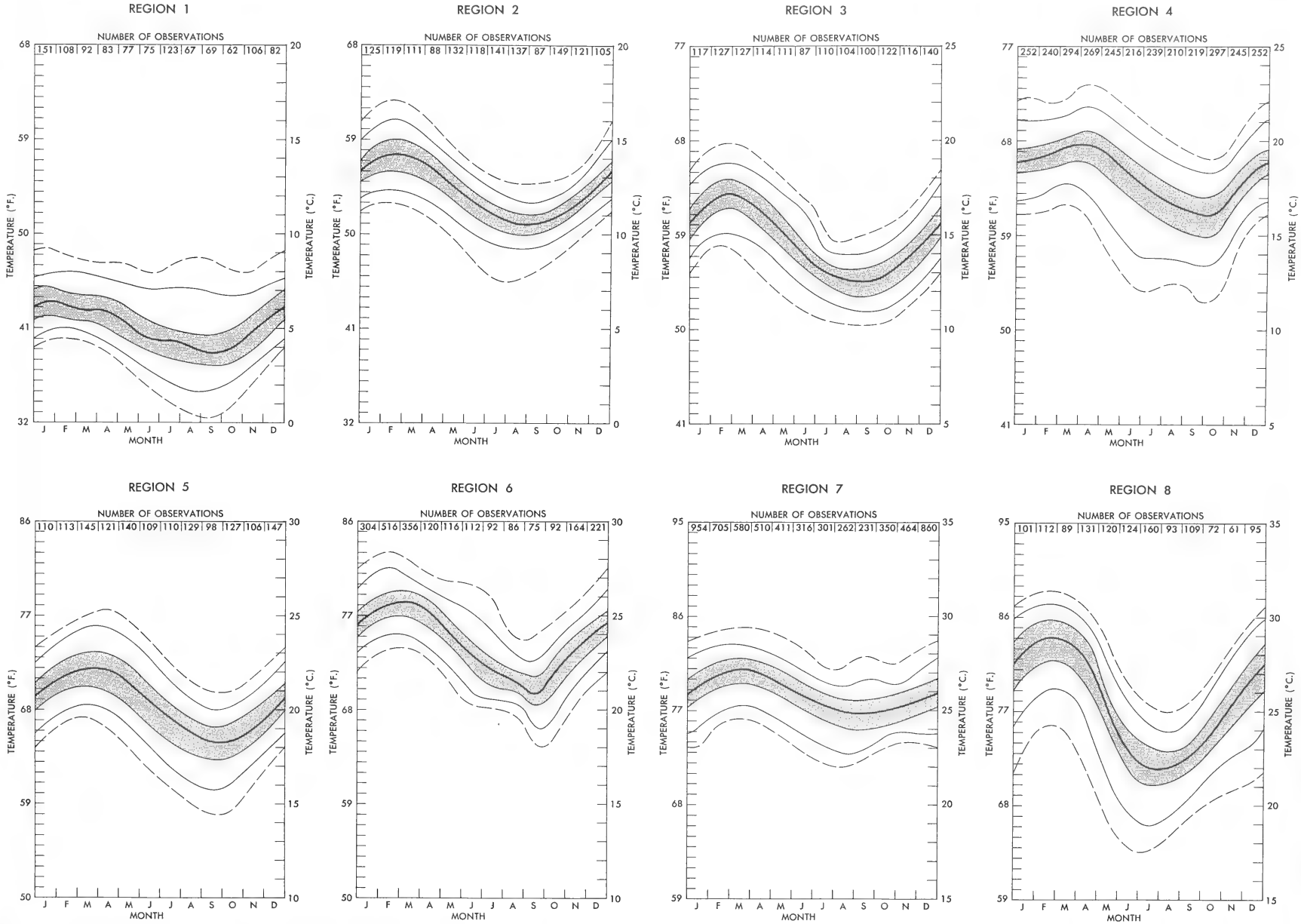


FIGURE 40 MONTHLY VARIABILITY OF SEA SURFACE TEMPERATURE IN SELECTED REGIONS—SOUTHEAST INDIAN OCEAN



SOUTHEAST INDIAN OCEAN

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MONTHLY CHARTS OF MEAN, MINIMUM, AND MAXIMUM SEA SURFACE TEMPERATURE OF THE INDIAN OCEAN. 1967. 50 p. of text and charts (SP-99).

This publication consists of a series of charts, based on ship injection temperature data, which show the monthly mean, minimum, and maximum sea surface temperature of the Indian Ocean.

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4. Physical Properties of Sea Water

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