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AIR MINISTRY

METEOROLOGICAL OFFICE

Geophysical Memoirs No. 90
FIFTH NUMBER, VOLUME XI)

SEASONAL CHANGE OF SURFACE TEMPERATURE OF THE NORTH ATLANTIC OCEAN

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LONDON: HER MAJESTY'S STATIONERY OFFICE
1953

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Geophys. Mem., London,
11, No. 90, 1953

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SEASONAL CHANGE OF SURFACE TEMPERATURE OF THE NORTH ATLANTIC OCEAN

SUMMARY

The facts of the seasonal change of surface temperature of the North Atlantic Ocean are presented by means of charts showing the distribution of harmonic parameters. This method makes it possible to write down by inspection an analytic expression for the process of seasonal change at any position within the area of the charts. The influence of the various factors underlying seasonal change is also briefly discussed. A new series of charts is then derived to show the distribution of the rate of change of mean sea-surface temperature for each month of the year.

§ 1—INTRODUCTION

The seasonal change of sea-surface temperature is of importance not only to oceanographers and meteorologists for its significance in the major problem of the heat exchange between ocean and atmosphere, but also to marine biologists for its effect on the growth and travel of the different forms of marine life. Whoever is interested in the effects of variations of sea-surface temperature requires a knowledge of the seasonal fluctuation, for it would appear unlikely that in temperate latitudes any other fluctuations could exceed in magnitude the seasonal one. A study of the seasonal change of sea-surface temperature should logically, therefore, precede any attempt to apply the method of anomalies of sea-surface temperature to any problem.

Climatic atlases are available depicting the mean distribution of sea-surface temperature for each month of the year, each chart being based on observations taken over a long period of years. Seasonal change can be assessed qualitatively from these charts by noting visually the changes that occur from month to month. For a detailed quantitative analysis, however, it is preferable to use the original observations. This paper summarizes a mass of sea-surface temperature data for the North Atlantic Ocean, and presents the facts of seasonal change in forms suitable for both theoretical investigation and practical use.

§ 2—SOURCES OF DATA

Tabulated values of sea-surface temperature, available for the periods 1887–99 and 1921–38, have been used. These data, based on British ships' logs, had already been used in the preparation of the sea-temperature charts in "Monthly meteorological charts of the Atlantic Ocean"[1]*, and, recently, in the preparation of more detailed charts of sea temperature for the North Atlantic[2]. Monthly mean values for 2° squares were, therefore, already available. In this later publication[2] some account was given of the limitations attached to the use of sea-temperature data.

The data were found to be relatively scanty in the coastal waters of the British Isles and in the North Sea. In these areas German data have been preferred. The mean values used, for 1°

* The index numbers refer to the Bibliography on p. 19.

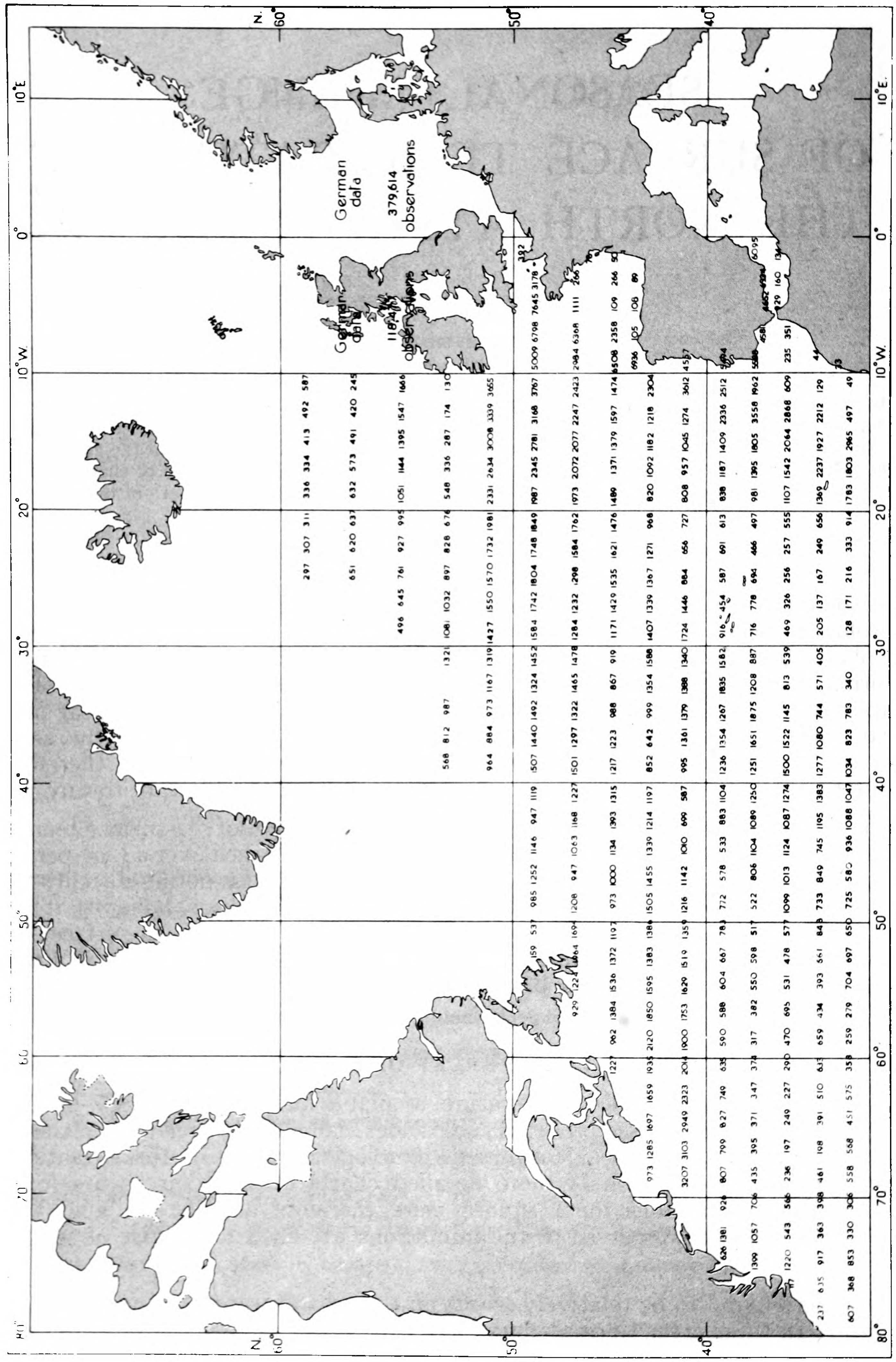

FIG. 1—DISTRIBUTION OF NUMBER OF OBSERVATIONS

squares, are based on observations made during the period 1862–1946, and hence are not directly comparable with the British data. There appears no reason to suppose, however, that the mean process of seasonal change can be significantly different.

The distribution of the number of observations used is shown in Fig. 1. Unfortunately, scarcity of observations has not permitted the investigation to be extended to northern waters. The analysis has also not been made for certain squares where the data were few in number or badly distributed throughout the year.

§ 3—ANALYSIS OF DATA

Monthly means for individual squares have been plotted. The smooth curve drawn through the values for the different months represents the course of seasonal change. By plotting data from different squares it is apparent that important differences exist between the characteristic curves. These differences are of :—

(i) Amplitude ; maximum departure from the yearly mean value varies appreciably.

(ii) Phase ; slight variations occur in the times of maxima and minima.

(iii) Shape ; curves show different degrees of asymmetry.

Harmonic analysis has been used to derive parameters which facilitate the examination of variations from square to square. Representing the sea-surface temperature by T, expressed in degrees Fahrenheit in this paper, the normal expansion in a Fourier series can be written

$$T = a_0 + a_1 \sin (t + A_1) + a_2 \sin (2t + A_2) + a_3 \sin (3t + A_3) + \ldots$$

where t, representing the time, takes values from 0° to 360°.

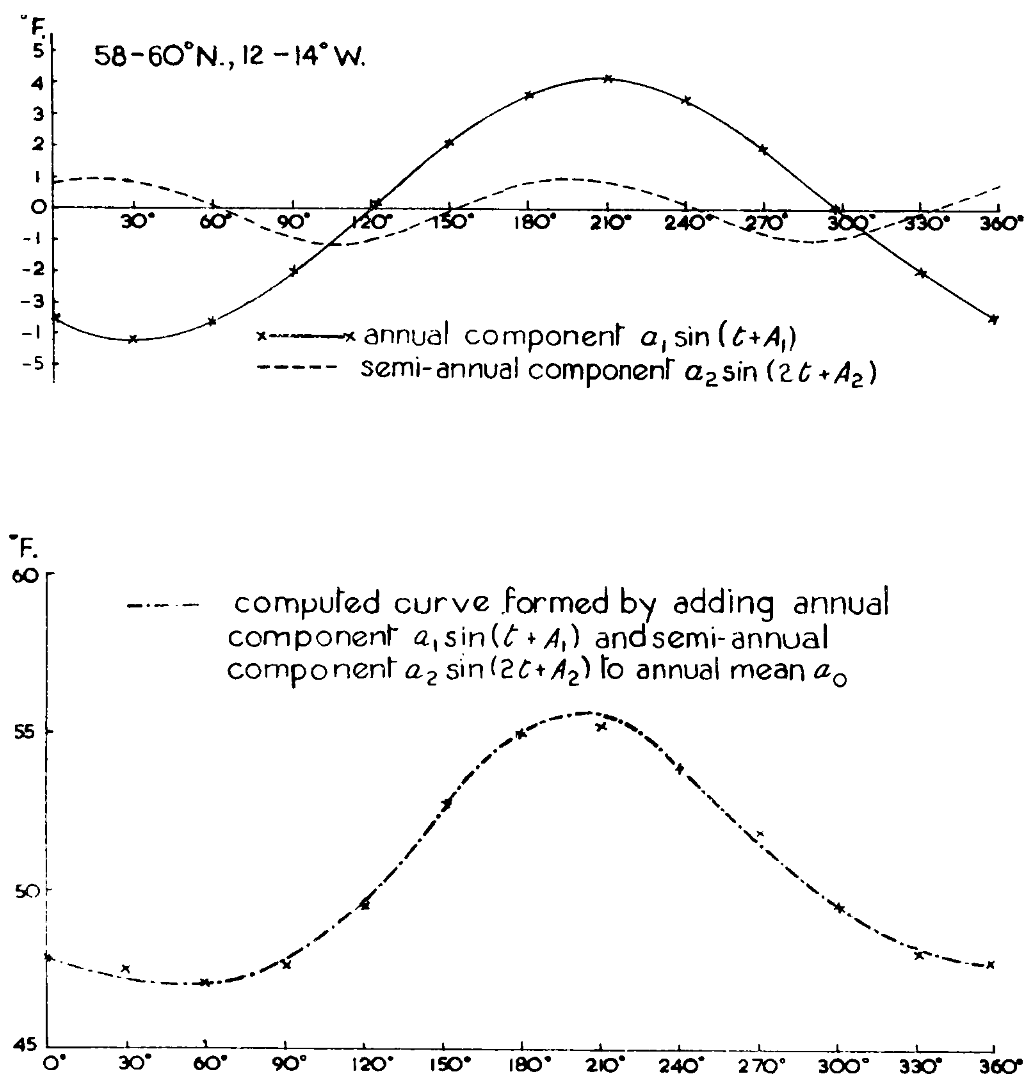

FIG. 2—FIT AFFORDED BY COMPUTED CURVE

The correspondence between t and the monthly values has been chosen as follows :—

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						degrees						
t ..	0	30	60	90	120	150	180	210	240	270	300	330

Since the monthly mean values relate to the mid point of the month the origin of t is at January 15.

Values of a_0, a_1, A_1, a_2, A_2, have been evaluated for each 2° or 1° square for which adequate data are available. The results are tabulated in the Appendix. Fig. 2 shows an example of the fit afforded by a curve computed from these values.

In general it is not profitable to attempt a closer approximation by evaluating a_3, A_3, a_4, A_4, . . .

§ 4—DISTRIBUTION OF HARMONIC PARAMETERS

The original sequence of data for each square has now been replaced by the harmonic parameters, a_0, a_1, A_1, a_2, A_2, and therefore a study of the distribution of these parameters should afford all the information required of the process of seasonal change.

Annual mean.—The parameter a_0 represents the annual mean of sea-surface temperature. The distribution of a_0, shown in Fig. 3, may be regarded as the basic pattern from which the monthly values fluctuate.

In representing the distribution of the other parameters a_1, A_1, a_2, A_2, a degree of smoothing has been found desirable to eliminate small casual variations which tend to mask the main pattern. In coastal areas this smoothing has been done by eye since it is difficult to find an objective method applicable to these areas. Over the oceans, however, except in areas of steep gradients the following objective method has been used. The mean of four values forming the mid points of adjacent 2° squares has been evaluated, and this mean value taken to apply to the centre point. After repeating for all squares, each value is used four times except along the edges of the pattern.

Amplitude of annual component.—The annual component, a_1, is, in general, much greater than the semi-annual component, a_2. It follows that the annual range of sea-surface temperature is chiefly determined by a_1. Fig. 4 shows the following main features :—

(i) Large values, 12° to 16° F. occur along the American coast from south of Newfoundland to 37° N. Values up to 13° F. are found at the mouth of the Elbe and up to 11° F. in the Skagerrak.

(ii) Low values occur to the north and west of Scotland (4° F.), off the Portuguese and Moroccan coasts (5° F.) and in the Gulf Stream off Florida (6° F.).

(iii) A belt of moderately high values extends from the American continent eastwards to the Azores and thence north-east to the Bay of Biscay.

Amplitude of semi-annual component.—Fig. 5 shows the following features :—

(i) The maximum value of the semi-annual amplitude a_2 does not exceed 3° F. The greatest values occur east-south-east of Newfoundland, east of Nova Scotia and on the American coast between 35° and 45°N.

(ii) A belt of relatively high values extends from 35° N., 60° W. east-north-east to just north of the Azores and thence north-east to the British Isles.

(iii) Low values occur on the southern flank of the Gulf Stream and North Atlantic Current up to a position east of the Newfoundland Bank.

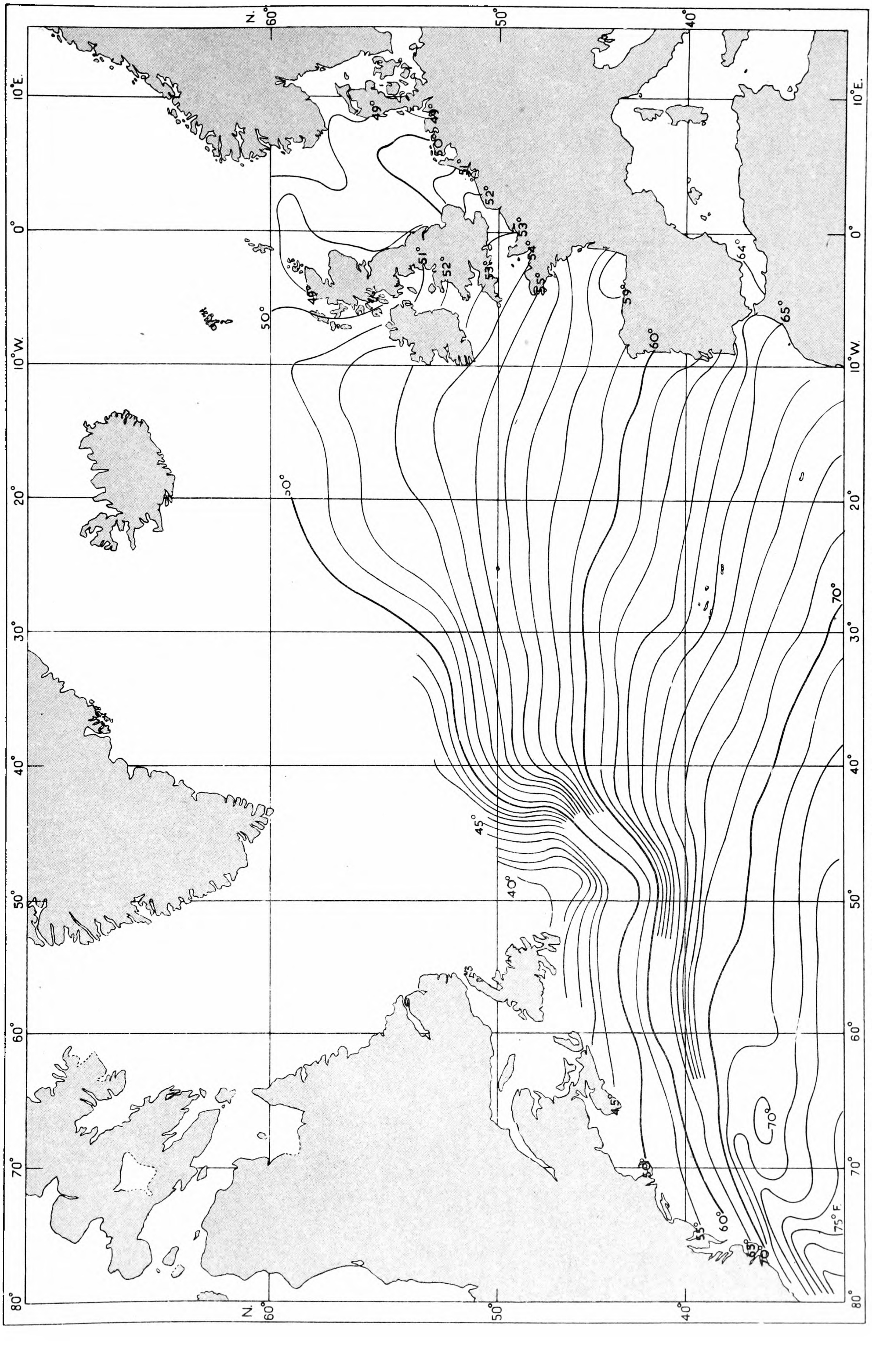

FIG. 3—DISTRIBUTION OF ANNUAL MEAN SEA-SURFACE TEMPERATURE (a_0)

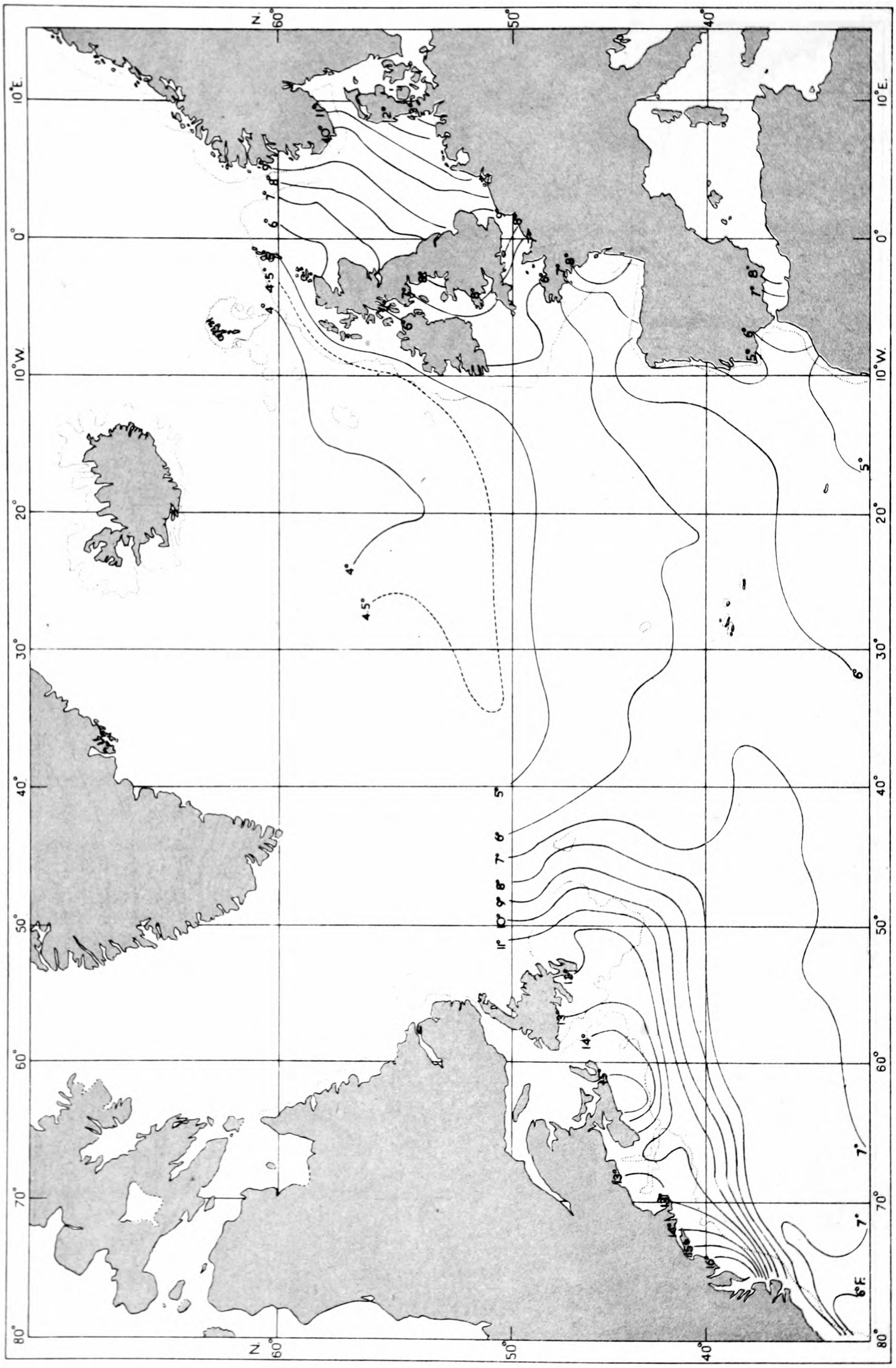

FIG 4-DISTRIBUTION OF AMPLITUDE OF ANNUAL COMPONENT (a_1)

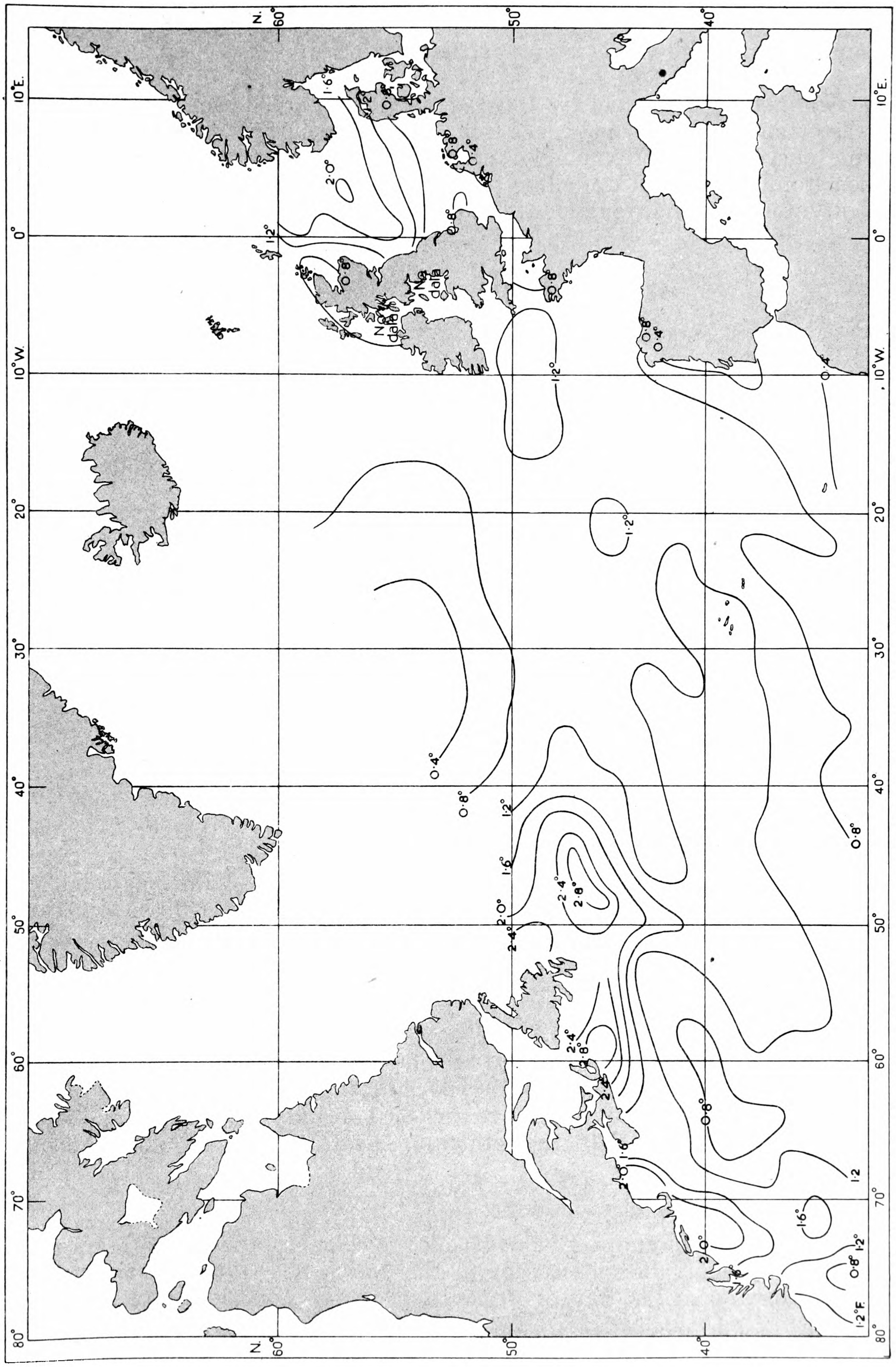

FIG.5 – DISTRIBUTION OF AMPLITUDE OF SEMI-ANNUAL COMPONENT (a_2)

(iv) Small values occur in the upwelling areas off the coasts of Portugal and Morocco.

(v) A small area of high values occurs in the North Sea.

Ratio of amplitudes.—The quantity $100a_2/a_1$ may be regarded as a measure of the degree of skewness or distortion of the seasonal curve from a pure sine curve. In areas where this quantity is small a sine curve will approximately represent the seasonal variation. Fig. 6 shows an example taken from the area of upwelling off Portugal (see p. 18). It is easily seen that the first component affords a good representation of the seasonal variation.

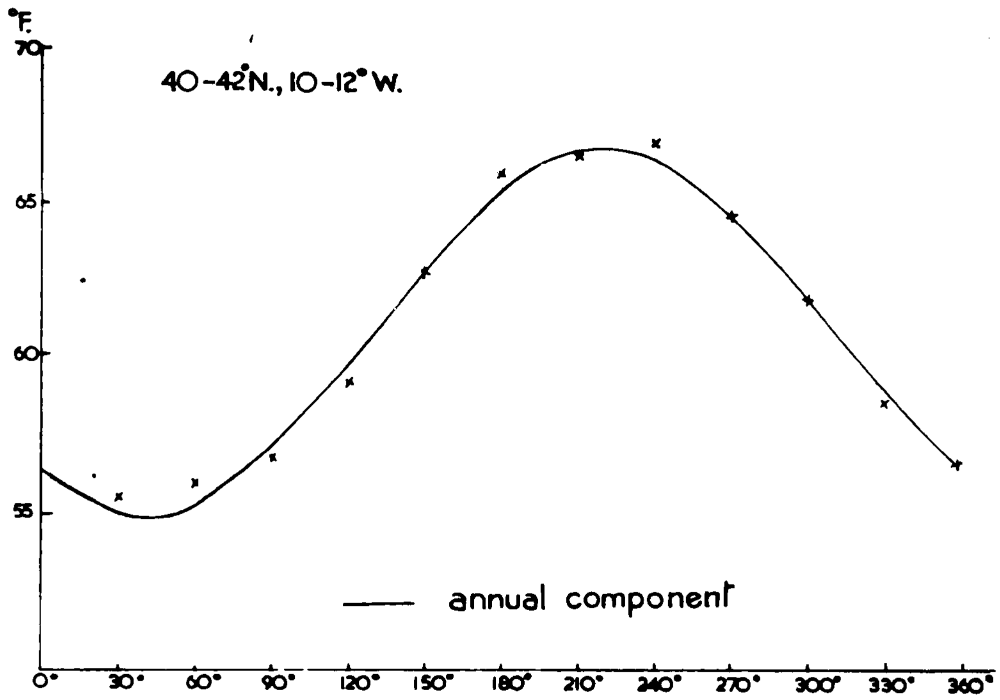

FIG. 6—GOODNESS OF FIT AFFORDED BY ANNUAL COMPONENT

Fig. 7 shows the following features :—

(i) The maximum values (over 30 per cent.) are reached in the northern part of the North Sea, north-west of Scotland and east of Newfoundland. Relatively high values also occur in a broad belt extending south-westward from the British Isles.

(ii) Low values occur in the upwelling areas off the coasts of Portugal and Morocco and south of the main belt of high values. There are also low values off the American coast, in the mid Atlantic north of 50° N., and in the southern coastal waters of the British Isles.

(iii) The greatest variability occurs in the North Sea and in the coastal waters of the British Isles.

Phase of annual component.—The phase angle A_1 of the annual component is important inasmuch as it largely determines the time at which the sea temperature reaches maximum and minimum values. It varies for the most part between 220° and 240°. An angle of 240° indicates that the minimum value of the component occurs on February 14 and the maximum value on August 16. When the angle is 220° the minimum occurs on March 7 and the maximum on September 7.

Fig. 8 shows the following characteristics :—

(i) Centres of both high and low values flank the course of the Gulf Stream and the North Atlantic Current. High values also occur in the North Sea, along the coasts of Germany, Denmark and Norway, in the Bay of Biscay and off the north coast of Spain.

(ii) A trough of low values off the Portuguese coast appears to be associated with the course of the Portugal Current.

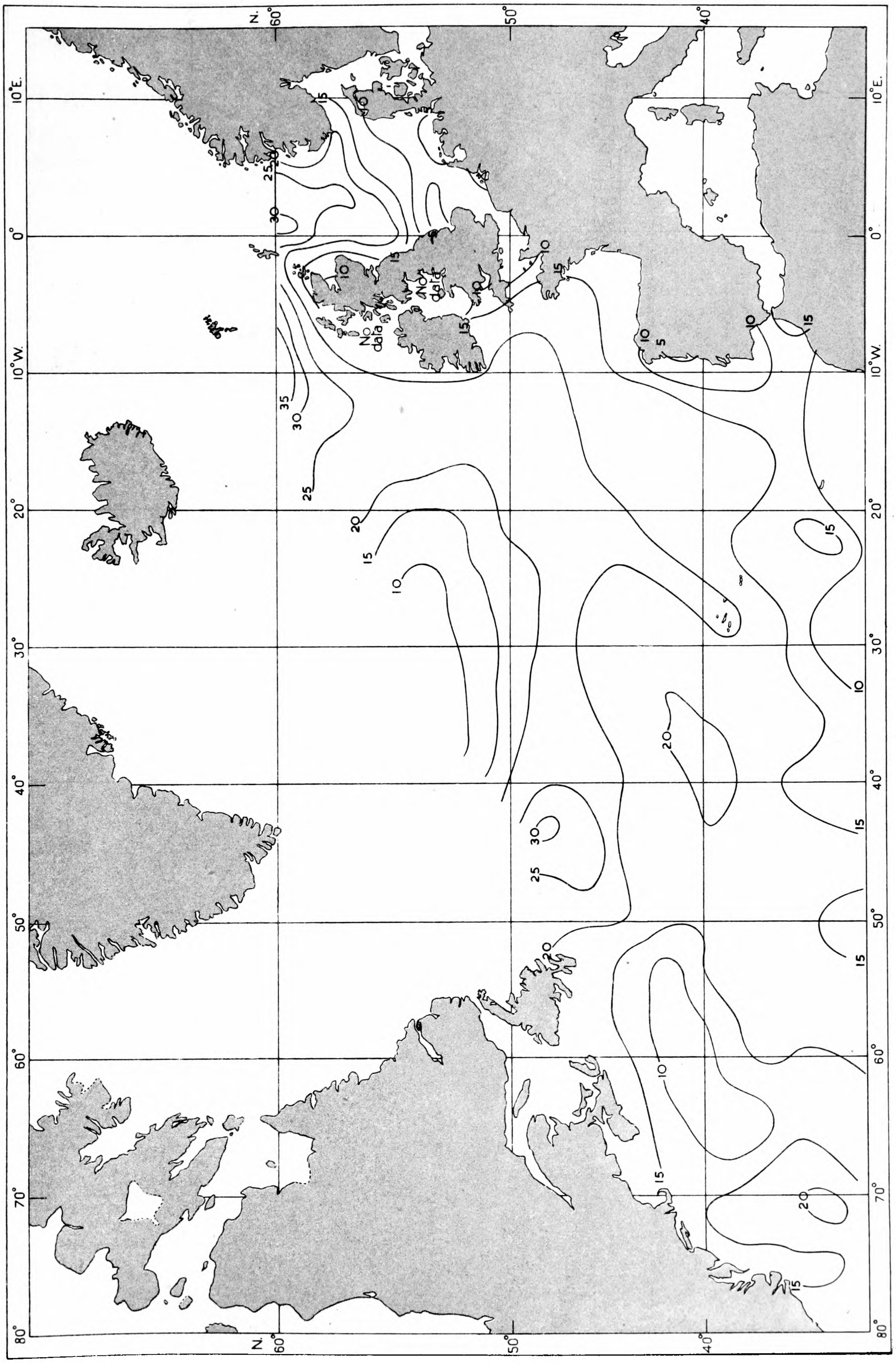

FIG. 7 – DISTRIBUTION OF 100 a_2/a_1

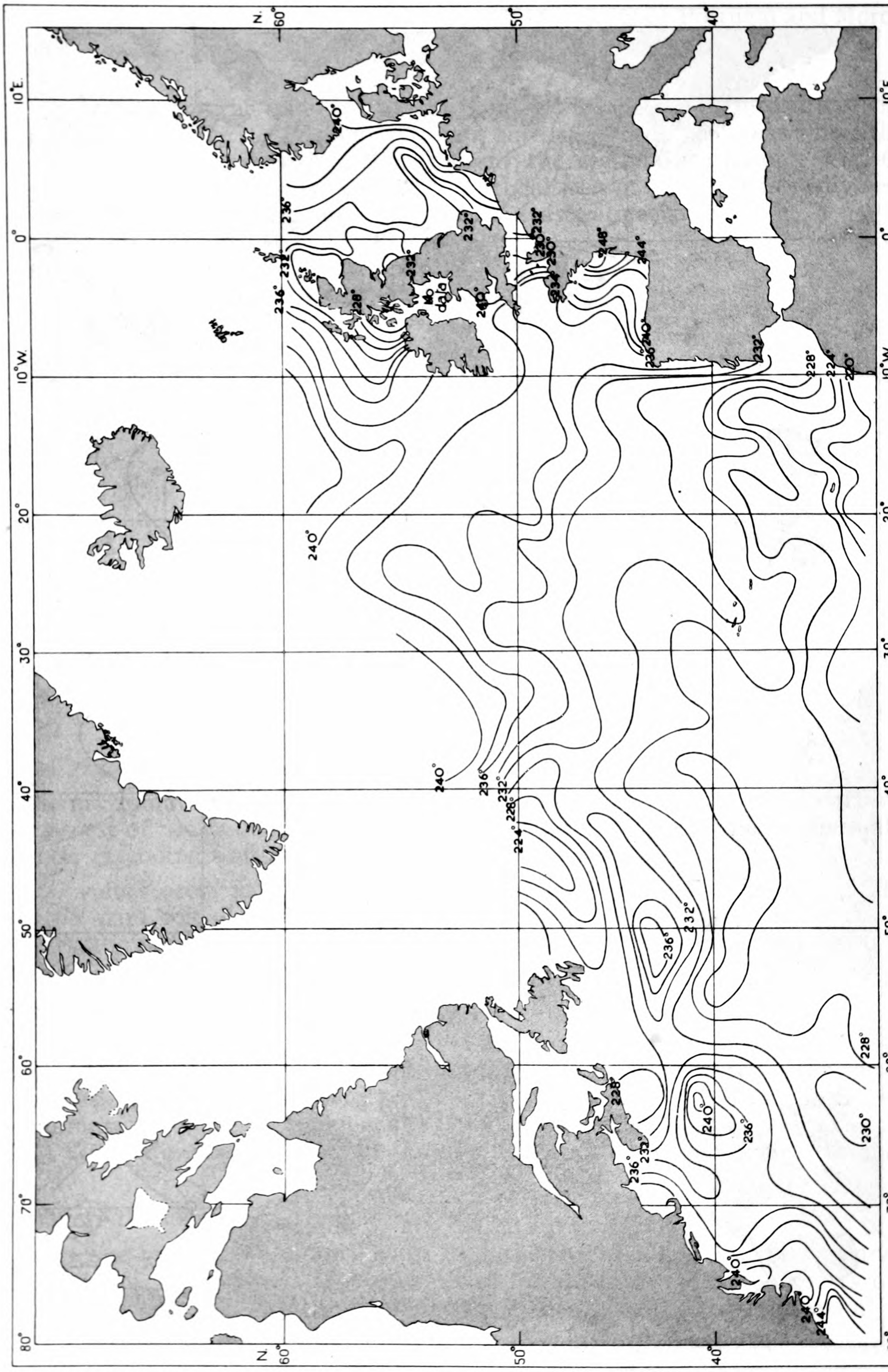

FIG.8-DISTRIBUTION OF PHASE OF ANNUAL COMPONENT (A_1)

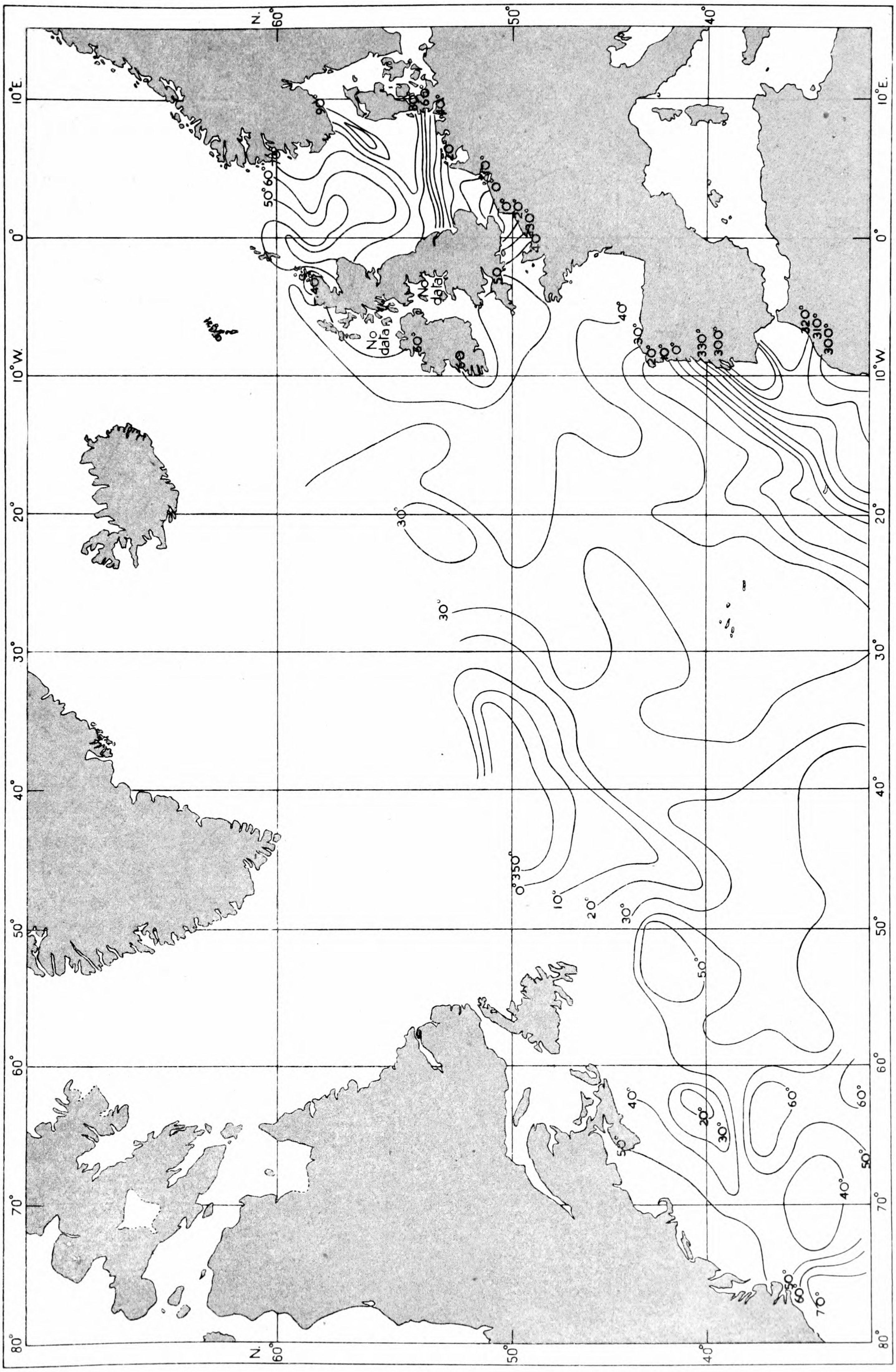

FIG. 9 – DISTRIBUTION OF PHASE OF SEMI-ANNUAL COMPONENT (A_2)

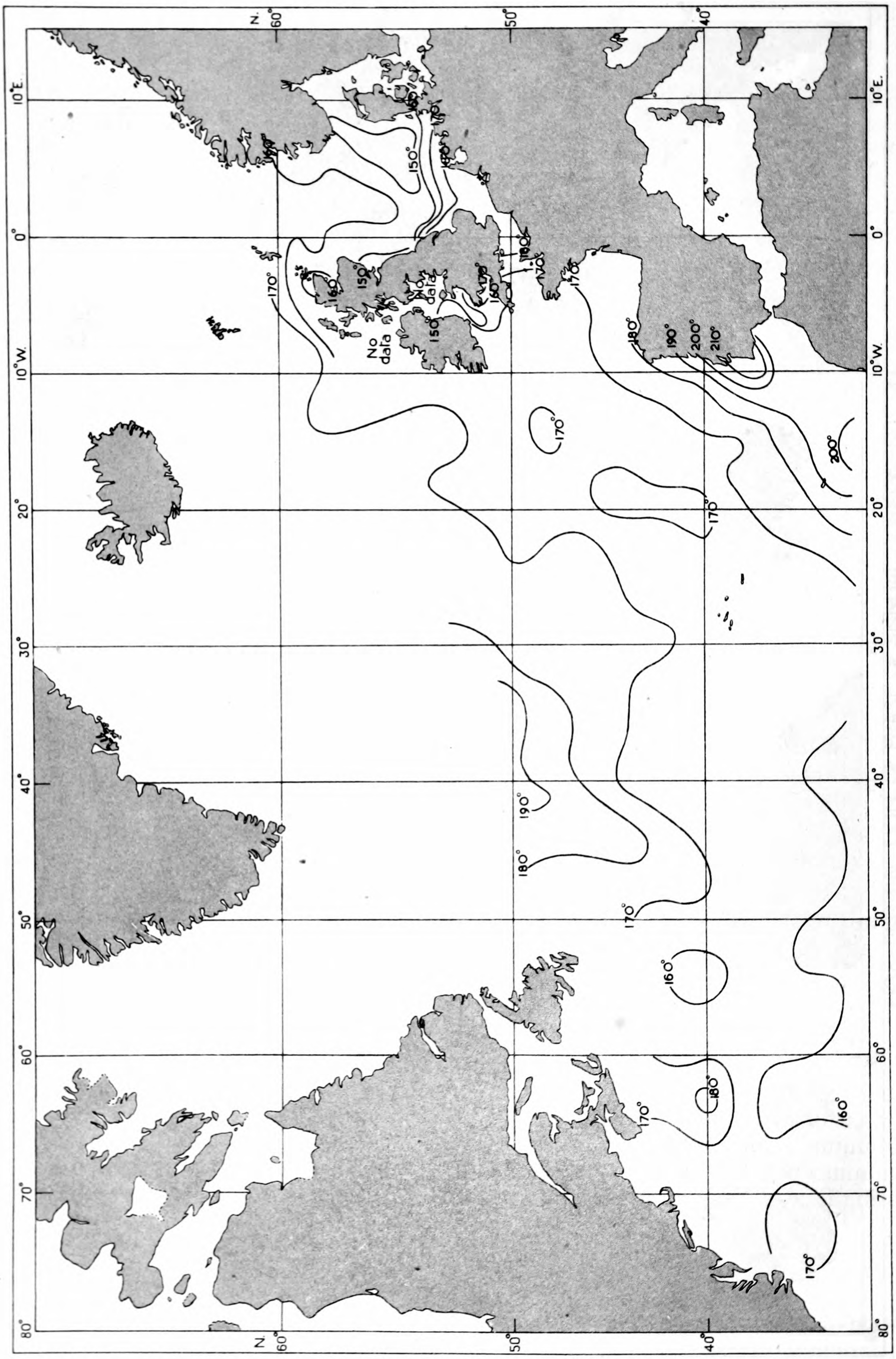

FIG.10–DISTRIBUTION OF $F = \frac{1}{2}(2A_1 - A_2 - 90°)$

(iii) There is some evidence of a ridge of high values extending south-west from the British Isles.

Phase of semi-annual component. The phase angle of the semi-annual component (A_2) modifies the times of maximum and minimum values determined primarily by A_1. Fig. 9 shows the following main features :—

(i) A belt of relatively high values extends from the British Isles south-westward to the Azores and thence westward to the American continent.

(ii) Low values occur in the upwelling areas off the coasts of Portugal and Morocco and in the region centred at 50° N., 40° W.

(iii) Both high and low values occur in the North Sea, where the distribution is complex.

If the semi-annual component is regarded as modifying the annual component then some method of representing its phase relative to that of the annual component must be found. The maximum value of the annual component is given by

$$t_1 + A_1 = 360° + 90°.$$

The maximum value of the second component is given by

$$2t_2 + A_2 = 360° + 90°.$$

Therefore,

$$t_2 - t_1 = \tfrac{1}{2}\,(2A_1 - A_2 - 90°) - 180°.$$

Denoting by F the quantity $\frac{1}{2}\,(2A_1 - A_2 - 90°)$, then when $F = 180°$ the maxima of the two components occur at the same time. At the time of minimum value of the annual component, however, the semi-annual component is then a maximum and is thus completely out of phase.

Function F.—The distribution of function F, given in Fig. 10, shows :—

(i) All values are relatively close to 180°. This means that the semi-annual component reinforces the annual component at its maximum value and weakens the annual component at its minimum value. The physical significance of this will be dealt with later.

(ii) Values greater than 180° occur in the upwelling areas off the coasts of Portugal and Morocco and also in an area centred about 50° N., 40° W.

(iii) Low values, less than 180°, occur in a relatively uniform belt extending from the British Isles south-westward to the Azores and thence westward to the American continent. The lowest values occur in an irregular belt extending across the southern half of the North Sea, particularly in the south-east.

At this stage the significance of a value of F differing from 180° may be noted. When F is less than 180° the time of occurrence of the maximum value of the annual variation is brought forward and the time of occurrence of the minimum value is set back or retarded. The time interval between minimum and maximum for increasing temperature is therefore less than the time interval for decreasing temperature. When F is greater than 180°, the time of occurrence of the maximum value of the annual variation is set back or retarded and the time of occurrence of the minimum value is brought forward. The time interval between minimum and maximum for increasing temperature is therefore greater than the time interval for decreasing temperature.

§ 5—THEORETICAL CONSIDERATIONS

In previous sections the facts of the process of seasonal change have been set out in terms of the harmonic parameters and their distribution in space. The physical factors concerned in determining the seasonal variation of sea-surface temperature are :—

(i) Total incoming radiation (direct and diffuse).

(ii) Exchange of heat between ocean and atmosphere.

(iii) Vertical transfer of heat in the ocean (convection and upwelling).

(iv) Horizontal transport of heat by ocean currents.

Total incoming radiation for certain ocean areas has been given by Kimball[3], taking account of the effect of variations in the amount of cloudiness and of the distribution of water vapour in the atmosphere. His data are given in Table I.

TABLE I—AVERAGE DAILY TOTAL OF SOLAR RADIATION (DIRECT + DIFFUSE) RECEIVED ON A HORIZONTAL SURFACE taken at the 21st of each month

°N.	°W.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
		gramme calories per square centimetre											
56	7	50	109	206	308	372	389	328	229	182	107	49	..
52	10	74	146	228	331	378	383	354	288	212	140	80	54
48	60	114	206	270	345	397	424	422	364	284	165	108	78
48	4	94	157	259	339	414	405	388	335	255	153	90	71
42	66–70	139	223	327	402	449	477	421	376	317	235	153	120
36	6	225	280	378	472	498	522	538	496	371	285	225	196
30	65–77	212	247	365	420	462	441	432	399	326	259	244	197
30	15	306	364	415	482	476	482	449	437	420	340	301	281

TABLE II—HARMONIC ANALYSIS OF THE DATA OF TABLE I

°N.	°W.	a_1'	A_1'	a_2'	A_2'
		gm. cal./m.^{2}	°	gm. cal./m.^{2}	°
52	10	166	310	11	261
48	60	172	306	18	26
48	4	175	307	7	309
42	66–70	172	301	36	316
36	6	174	304	13	21
30	65–77	130	310	15	271
30	15	98	313	11	320

Table II suggests that a_1', the annual amplitude of the total incoming radiation, reaches a maximum in a latitude between 36° N. and 48° N. and decreases to north and south, the decrease towards the equator being particularly rapid. Table II also suggests that A_1' has only a small latitudinal variation. If this can be regarded as real, values increase to both north and south of the minimum value in latitude 42° N. However, owing to the large differences of longitude the interpretation of the data is doubtful. Values of a_2' and A_2' appear to be too scattered to permit of generalization with respect to latitude.

While sea-surface temperature cannot be regarded as determined solely by radiation income, it is nevertheless significant that the amplitude of the yearly component of the radiation income has a latitudinal maximum corresponding to the latitudinal belt of maximum values of a_1 shown in Fig. 4.

Sverdrup[4] has stated that whereas in the southern hemisphere the latitudinal variation of the annual range of sea-surface temperature appears to be closely connected with that of the radiation income, no such correspondence is evident in the North Atlantic. This rather anomalous result he explains by the effect of the greater distribution of land in the northern hemisphere permitting the cooling of the seas by outbursts of cold continental air in winter. In reaching this conclusion, however, Sverdrup used values for different latitudes averaged over all longitudes of the oceans. It is easily appreciated from Fig. 4 how this procedure must necessarily mask the effect of the radiation income. The present results on the other hand demonstrate the influence of the radiation income outside coastal areas in the North Atlantic. Near the coasts the effects of other factors are sufficiently great to mask that of the radiation income.

Exchange of heat between ocean and atmosphere.—Although it has been shown that the effect of radiation income can be traced in the distribution of a_1 it is at once apparent that other factors can be much more effective ; for example, the high values of a_1 off the American coast and in the North Sea at once suggest the influence of cold outbreaks of continental air during the winter months. Off the American coast the highest values occur because the wind is predominately from the west. The high values in the North Sea, on the other hand, must be due to the winter occurrence of easterly winds. A full discussion would necessitate examining the major problem of the heat exchange between atmosphere and ocean.

Vertical transfer of heat in the ocean.—Convection in the ocean is also of primary importance. When the sea cools in winter the cooling takes place at the surface ; the surface layer cools, becomes denser than the water below and hence sinks, warmer water rising by convection to take its place. This warmer water becomes cooled in its turn and is again replaced. Convection, therefore, ensures that the cooling process is not confined to the surface layers but is distributed over a great depth of water. Helland-Hansen[5] has stated that towards the end of the winter isothermal conditions may extend to great depths. In the relatively shallow waters of the continental shelves this isothermal state may be reached relatively early in the winter and then a progressive cooling takes place. In shallow waters, therefore, the annual amplitude tends to be greater than in the open ocean where vast under-water reserves of heat are available to off-set the winter cooling. Although the winter effect is greater, it is worth noting that in summer, too, the shallow waters near the coastline tend to heat up more rapidly than the open sea. Fig. 4, showing the distribution of a_1, illustrates how the isopleths follow the contours of the continental shelf off the American coast.

There is a fundamental difference between the cooling and heating processes in the ocean. In autumn and winter, as already noted, convection helps to maintain the surface temperature by making available the under-water reserves of heat. In spring and summer, on the other hand, the surface water is warmed, but as the warmer water is less dense than the colder water below there is no tendency for convection and the ocean warms progressively from the surface. The turbulence set up by ocean waves can ensure a certain equalization of temperature near the surface, but the effect of waves becomes negligible at a relatively small depth. As the heating continues a progressively greater stratification of temperature is set up. If the effect on surface temperature of the different characteristics of the cooling and heating processes is considered, it is seen that in winter convection affects the temperature by diminishing its rate of fall and in summer the stratification also affects the temperature by increasing its rate of rise. The effect is to introduce a six-monthly oscillation into the annual variation of the temperature, and it is suggested that the six-monthly component, that has been found, can to some extent be explained in this way. This suggestion is supported by the following considerations. The phase of the second component is such that extreme values are reached very close to the maximum and minimum values of the annual component. Over the greater part of the ocean F is less than 180°, and, as has already been seen, the effect of the second component is to advance the maximum value and retard the minimum value. In one of the areas where F exceeds 180° it is known that upwelling in spring prevents stratification and delays the time of maximum temperature. The amplitude of the six-monthly component is also small in this area.

Turning to the charts showing the distribution of a_2 and 100 a_2/a_1, it is easily seen that there is no definite relation between the amplitudes of the two components. This suggests that the explanation advanced above can only account for a part of the six-monthly component and that other factors are also important. It is obvious, for example, that the distribution of salinity must be taken into account in any full discussion, for density is a function of salinity as well as of temperature.

Vertical transfer can also take place by the process known as upwelling which occurs on steep coasts when the wind blows from a suitable direction. In the northern hemisphere, for example, a wind blowing with a component parallel to the coastline tends to heap up water to the right of its direction ; if the wind is blowing with the land to the left of its direction the water is driven away from the coast and upwelling of water at the coastline must then necessarily occur. This process can explain the low values of a_1 and a_2 found off the coasts of Portugal and north-west Africa.

Horizontal transport of heat by ocean currents.—A perusal of the charts suggests that the horizontal transfer of heat by ocean currents is of some importance. For example, relatively low values of a_1, the annual amplitude, are associated with the Gulf Stream and the North Atlantic Current. This effect, however, may, at least in part, be explained by selective convection. The surface waters of the Gulf Stream and the North Atlantic Current have a high salinity which would favour the convection process already discussed. The seasonal change of surface temperature is further complicated by the fact that the strength and position of the ocean currents also vary seasonally.

§ 6—RATE OF CHANGE OF SEA-SURFACE TEMPERATURE

Although the distributions of the harmonic parameters are theoretically sufficient for the discussion of the seasonal variation of sea-surface temperature their practical application is not easy. Of some practical importance would be a knowledge of the rate of change of sea temperature as a function of time and space.

The sea-surface temperature T at any place can be represented by the expression

$$a_0 + a_1 \sin (t + A_1) + a_2 \sin (2t + A_2)$$

where the harmonic parameters are known. The expression for the rate of change of sea temperature $\partial T/\partial t$ is, therefore, by differentiation

$$a_1 \cos (t + A_1) + 2a_2 \cos (2t + A_2).$$

Values of this expression can be computed for different values of t (0°, 30°, 60°, ... 330°) and the variation of $\partial T/\partial t$ throughout the year determined. Fig. 11 shows an example, for the 2° square 30–32° N., 60–62° W., of the seasonal variation of $\partial T/\partial t$ compounded from the simple harmonic curves $a_1 \cos (t + A_1)$ and $2a_2 \cos (2t + A_2)$. Notable features of this curve are the high value of $\partial T/\partial t$ at its maximum and the difference of shape of the crest and trough.

This computation has been made for all the 2° and 1° squares under consideration, and a new series of charts constructed to show the distribution of $\partial T/\partial t$ for each month of the year. They are given in Fig. 12. The values of $\partial T/\partial t$, expressed in degrees Fahrenheit per radian, may for practical purposes be converted into degrees Fahrenheit per month by multiplying by the factor one half.

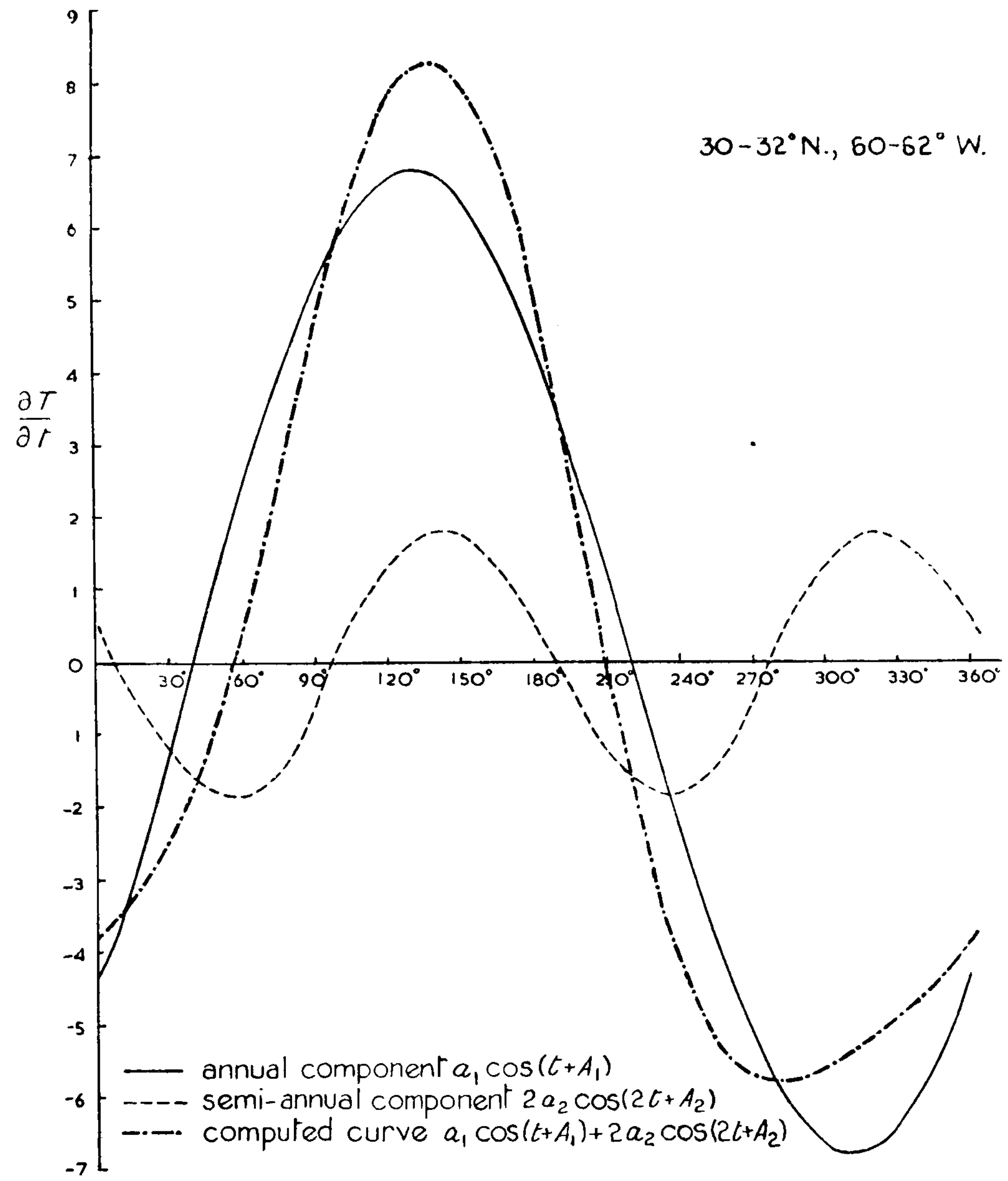

FIG. 11—SEASONAL VARIATION OF $\partial T/\partial t$

Unit :—1° F. per radian where 2π radians = 12 months

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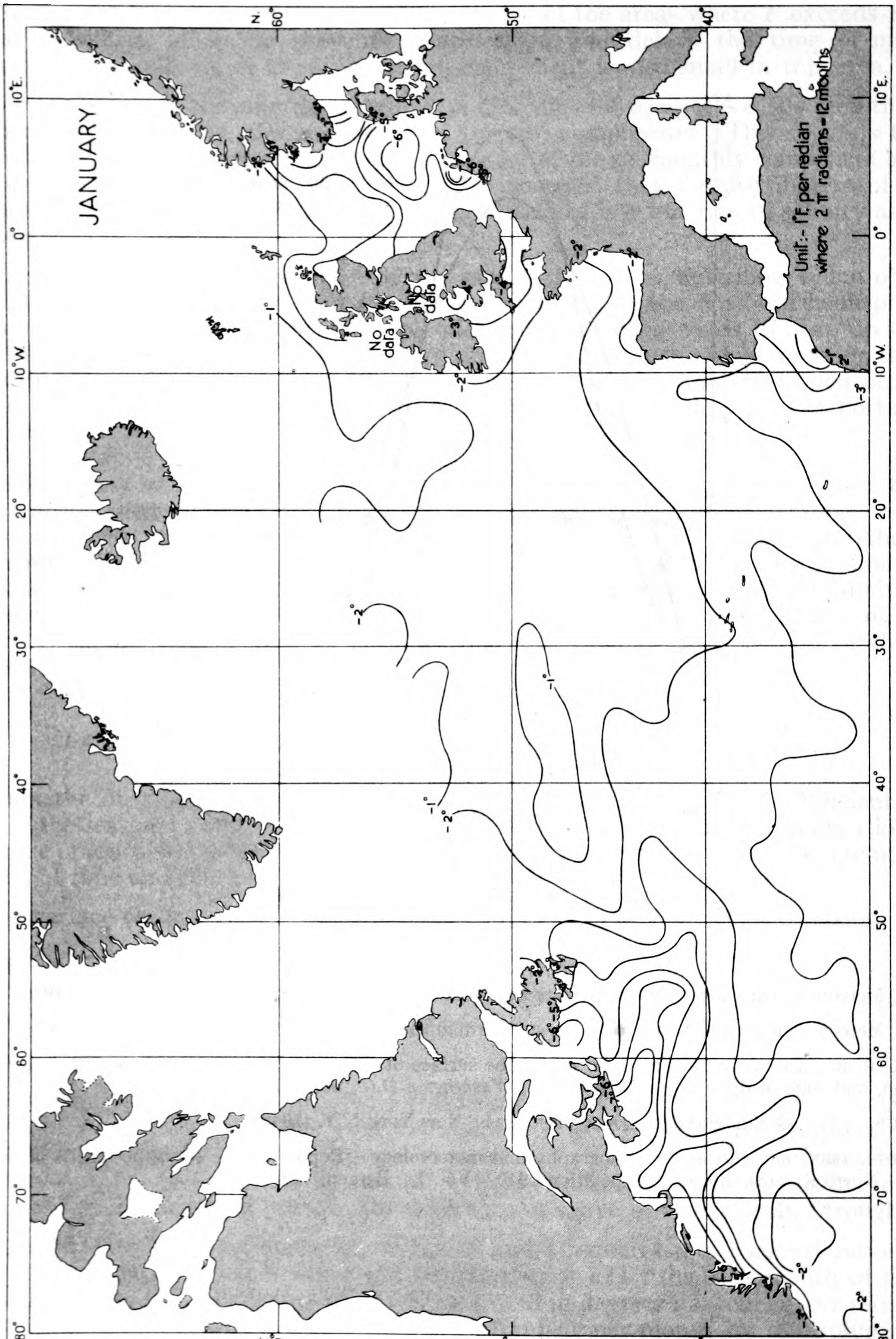

FIG.12–DISTRIBUTION OF RATE OF CHANGE OF MEAN SEA-SURFACE TEMPERATURE

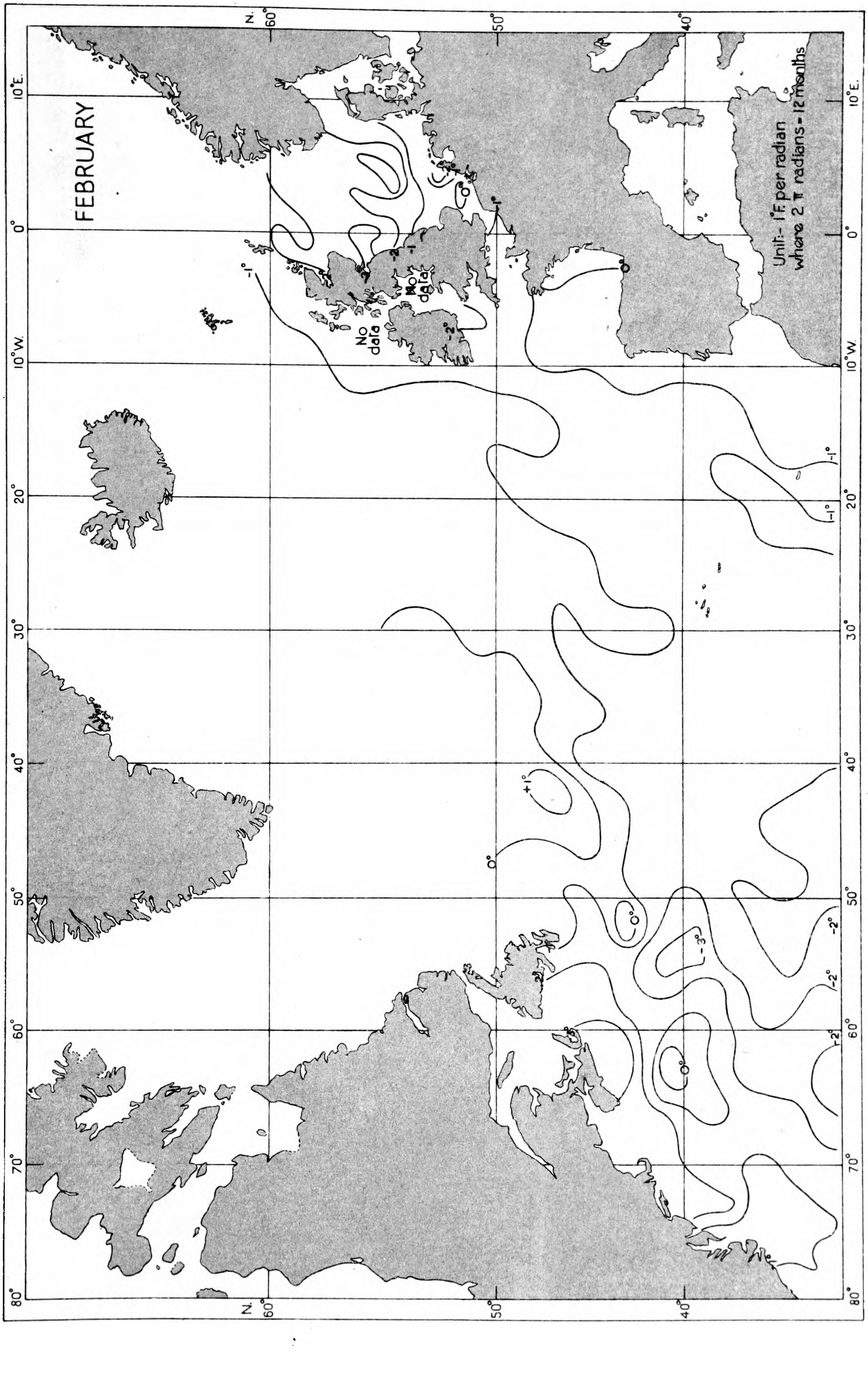

FIG. 12— *continued*

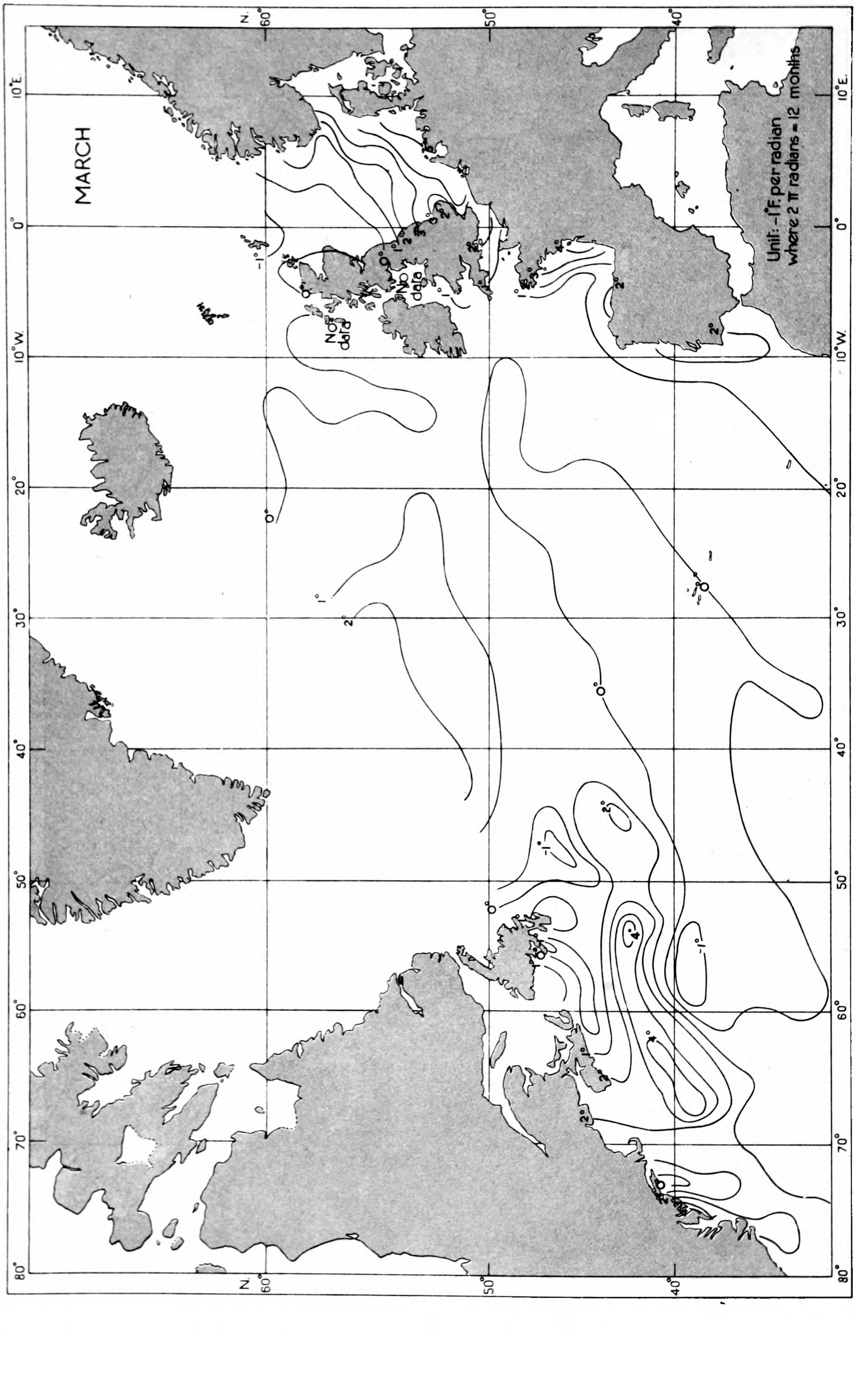

FIG. 12 — *continued*

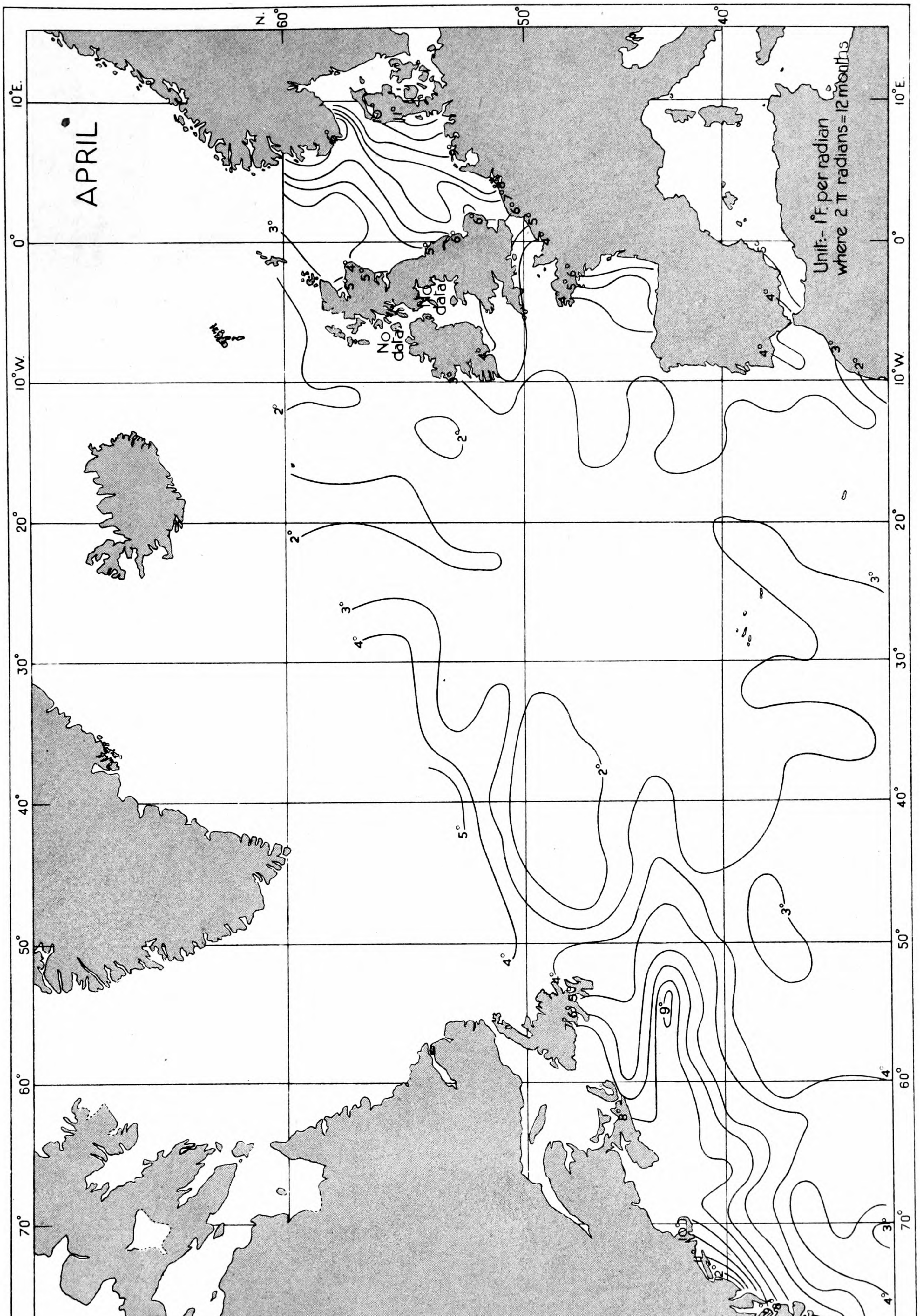

FIG. 12 — *continued*

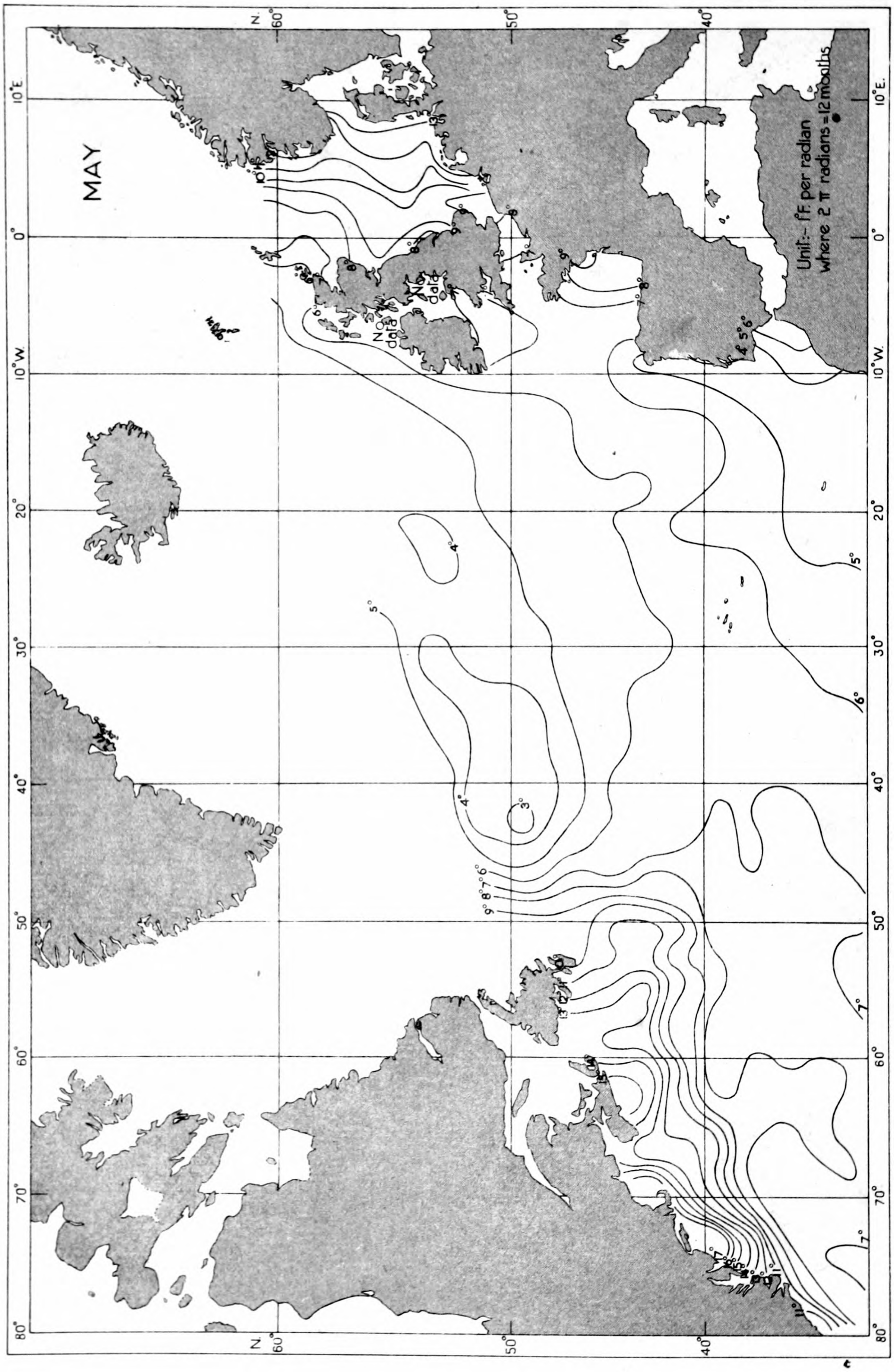

FIG.12— *continued*

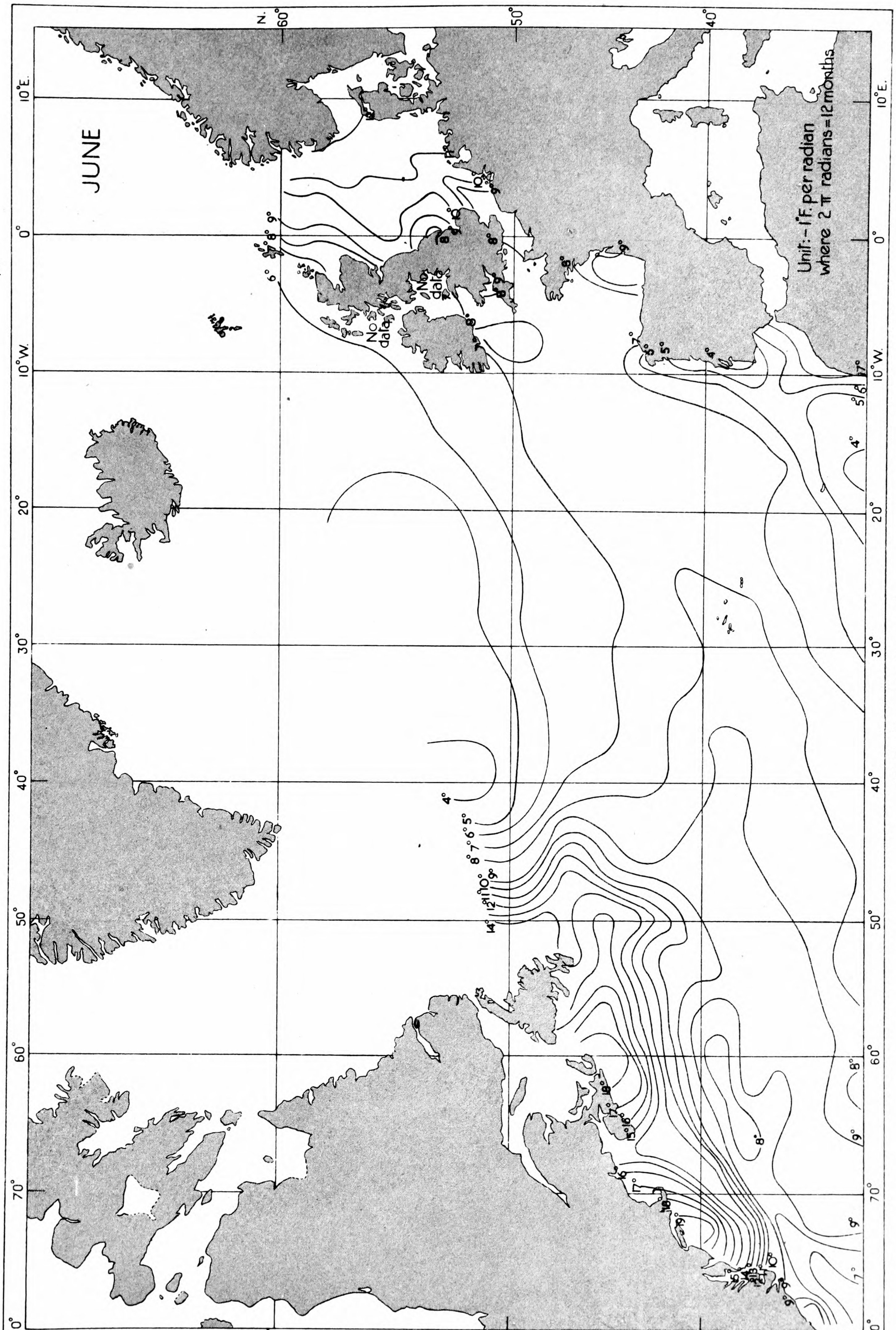

FIG. 12— continued

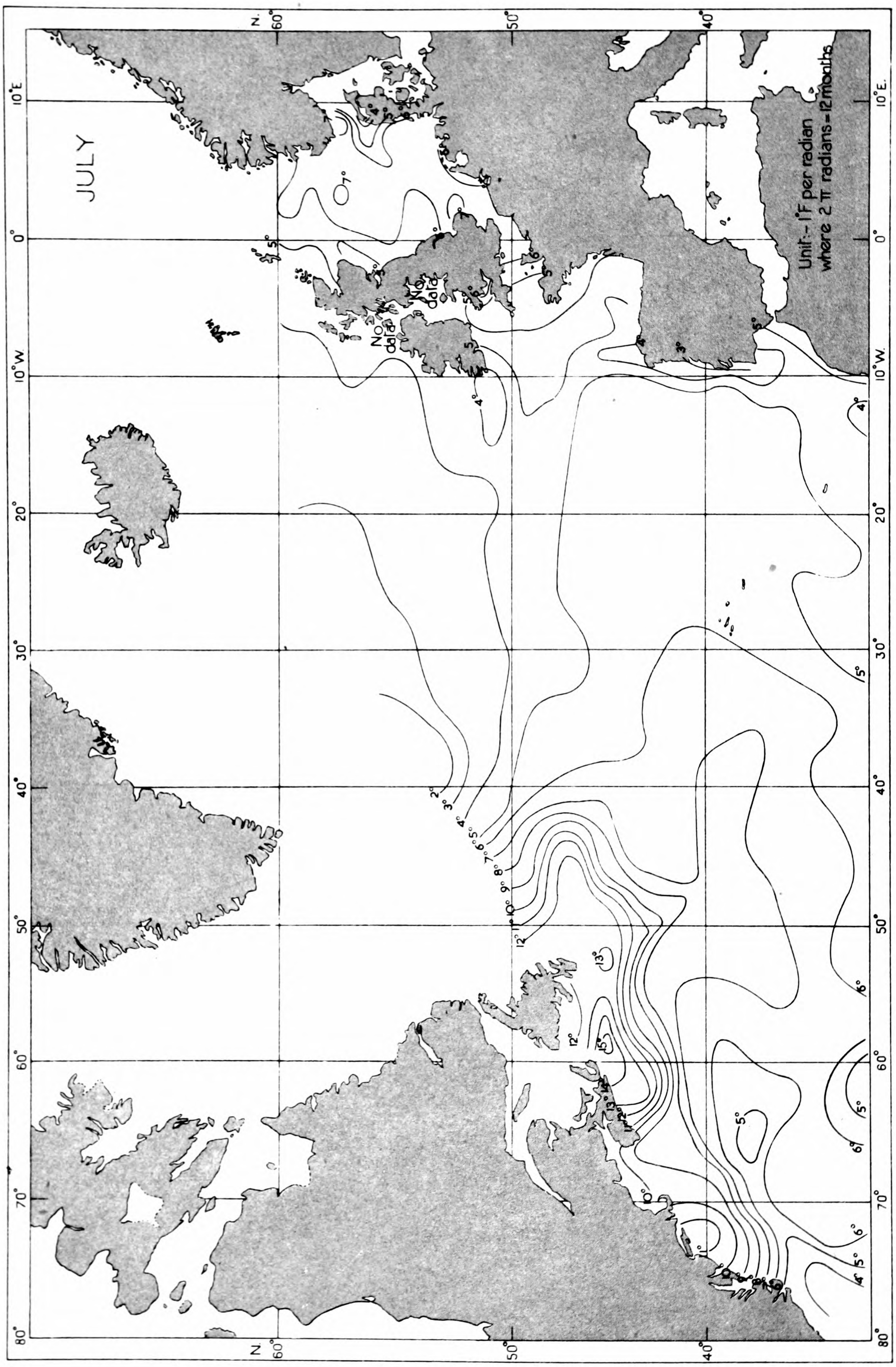

FIG.12— *continued*

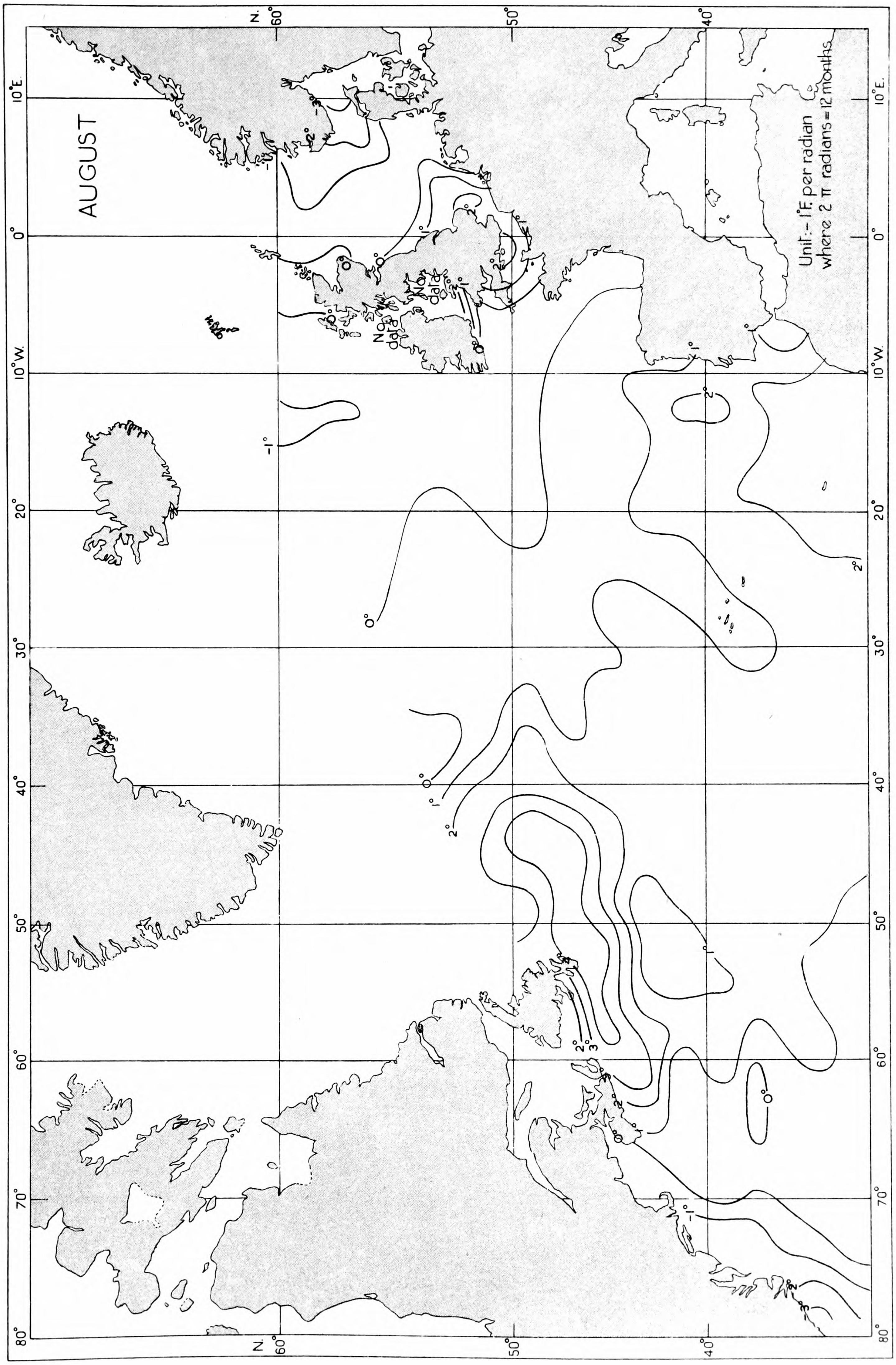

FIG. 12—*continued*

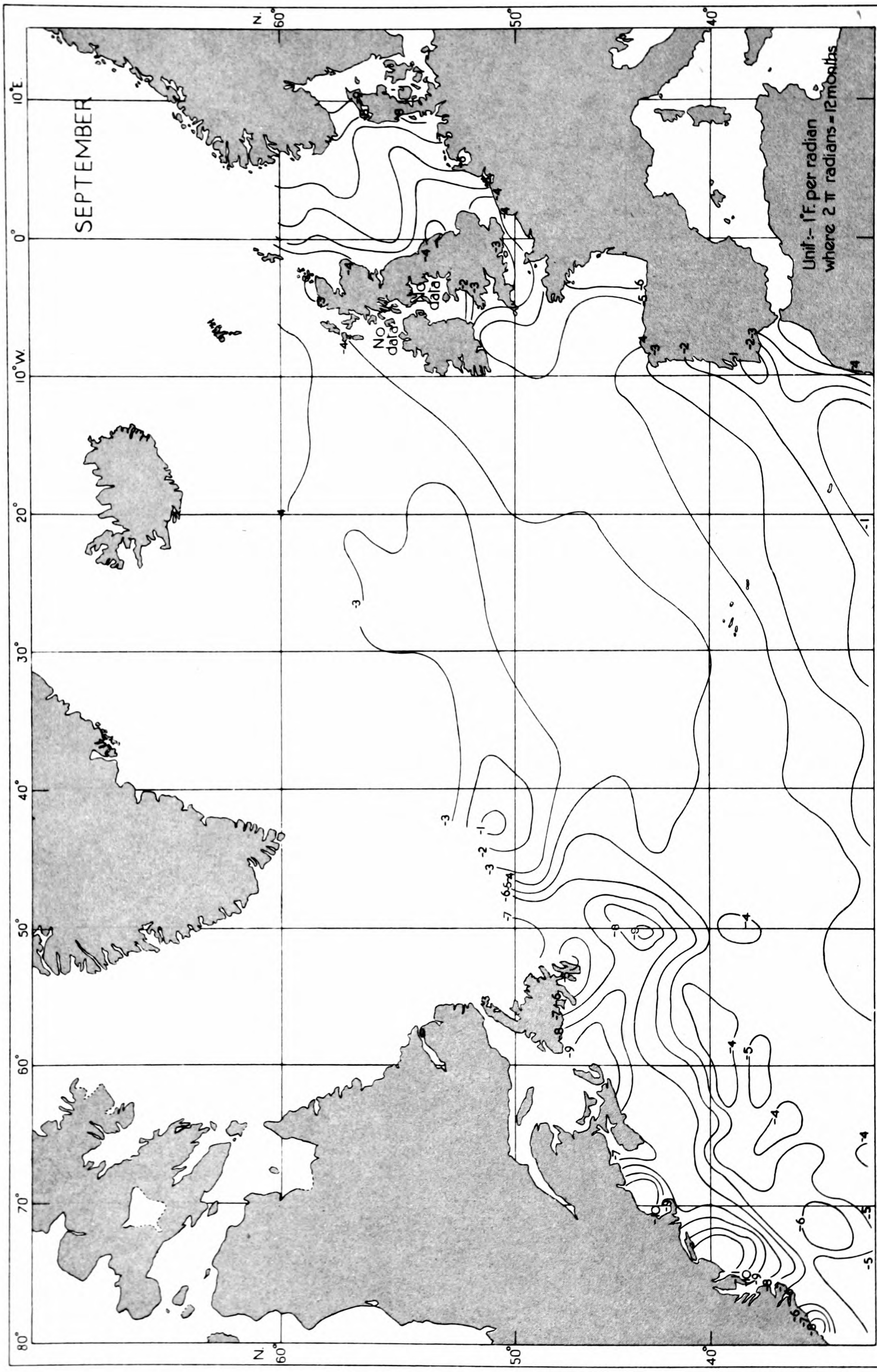

FIG. 12 — *continued*

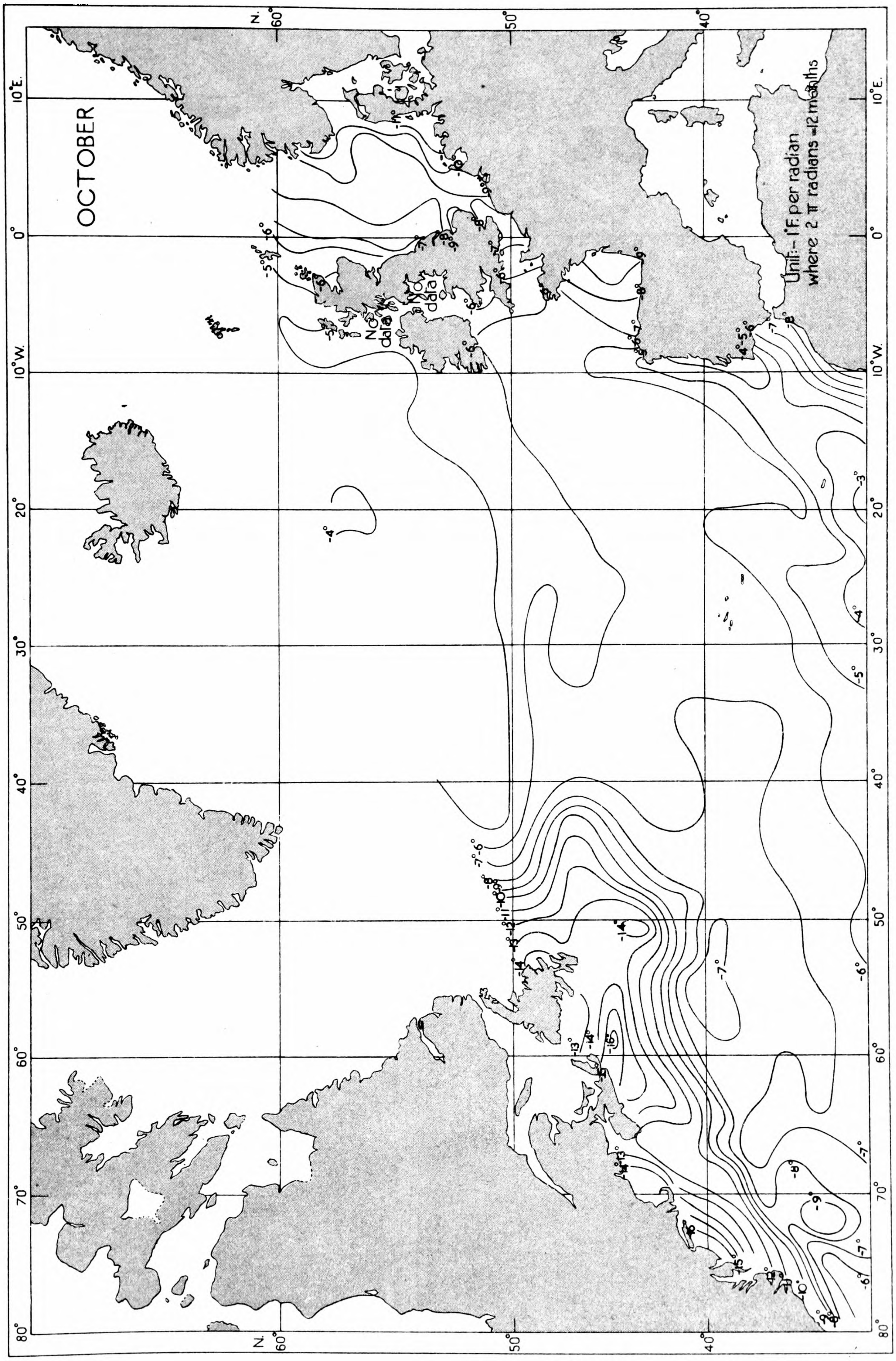

FIG. 12—*continued*

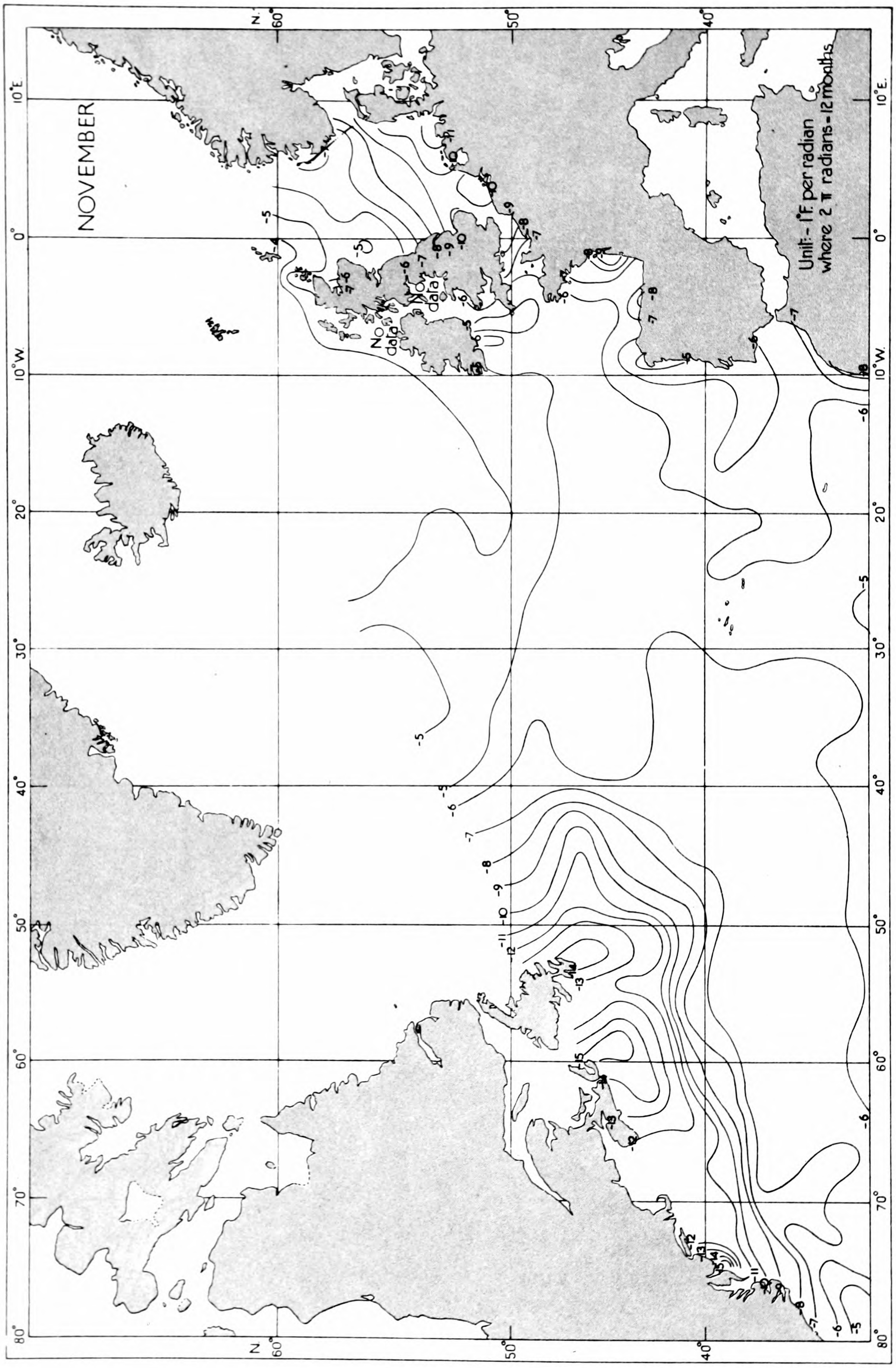

FIG. 12—*continued*

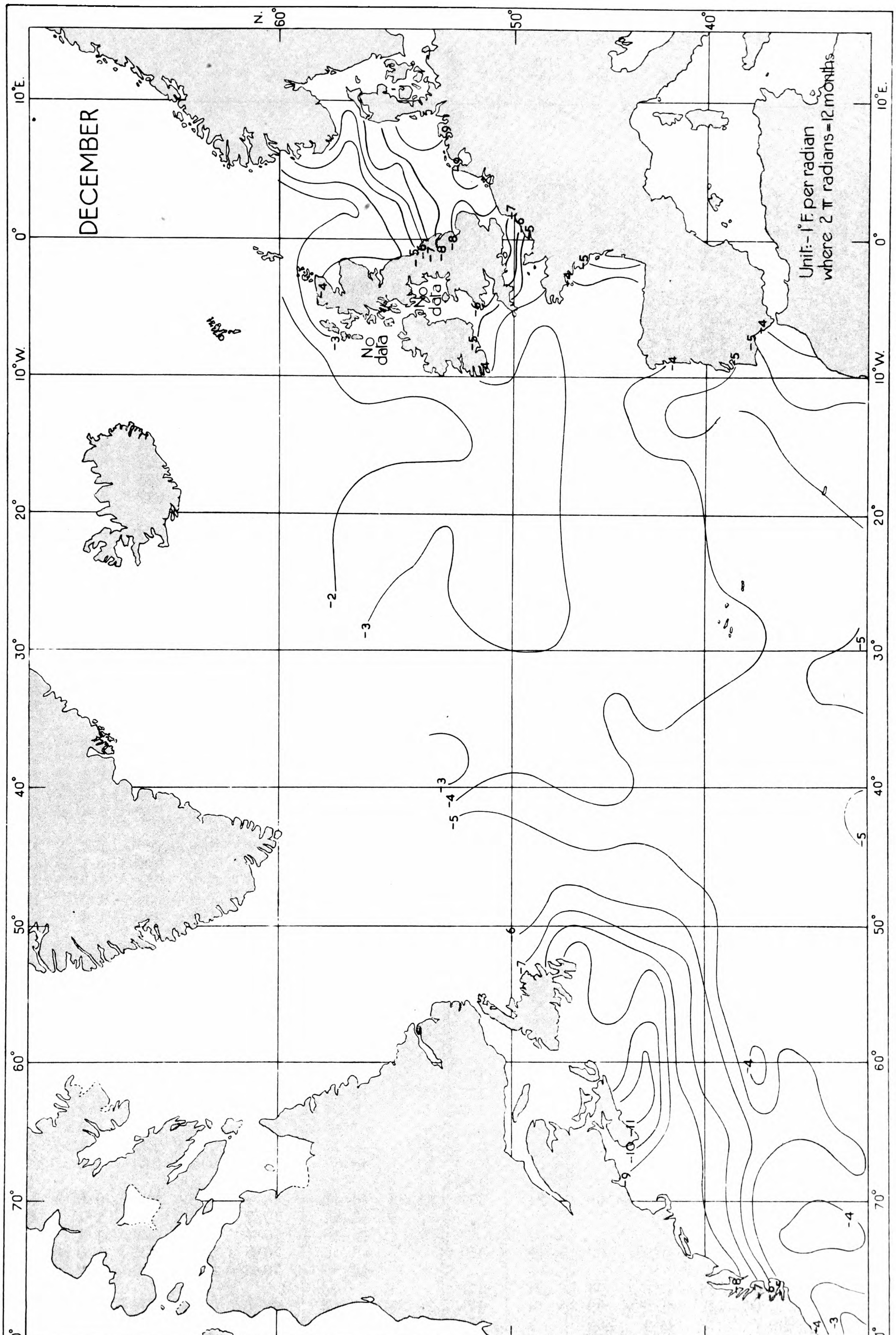

FIG.12—*continued*

APPENDIX—TABULATION OF HARMONIC PARAMETERS

Position		a_0	a_1	A_1	a_2	A_2	$\frac{100a_2}{a_1}$	F
° N.	° W.	° F.	° F.	°	° F.	°		°
Square 109								
34–36	00–02	65·5	8·4	240	1·4	51	17	169
	02–04	64·8	8·3	243	1·9	58	23	169
	04–06	63·5	5·8	236	0·4	26	7	178
	06–08	64·8	6·4	238	1·1	27	17	179
	08–10	65·3	5·9	233	0·8	347	14	195
36–38	00–02	64·8	9·2	238	1·5	22	16	182
	02–04	63·8	7·8	240	1·3	25	17	183
	04–06	63·2	6·4	235	0·7	34	11	173
	06–08	64·3	6·3	235	0·6	14	10	183
	08–10	62·7	4·8	230	0·4	265	8	233
38–40	08–10	60·9	4·7	232	0·3	270	6	232
30–32	08–10	60·4	7·0	233	1·8	358	26	189
Square 110								
30–32	10–12	66·1	3·6	215	0·5	296	14	202
	12–14	66·9	4·8	222	0·3	330	6	192
	14–16	67·3	4·9	219	0·6	304	12	202
	16–18	67·9	5·0	220	0·4	319	8	195
	18–20	68·5	5·2	217	0·4	270	8	217
32–34	10–12	66·5	4·7	229	1·2	301	26	213
	12–14	66·3	5·2	222	0·4	319	8	197
	14–16	66·7	5·1	220	0·4	335	8	187
	16–18	67·1	5·3	224	0·4	315	7	201
	18–20	67·5	5·4	223	0·5	15	9	171
34–36	10–12	65·5	5·6	228	0·6	27	11	169
	12–14	65·5	5·6	223	0·6	330	11	193
	14–16	65·5	5·6	222	0·6	341	11	187
	16–18	66·1	6·0	225	0·9	15	15	173
	18–20	66·3	6·0	226	0·8	001	13	181
36–38	10–12	63·6	5·2	224	0·3	290	6	214
	12–14	63·9	5·8	222	0·7	342	12	186
	14–16	64·6	6·2	228	1·0	35	16	165
	16–18	64·8	6·3	227	1·4	13	22	175
	18–20	64·9	6·1	225	1·0	10	16	175
38–40	10–12	62·5	6·0	227	0·5	11	8	177
	12–14	62·6	5·8	225	1·0	355	17	183
	14–16	63·0	6·1	228	1·0	33	16	167
	16–18	63·2	6·2	226	1·0	32	16	165
	18–20	63·1	6·2	228	1·1	19	18	173
Square 111								
30–32	20–22	68·6	5·0	219	0·3	359	6	175
	22–24	68·8	5·3	222	0·8	358	15	178
	24–26	69·3	5·7	224	0·6	47	11	155
	26–28	69·5	5·3	223	0·2	35	4	161
	28–30	..	..	..	..	..	..	..
32–34	20–22	67·3	5·8	225	1·0	01	17	179
	22–24	67·8	5·3	226	1·1	06	21	178
	24–26	..	..	..	..	..	..	..
	26–28	..	..	..	..	..	..	..
	28–30	68·7	5·6	226	0·9	60	16	151
34–36	20–22	66·6	5·8	225	0·8	04	14	178
	22–24	66·9	5·9	229	0·8	09	14	179
	24–26	67·2	5·9	228	0·4	50	7	158
	26–28	67·5	6·1	227	0·9	39	15	163
	28–30	67·6	6·1	226	1·0	13	16	175
Square 111—*continued*								
36–38	20–22	65·3	6·3	225	0·8	44	13	158
	22–24	65·5	6·2	226	0·7	25	11	169
	24–26	65·5	6·2	228	0·9	34	15	166
	26–28	66·0	6·3	229	1·2	28	19	170
	28–30	66·4	6·1	230	1·3	40	21	165
38–40	20–22	63·7	5·9	230	1·1	28	19	171
	22–24	63·9	6·1	230	1·0	32	16	169
	24–26	64·7	6·2	229	1·1	30	18	169
	26–28	64·4	6·3	230	1·3	47	21	161
	28–30	64·6	6·3	230	1·3	38	21	166
Square 112								
30–32	30–32	..	..	..	..	..	..	..
	32–34	70·9	6·1	224	0·4	24	7	167
	34–36	71·2	6·4	224	0·9	28	14	165
	36–38	71·4	6·0	225	0·9	40	15	160
	38–40	71·9	6·1	227	0·6	53	10	155
32–34	30–32	69·2	6·2	224	0·5	33	8	163
	32–34	69·8	6·4	223	0·6	22	9	167
	34–36	70·1	6·6	224	1·1	27	17	165
	36–38	70·3	6·4	226	1·0	27	16	167
	38–40	70·6	6·5	227	0·7	63	11	151
34–36	30–32	68·2	6·2	228	0·8	36	13	165
	32–34	68·5	6·9	226	1·2	31	17	165
	34–36	68·8	6·5	228	1·1	28	17	169
	36–38	69·1	6·8	229	1·2	25	18	171
	38–40	69·6	6·9	226	0·9	31	13	165
36–38	30–32	66·8	6·6	230	1·2	45	18	163
	32–34	67·0	6·8	228	1·2	37	18	165
	34–36	67·5	6·7	226	1·2	25	18	169
	36–38	68·0	7·0	227	1·4	27	20	169
	38–40	68·2	7·2	229	1·4	20	19	174
38–40	30–32	65·2	6·4	227	1·2	37	19	163
	32–34	66·1	6·4	228	1·1	45	17	161
	34–36	66·3	6·7	227	1·3	27	19	169
	36–38	67·0	6·9	230	1·5	42	22	164
	38–40	67·3	6·8	226	1·4	27	21	167
Square 113								
30–32	40–42	72·1	6·5	225	0·6	58	9	151
	42–44	72·3	6·4	223	0·6	46	9	155
	44–46	72·6	6·4	225	1·0	38	16	161
	46–48	72·8	6·7	225	1·4	41	21	159
	48–50	73·1	6·7	227	1·0	51	15	157
32–34	40–42	71·1	6·7	226	0·9	40	13	161
	42–44	71·4	6·9	228	1·2	34	17	166
	44–46	71·6	6·8	227	1·3	42	19	161
	46–48	71·8	7·0	227	1·1	43	16	161
	48–50	72·0	7·2	228	1·0	37	14	165
34–36	40–42	69·8	7·0	228	0·9	42	13	162
	42–44	70·2	7·2	229	1·1	42	15	163
	44–46	70·4	7·1	228	1·1	44	15	161
	46–48	70·5	7·3	226	1·0	34	14	164
	48–50	70·5	7·0	228	1·2	35	17	165
36–38	40–42	68·6	7·2	226	1·4	30	19	166
	42–44	69·0	6·8	227	1·2	38	18	163
	44–46	69·5	6·9	225	1·1	34	16	163
	46–48	69·6	7·2	225	1·5	31	21	165
	48–50	69·5	7·2	225	1·4	34	19	163

APPENDIX—*continued*

Position °N.	°W.	a_0 °F.	a_1 °F.	A_1 °	a_2 °F.	A_2 °	$\frac{100a_2}{a_1}$	F °
				Square 113—*continued*				
38–40	40–42	67·5	6·8	225	1·4	36	21	162
	42–44	68·1	7·2	225	1·5	35	21	163
	44–46	67·9	7·4	228	1·4	30	19	168
	46–48	68·0	7·6	228	1·6	39	21	163
	48–50	68·7	7·3	225	1·2	29	16	165
				Square 114				
30–32	50–52	73·6	6·5	228	0·8	56	12	155
	52–54	73·3	6·5	228	0·9	35	14	165
	54–56	73·7	6·6	228	0·9	24	14	171
	56–58	73·6	6·8	227	1·1	43	16	161
	58–60	73·6	6·6	226	1·3	49	20	157
32–34	50–52	71·9	7·2	226	1·1	42	15	160
	52–54	70·1	6·6	225	1·1	60	17	150
	54–56	71·9	6·7	228	1·6	54	24	156
	56–58	71·8	7·4	230	1·1	38	15	166
	58–60	71·8	7·6	228	1·3	39	17	163
34–36	50–52	70·6	7·0	226	1·5	45	21	159
	52–54	70·8	7·3	225	1·4	35	19	163
	54–56	70·7	7·5	227	1·4	35	19	165
	56–58	70·9	7·3	227	1·3	36	18	164
	58–60	70·9	7·4	229	1·1	36	15	166
36–38	50–52	69·8	7·2	227	1·2	20	17	172
	52–54	69·8	7·2	228	1·3	28	18	169
	54–56	70·2	6·9	227	1·3	31	19	167
	56–58	70·2	7·2	227	1·3	40	18	162
	58–60	70·7	7·1	230	1·4	51	20	159
38–40	50–52	69·1	7·2	225	1·1	39	15	161
	52–54	69·0	7·5	223	1·4	48	19	154
	54–56	69·4	7·3	226	1·6	56	22	153
	56–58	69·7	7·4	227	0·8	30	11	167
	58–60	69·7	7·3	230	0·7	20	10	175
				Square 115				
30–32	60–62	73·4	6·8	230	0·9	72	13	149
	62–64	73·6	6·9	233	0·8	63	12	157
	64–66	73·0	6·9	233	1·0	52	14	162
	66–68	73·5	7·7	227	0·9	44	12	160
	68–70	73·6	7·6	229	1·2	48	16	160
32–34	60–62	72·2	7·7	231	1·1	50	14	161
	62–64	72·0	7·8	230	1·2	57	15	157
	64–66	72·1	7·7	229	1·0	53	13	157
	66–68	72·9	7·7	230	1·3	41	17	165
	68–70	72·3	7·8	230	1·0	28	13	171
34–36	60–62	70·9	7·4	228	1·0	48	14	159
	62–64	71·4	7·3	230	0·8	67	11	151
	64–66	71·1	7·6	228	0·7	47	9	159
	66–68	70·7	7·3	232	1·2	45	16	165
	68–70	71·1	7·4	231	1·6	35	22	169
36–38	60–62	70·8	7·1	232	1·4	50	20	162
	62–64	71·0	7·7	235	1·2	65	16	157
	64–66	71·3	7·6	235	0·6	75	8	153
	66–68	71·9	7·4	236	0·4	70	5	156
	68–70	72·1	7·3	234	0·9	49	12	165
38–40	60–62	69·3	7·7	235	0·7	. .	9	. .
	62–64	69·3	8·0	233	0·5	17	6	179
	64–66	67·8	9·7	239	0·7	26	7	181
	66–68	65·2	11·0	235	0·4	. .	4	. .
	68–70	64·0	10·5	234	1·5	28	14	175

Position °N.	°W.	a_0 °F.	a_1 °F.	A_1 °	a_2 °F.	A_2 °	$\frac{100a_2}{a_1}$	F °
				Square 116				
30–32	70–72	73·4	7·1	230	1·5	33	21	169
	72–74	74·2	7·4	233	1·6	48	22	164
	74–76	74·6	6·7	237	0·9	27	13	179
	76–78	76·1	6·1	237	0·8	78	13	153
	78–80	77·1	5·8	244	1·1	71	19	163
32–34	70–72	70·7	8·1	236	1·8	50	22	166
	72–74	73·1	7·6	237	1·7	30	22	177
	74–76	74·6	6·5	239	0·6	58	9	165
	76–78	75·6	6·7	246	0·8	83	12	159
	78–80	72·5	8·9	245	1·7	72	19	164
34–36	70–72	71·7	7·3	237	1·4	25	19	179
	72–74	73·3	6·7	241	1·1	38	16	177
	74–76	70·9	8·7	241	1·7	36	20	178
	76–78	72·1	8·3	238	1·1	90	13	148
36–38	70–72	70·7	8·0	236	1·1	50	14	166
	72–74	65·4	11·0	238	2·3	50	21	168
	74–76	60·0	14·6	242	1·6	51	11	171
38–40	70·72	60·4	11·7	235	1·8	36	15	172
	72–74	57·3	14·3	234	2·9	62	20	158
	74–76	55·5	16·6	240	1·8	50	11	170
				Square 145				
40–42	08–10	60·4	4·9	234	0·2	350	4	194
42–44	02–04	60·1	7·6	241	1·4	49	19	171
	04–06	58·9	7·4	240	0·7	5	9	193
	06–08	58·8	6·4	242	1·1	35	17	179
	08–10	58·9	5·0	234	0·5	36	10	171
44–46	00–02	57·4	8·9	246	0·7	340	8	211
	02–04	58·7	8·0	241	1·6	45	20	173
	04–06	59·3	6·6	231	0·6	60	9	156
	06–08	57·9	6·3	235	1·0	38	16	171
	08–10	58·4	6·1	235	1·0	30	16	175
46–48	00–02	57·4	8·5	248	1·0	54	12	176
	02–04	56·4	7·5	250	1·0	42	13	184
	04–06	56·1	6·1	238	1·2	42	20	172
	06–08	56·8	6·0	235	1·1	40	18	170
	08–10	56·9	5·8	235	1·0	39	17	171
48–50	00–02	53·2	6·7	229	1·1	40	16	164
	02–04	53·9	6·1	227	0·5	45	8	159
	04–06	54·5	5·7	235	1·0	62	18	159
	06–08	54·9	6·3	237	1·4	55	22	165
	08–10	55·3	6·0	237	1·4	45	23	169
				Square 146				
40–42	10–12	61·0	5·9	230	0·4	17	7	175
	12–14	61·3	6·3	229	1·1	26	17	171
	14–16	61·4	6·4	228	1·0	31	15	169
	16–18	61·5	6·6	231	1·3	30	20	171
	18–20	62·0	6·2	228	1·1	39	18	163
42–44	10–12	59·5	5·8	230	0·9	17	16	177
	12–14	59·9	6·1	228	1·2	31	20	167
	14–16	60·3	6·3	231	1·0	45	16	163
	16–18	60·5	6·1	229	1·1	34	18	167
	18–20	60·5	5·8	230	1·3	23	22	167

APPENDIX—*continued*

Position °N.	Position °W.	a_0 °F.	a_1 °F.	A_1 °	a_2 °F.	A_2 °	$\frac{100a_2}{a_1}$	F °
Square 146—*continued*								
44–46	10–12	58·4	6·3	229	1·1	35	17	167
	12–14	58·7	6·2	232	1·1	46	18	164
	14–16	58·7	5·8	232	1·2	46	21	164
	16–18	58·9	5·8	232	1·1	32	19	171
	18–20	59·2	5·7	232	1·1	31	19	171
46–48	10–12	57·1	5·8	234	1·1	44	19	167
	12–14	57·2	5·8	233	0·9	46	16	165
	14–16	57·5	5·8	234	1·0	35	17	171
	16–18	57·6	5·6	233	1·0	38	17	169
	18–20	57·9	5·4	231	1·3	32	24	170
48–50	10–12	55·7	5·4	234	1·4	46	26	166
	12–14	56·0	5·2	237	1·4	35	27	175
	14–16	56·3	4·8	243	1·7	44	35	176
	16–18	56·4	5·2	235	1·1	50	21	165
	18–20	56·9	5·0	236	1·2	47	24	167
Square 147								
40–42	20–22	62·4	6·0	231	1·0	13	17	179
	22–24	62·5	5·9	230	1·2	38	20	166
	24–26	62·7	6·2	230	1·3	31	21	169
	26–28	62·9	6·2	232	1·2	43	19	165
	28–30	63·0	6·0	228	1·3	22	22	172
42–44	20–22	60·6	6·2	229	1·1	36	18	166
	22–24	61·0	6·2	230	1·1	41	18	165
	24–26	61·5	5·9	230	1·2	34	20	168
	26–28	61·8	5·6	226	1·2	29	21	167
	28–30	62·3	5·7	229	1·1	25	19	171
44–46	20–22	59·4	5·7	232	1·3	36	23	169
	22–24	59·6	5·4	231	1·4	32	26	170
	24–26	60·2	5·6	231	0·8	30	14	171
	26–28	60·4	5·5	228	1·0	23	18	171
	28–30	60·8	5·6	231	1·0	29	18	171
46–48	20–22	58·3	5·4	228	1·0	33	19	167
	22–24	58·4	5·4	229	1·0	26	19	171
	24–26	58·3	5·3	232	1·3	20	25	177
	26–28	58·4	5·3	232	1·2	36	23	169
	28–30	58·3	5·2	232	0·9	39	17	167
48–50	20–22	56·5	4·7	236	1·1	42	23	170
	22–24	56·3	4·8	235	0·9	43	19	169
	24–26	56·4	5·1	236	0·8	35	16	173
	26–28	56·4	5·1	233	1·0	30	20	173
	28–30	56·2	4·8	233	1·2	21	25	177
Square 148								
40–42	30–32	63·7	6·1	227	1·1	15	18	175
	32–34	64·5	6·0	227	1·1	35	18	165
	34–36	65·1	6·6	230	1·2	22	18	174
	36–38	65·3	6·7	225	1·4	33	21	163
	38–40	65·5	6·3	221	1·6	01	25	175
42–44	30–32	63·0	5·9	230	1·1	22	19	174
	32–34	63·1	6·2	230	1·3	37	21	167
	34–36	63·5	6·4	228	1·6	38	25	164
	36–38	63·1	6·2	230	0·9	31	14	169
	38–40	63·2	6·1	228	1·2	28	20	169

Position °N.	Position °W.	a_0 °F.	a_1 °F.	A_1 °	a_2 °F.	A_2 °	$\frac{100a_2}{a_1}$	F °
Square 148—*continued*								
44–46	30–32	61·0	5·6	230	1·2	31	21	169
	32–34	60·8	5·6	228	1·0	15	18	175
	34–36	60·6	5·8	228	0·8	26	14	170
	36–38	60·7	5·7	230	1·0	14	18	178
	38–40	60·9	6·0	225	1·2	38	20	161
46–48	30–32	58·2	5·4	234	0·9	44	17	167
	32–34	57·9	5·2	232	1·1	39	21	167
	34–36	58·0	5·3	235	1·1	19	21	181
	36–38	58·1	5·3	234	1·4	25	26	177
	38–40	58·3	5·3	230	1·3	19	25	175
48–50	30–32	55·8	5·1	235	1·0	20	20	180
	32–34	55·4	4·7	236	1·2	15	25	183
	34–36	55·3	4·7	235	1·3	356	28	192
	36–38	55·7	4·8	229	1·1	351	23	189
	38–40	55·3	5·2	227	1·1	353	21	185
Square 149								
40–42	40–42	65·9	6·4	229	1·1	26	17	171
	42–44	65·8	6·1	227	1·3	36	21	164
	44–46	65·6	6·8	228	1·4	38	21	164
	46–48	64·1	8·1	229	0·8	360	10	166
	48–50	61·8	8·9	230	1·4	24	16	173
42–44	40–42	63·3	6·6	228	1·0	38	15	164
	42–44	63·5	6·8	229	1·0	20	15	174
	44–46	62·4	7·5	231	0·6	350	8	191
	46–48	57·4	8·5	232	1·2	31	14	171
	48–50	48·9	10·1	235	1·7	32	15	174
44–46	40–42	60·8	6·5	228	1·4	24	21	171
	42–44	59·6	7·1	232	1·3	04	18	185
	44–46	55·0	7·7	233	1·9	14	25	181
	46–48	49·3	8·5	232	1·8	06	21	184
	48–50	43·1	10·8	231	2·8	28	26	172
46–48	40–42	56·9	6·0	234	1·4	354	23	192
	42–44	51·1	7·4	235	2·5	02	34	189
	44–46	45·7	8·6	225	2·8	02	33	179
	46–48	42·0	10·0	224	2·8	10	28	174
	48–50	40·4	10·8	226	2·5	12	23	175
48–50	40–42	54·8	5·0	228	1·2	342	24	192
	42–44	51·2	5·7	221	1·7	342	30	185
	44–46	46·2	7·0	222	1·8	346	26	184
	46–48	43·1	7·5	225	1·6	357	21	181
	48–50	39·9	9·2	230	2·0	17	22	177
Square 150								
40–42	50–52	61·9	9·2	233	1·6	62	17	157
	52–54	63·0	9·3	231	0·9	25	10	173
	54–56	63·8	9·2	225	0·8	78	9	141
	56–58	64·6	8·9	227	0·9	54	10	155
	58–60	63·8	9·3	231	0·7	35	8	169
42–44	50–52	48·2	11·8	238	2·2	25	19	181
	52–54	52·0	11·8	238	1·1	14	9	186
	54–56	53·3	12·4	235	0·7	67	6	157
	56–58	52·9	12·8	233	1·0	37	8	169
	58–60	51·1	13·3	230	0·9	28	7	171

APPENDIX—*continued*

Square 150—*continued*

Position °N.	Position °W.	a_0 °F.	a_1 °F.	A_1 °	a_2 °F.	A_2 °	$\frac{100a_2}{a_1}$	F °
44–46	50–52	44·3	12·4	229	2·4	17	19	175
	52–54	45·0	12·5	226	2·4	12	19	175
	54–56	45·2	12·6	229	2·4	25	19	171
	56–58	44·6	14·0	228	2·6	28	18	169
	58–60	43·7	14·6	229	3·0	14	21	177
46–48	50–52	40·5	12·0	228	2·3	03	19	181
	52–54	40·1	11·9	228	2·1	348	18	189
	54–56	41·7	12·2	229	2·1	19	17	175
	56–58	41·9	12·9	230	1·5	36	12	167
48–50	50–52	39·0	11·0	230	2·5	23	23	173
	52–54	39·0	11·7	231	2·8	10	24	181

Square 151

Position °N.	Position °W.	a_0 °F.	a_1 °F.	A_1 °	a_2 °F.	A_2 °	$\frac{100a_2}{a_1}$	F °
40–42	60–62	61·5	10·3	238	0·9	50	9	168
	62–64	59·2	11·2	242	1·0	14	9	190
	64–66	56·2	11·7	238	1·4	24	12	181
	66–68	52·8	12·1	235	1·3	47	11	167
	68–70	51·5	12·3	232	1·3	49	11	163
42–44	60–62	49·6	14·6	227	1·5	36	10	164
	62–64	48·5	15·0	227	1·7	35	11	165
	64–66	46·3	13·3	230	1·3	46	10	162
	66–68	46·5	11·7	234	1·0	45	9	167
	68–70	49·2	13·2	238	2·4	53	18	167
44–46	60–62	44·4	14·8	228	2·7	23	18	171

Square 181 (German data)

Position °N.	Position °W.	a_0 °F.	a_1 °F.	A_1 °	a_2 °F.	A_2 °	$\frac{100a_2}{a_1}$	F °
50–51	0– 1	52·8	7·9	228	0·5	00	6	183
	1– 2	52·9	7·6	227	0·4	06	5	179
	2– 3	53·2	7·0	226	0·5	12	7	175
	3– 4	53·5	6·5	228	0·5	47	8	159
	4– 5	53·7	6·4	232	0·8	64	12	155
	5– 6	53·3	6·0	231	0·7	61	12	155
	6– 7	53·6	6·6	236	1·4	72	21	155
	7– 8	54·1	6·8	237	1·2	39	18	173
	8– 9	54·4	6·8	237	1·3	59	20	162
	9–10	54·6	6·3	238	0·8	62	13	162
51–52	3–4	52·5	8·3	232	0·7	30	8	172
	4–5	52·7	7·4	231	0·8	07	11	182
	5–6	53·0	6·6	231	0·8	93	12	140
	6–7	53·1	6·0	233	1·1	78	19	149
	7–8	53·2	6·4	234	1·3	38	21	170
	8–9	53·1	6·3	237	0·6	61	10	161
52–53	5–6	51·8	6·2	215	0·4	22	7	159
	6–7	52·2	6·1	223	0·5	325	8	195
53–54	5–6	51·3	6·5	220	0·6	60	9	145
54–55	0–1	48·9	7·6	234	0·9	75	12	151
	1–2	49·0	7·0	236	1·3	270	18	. .
	5–6	50·5	5·8	216	0·2	51	3	146
55–56	0–1	49·5	7·6	234	1·6	62	21	158
	1–2	48·9	7·4	225	1·3	75	18	143
56–57	0–1	49·2	6·9	231	1·6	66	23	153
	1–2	48·5	6·6	230	1·0	75	15	148
	2–3	48·4	7·1	233	0·8	87	11	145

Square 181 (German data)—*continued*

Position °N.	Position °W.	a_0 °F.	a_1 °F.	A_1 °	a_2 °F.	A_2 °	$\frac{100a_2}{a_1}$	F °
57–58	0– 1	49·2	6·3	233	1·3	66	21	155
	1– 2	48·2	6·3	227	0·9	55	14	154
	2– 3	49·3	6·5	230	0·9	56	14	157
	3– 4	47·9	7·3	234	0·4	40	5	169
58–59	0– 1	48·8	5·4	232	1·3	50	24	162
	1– 2	48·7	5·5	229	0·9	70	16	149
	2– 3	48·5	5·4	229	0·7	30	13	169
	3– 4	48·8	5·3	228	0·7	35	13	165
	4– 5	49·1	5·1	226	0·8	49	16	156
	5– 6	49·6	5·4	227	0·8	58	15	153
	6– 7	50·1	5·1	234	0·9	66	18	156
	7– 8	50·5	4·5	236	0·9	46	20	168
	8– 9	50·6	4·2	241	1·0	38	24	177
	9–10	50·8	4·3	242	0·9	45	23	175
59–60	0– 1	48·8	5·8	232	1·7	60	30	157
	1– 2	48·6	4·9	226	0·9	54	19	154
	2– 3	48·8	5·7	230	0·8	47	14	161
	3– 4	49·2	4·6	226	0·9	50	20	156
	4– 5	49·6	4·4	232	1·0	51	23	161
	5– 6	49·9	4·0	223	1·0	35	25	160
	6– 7	50·4	4·4	238	1·5	45	34	170
	7– 8	50·1	3·7	238	1·2	40	32	174
	8– 9	50·3	3·4	237	1·2	30	35	177
	9–10	50·0	3·3	234	1·4	30	42	174

Square 182

Position °N.	Position °W.	a_0 °F.	a_1 °F.	A_1 °	a_2 °F.	A_2 °	$\frac{100a_2}{a_1}$	F °
50–52	10–12	54·4	5·2	240	1·1	61	21	165
	12–14	54·8	4·9	237	1·0	48	20	168
	14–16	54·8	4·6	235	1·0	50	22	165
	16–18	55·0	4·7	237	1·0	42	21	171
	18–20	55·1	4·6	238	1·0	53	22	167
52–54	10–12	. .	. .	. .	. .	. .	. .	. .
	12–14	53·9	4·5	238	1·3	42	29	172
	14–16	54·3	4·4	238	1·2	35	27	175
	16–18	53·8	4·3	237	0·8	44	19	170
	18–20	53·7	4·1	233	0·5	53	12	161
54–56	10–12	52·6	4·4	240	0·9	71	20	159
	12–14	52·8	4·1	240	1·0	41	24	175
	14–16	52·9	4·0	240	0·8	34	20	178
	16–18	52·9	3·9	239	0·8	34	21	177
	18–20	52·9	3·9	238	1·0	38	26	174
56–58	10–12	52·0	4·1	227	0·9	37	22	163
	12–14	52·3	4·5	237	1·3	65	29	159
	14–16	51·6	4·1	239	0·9	47	22	171
	16–18	51·4	3·9	241	0·8	33	21	179
	18–20	51·4	3·9	240	0·8	15	21	187
58–60	10–12	51·1	3·8	242	1·1	47	29	173
	12–14	50·6	4·1	242	1·0	55	24	169
	14–16	50·3	4·0	244	1·1	52	28	173
	16–18	50·3	3·8	243	1·0	48	26	174
	18–20	50·3	3·7	242	1·0	47	27	173

Square 183

Position °N.	Position °W.	a_0 °F.	a_1 °F.	A_1 °	a_2 °F.	A_2 °	$\frac{100a_2}{a_1}$	F °
50–52	20–22	55·0	4·4	236	1·0	50	23	166
	22–24	54·9	4·4	230	1·0	41	23	165
	24–26	54·5	4·6	239	0·9	46	20	171
	26–28	54·4	4·5	233	0·8	31	18	173
	28–30	54·0	4·4	233	0·7	34	16	171

APPENDIX I—*continued*

Position (° N.)	Position (° W.)	a_0 (° F.)	a_1 (° F.)	A_1 (°)	a_2 (° F.)	A_2 (°)	$\frac{100a_2}{a_1}$	F (°)
				Square 183—*continued*				
52–54	20–22	53·1	4·2	237	0·3	15	7	185
	22–24	52·9	4·0	238	0·3	03	7	191
	24–26	52·5	3·7	236	0·4	43	11	169
	26–28	52·1	4·2	235	0·2	38	5	171
	28–30	51·0	4·3	237	0·5	356	12	194
54–56	20–22	52·9	4·0	235	0·8	31	20	175
	22–24	52·6	4·3	235	0·7	43	16	169
	24–26	51·9	4·4	235	0·5	30	11	175
	26–28	51·2	4·8	238	0·3	36	6	175
	28–30	49·7	5·1	239	0·1	112	2	138
56–58	20–22	51·4	4·0	239	0·6	60	15	164
	22–24	51·5	3·7	237	0·6	30	16	177
	24–26	50·6	4·2	238	0·7	55	17	165
				Square 184				
50–52	30–32	[illegible]	[illegible]	235	0·3	17	7	181
	32–34	53·0	4·3	238	0·2	350	5	198
	34–36	52·6	4·5	239	0·4	337	9	205
	36–38	52·0	4·7	237	0·4	354	9	195
	38–40	51·8	4·2	235	0·7	326	17	207
52–54	30–32	50·2	4·4	242	0·6	13	14	191
	32–34	..	..	..	..	..	..	..
	34–36	48·6	4·7	239	0·6	11	13	189
	36–38	48·1	4·3	250	0·4	58	9	176
	38–40	47·5	5·7	242	0·4	98	7	148
				Square 185				
50–52	40–42	52·0	4·9	231	0·9	332	18	200
	42–44	51·9	5·4	228	0·8	352	15	187
				Square 216 (German data)				
° N.	° E.							
50–51	0–1	52·4	8·4	232	0·7	8	8	183
	1–2	52·2	8·7	233	0·5	11	6	182
51–52	1–2	52·1	8·8	233	0·5	0	6	185
	2–3	52·1	9·0	233	0·6	357	7	189
	8–4	51·5	10·4	239	0·4	09	4	189
52–53	1–2	50·5	9·8	235	0·8	14	8	183
	2–3	51·5	9·4	230	0·9	19	10	176
	3–4	51·5	9·7	234	0·6	10	6	184
	4–5	50·5	11·5	235	0·9	117	7	..
53–54	0–1	49·0	8·2	233	0·4	03	5	182
	1–2	49·4	9·3	233	0·3	60	3	158
	2–3	50·0	9·3	233	0·3	60	3	158
	3–4	50·8	9·7	232	0·5	42	5	166
	5–6	50·7	10·8	239	0·5	46	5	171
	6–7	50·2	11·5	240	0·6	46	5	172
	7–8	49·8	12·0	240	0·5	47	4	172

Position (° N.)	Position (° E.)	a_0 (° F.)	a_1 (° F.)	A_1 (°)	a_2 (° F.)	A_2 (°)	$\frac{100a_2}{a_1}$	F (°)
				Square 216 (German data)—*continued*				
54–55	1–2	49·5	8·6	235	0·9	73	10	153
	2–3	49·8	9·5	236	0·9	73	10	154
	3–4	49·9	9·8	234	1·0	82	10	148
	4–5	50·3	10·0	231	1·0	86	10	143
	5–6	50·5	10·3	232	0·7	78	7	148
	6–7	50·4	11·2	235	0·9	82	8	149
	7–8	49·8	12·0	237	0·6	98	5	143
	8–9	49·4	12·8	242	0·7	85	6	154
55–56	0–1	49·7	8·1	231	1·7	70	21	151
	1–2	49·6	8·0	235	1·5	55	19	162
	2–3	49·6	8·6	235	1·6	50	19	165
	3–4	49·6	9·2	235	1·1	70	12	155
	4–5	49·9	9·6	235	1·3	70	13	155
	5–6	50·1	9·9	234	1·3	95	13	142
	6–7	49·9	10·3	232	0·9	85	9	145
	7–8	49·8	11·2	237	0·8	85	7	150
56–57	0–1	49·6	7·2	232	1·8	63	25	155
	1–2	49·5	7·4	235	1·8	58	24	161
	2–3	49·3	8·0	235	1·7	56	21	162
	3–4	49·2	8·4	235	1·5	53	18	163
	5–6	49·3	9·4	234	1·5	65	17	156
	6–7	49·7	9·8	238	1·3	95	13	146
	7–8	49·3	10·4	238	1·3	105	13	140
	8–9	48·7	11·2	241	1·2	81	11	156
57–58	1– 2	49·7	7·0	230	1·9	44	24	163
	2– 3	49·4	7·5	234	2·0	50	26	164
	3– 4	48·8	7·9	235	2·0	50	25	165
	4– 5	48·5	8·5	237	1·8	58	21	163
	5– 6	49·0	8·7	236	1·9	64	22	159
	6– 7	49·0	9·3	238	1·8	70	20	158
	7– 8	49·3	9·0	239	2·3	61	26	163
	8– 9	49·0	10·3	240	1·8	98	18	146
	9–10	48·8	10·8	244	1·6	86	15	156
58–59	0–1	49·3	6·6	233	1·5	45	23	165
	1–2	49·0	6·4	234	1·6	59	25	160
	2–3	49·3	6·8	235	1·8	63	26	159
	3–4	49·1	7·6	238	1·7	56	22	165
	4–5	48·6	8·6	236	1·8	72	21	155
	5–6	48·5	9·6	238	1·6	71	16	157
	6–7	48·5	10·4	239	1·6	71	16	158
59–60	0–1	48·9	6·0	235	1·8	59	30	160
	1–2	48·8	6·3	235	1·8	45	29	167
	2–3	49·0	6·7	240	1·4	55	21	167
	3–4	49·1	7·4	233	2·1	50	28	163
	4–5	48·8	8·6	238	1·8	70	21	158