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TECHNICAL NOTE NO. 61

SEA SURFACE TEMPERATURE IN THE SOUTH CHINA SEA

1961–1970

BY

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SUMMARY

Sea surface temperature data measured by the bucket method over the South China Sea were analysed for the decade 1961-1970.

For each one-degree square, ten-day means, monthly means, seasonal and annual means were computed. The results were analysed manually and presented in the form of isopleth charts. Supplementary information including the mean monthly positions of specified isotherms and mean month-to-month changes were also presented.

In order to facilitate the study of climatological variations, the following analyses were carried out. Monthly means for the first and second halves of the decade were computed and compared. The interannual variation of monthly means was characterised by the standard deviations of the one-year means about the ten-year means. The results were computed for each month of the year and presented in separate charts. Finally, the departures of the one year means from the ten-year means for ten selected areas in the South China Sea were also computed.

The appendix analysed the reliability of the results of the analyses. It was concluded that the accuracy of the ten-year monthly means was of the order of 0.1°C to 0.2°C. The interannual variation was also adequately resolved by the accuracy of the data.

CONTENTS

1. INTRODUCTION

This report is prepared to provide information on sea surface temperature over the South China Sea, which may be required for various purposes such as climatology, fisheries research, fog forecasting, cargo handling, satellite interpretation, tropical cyclone forecasting, and others.

The sea area covered is bounded by the equator, latitude 25°N, longitudes 100°E and 120°E.

In normal practice, weather observations are made by ships' officers at the main synoptic hours (i.e. 00, 06, 12 and 18 G.M.T.) while they are at sea. These observations are recorded in code in logbooks or on logsheets. These coded messages are then sent to a nearby coastal radio station for onward transmission to a national meteorological centre for use by forecasters. The logbooks or logsheets are, in due course, sent back to the original meteorological centre where the ship was recruited as a weather observing ship. The coded reports are then scrutinized and corrected where necessary by meteorological personnel. Afterwards, these coded reports are put on punch cards in the International Maritime Meteorological Punch Card format. The punched cards are sorted according to the positions where the observations were made and then forwarded to the appropriate meteorological centre responsible for the marine climatology of each particular area (WMO 1977).

Hong Kong is responsible for the marine climatology of the area covered by this summary. Annual Marine Climatological Summaries for two selected areas have been produced for the years 1961 to 1966 (Royal Observatory, 1970 to 1979).

The basic data in this report are obtained from those punched cards which contain sea surface temperature observations made by both Hong Kong and foreign weather observing ships. 1961 to 1970 was the ten-year period in which most data were available at the time when the preparation of this report began.

2. INSTRUMENTS AND METHODS OF MEASUREMENT OF SEA SURFACE TEMPERATURE

The majority of sea surface temperature reports are obtained by one of the two following methods :

(a) the "bucket" method - taking a sample of sea surface water with a specially designed bucket and measuring its temperature on board ship ; and

(b) the "condenser intake" method - reading the temperature of the ship's condenser intake water.

Comparisons of sea surface temperatures obtained by these two methods show that results obtained are not the same in most cases (James & Fox 1972). It is very difficult to relate the two types of readings because there are too many factors involved e.g. ship displacement, depth of intake, distance inboard of intake thermometer, wind speed, ship speed, precipitation, wave height etc. Thus, it is thought appropriate that the sea surface

temperature data set has to be divided into two subsets according to the methods of measurement.

Before 1968, the majority of sea surface temperatures reported by ships travelling in the area studied were obtained by the "bucket" method. For this reason, this report deals only with readings obtained by this method.

3. DATA PROCESSING

The ships' weather reports were transferred from the punched cards onto magnetic tape. The sea surface temperatures, methods of measurement, ships' positions and observation dates and times were extracted from each report. Those temperatures given in Fahrenheit were converted into Celsius and temperature readings below 0°C or above 40°C were discarded.

The sea area concerned was divided into 500 one-degree squares. For each one-degree square, the number of reports and the average sea surface temperatures for the first, second and third* ten-day periods and for the whole month were calculated for each month. Separate calculations were carried out for each of the two methods of measurements (viz, bucket and condenser intake). The results were stored on tape for further processing. The monthly values were printed out on a latitude-longitude grid for manual checking and analysis.

Ten of the one-degree squares were selected for further studies. They were the one-degree squares with their southwestern corners on the following grid points :

(i)	20N	119E
(ii)	15N	116E
(iii)	10N	111E
(iv)	5N	107E
(v)	1N	104E
(vi)	24N	119E
(vii)	21N	114E
(viii)	18N	107E
(ix)	11N	101E
(x)	1N	102E

The squares are spaced at intervals of about 5 degrees of latitude and about 4 degrees of longitude. This spacing is intended to provide adequate coverage of the South China Sea. The squares also lie close to the main sea routes from Singapore to Taiwan and Japan. Figure 2 shows the locations of the squares.

4. NOTES ON TABLES AND CHARTS

(1) Spatial distribution of ships' reports (Figure 1)

The number of reports in the ten-year period in each one-degree square are shown in Figure 1. The reports are concentrated along the main commercial sea routes; i.e. from Singapore to Bashi Channel, from Hong Kong

* (the last eleven days for months with 31 days; last eight or nine days for February)

to Taiwan Strait and from Hong Kong to Bangkok and Singapore passing just to the east of the Vietnam coast. A maximum in the Gulf of Tonkin was related to increased activity during the Vietnam conflict.

(2) Temporal distribution of ships' reports in the ten selected areas (Table 1)

The locations of the ten selected areas are given in Figure 2. The number of reports in all areas increased from 1961 to a maximum around 1967 and then gradually decreased. This is partly because of the increased usage of condenser intakes for sea surface temperature measurements after 1967.

(3) Ten-year mean sea surface temperatures in the South China Sea for (a) first 10-day, (b) second 10-day and (3) third 10-day periods of each month (Figures 3 - 14(a)-(c))

The mean for each period was first computed for each square for each individual year. The ten-year mean was then obtained by adding up these values and dividing by the number of years with data. (There were some 10-day periods with no reports in certain years.) This procedure was intended to give equal weight to each year. The alternative procedure of calculating the mean of all observations within the ten-year period was not adopted owing to the non-uniform distribution of data during this period (as shown in Table 1). Results were analysed manually and are presented in isopleth charts.

(4) Ten-year monthly mean sea surface temperatures (Figures 3 - 14(d))

The mean for each month was first computed for the individual years. The ten-year monthly mean was then obtained by adding up these values and dividing by the number of years with data. The results were analysed manually and are presented in isopleth charts.

(5) Ten-year seasonal and annual mean sea surface temperatues (Figures 15 - 19)

The ten-year seasonal and annual means were computed from the corresponding ten-year monthly means. Results were analysed manually and are presented in isopleth charts.

(6) Mean monthly position of specified isotherms (Figures 20 - 24)

The monthly positions of specified isotherms (28°C, 26°C, 24°C, 20°C, 16°C) were extracted from the ten-year monthly mean charts. Results are presented in charts, two for each isotherm. These charts show the movement of each isotherm up and down the South China Sea during the year. Figure 21 showing the 26°C isotherm is of special interest to tropical cyclone studies since this temperature is usually taken as a threshold value below which tropical cyclones are not expected to develop.

(7) Mean month-to-month variation (Figures 25 - 36)

The ten-year monthly mean for each month was compared with that of the preceding month. For the sake of convenience, the January mean was compared with the December mean although only nine pairs of consecutive months were involved. The results are presented in isopleth chart format at 1°C intervals. Positive value indicates a higher mean temperature than that of the preceding month. It is noted that the month-to-month changes of mean sea surface temperatures are in the region of ±1°C for most of the area except for the northern part. In the Taiwan Strait and the Gulf of Tonkin, changes are as much as 4°C in some months.

(8) Changes in mean sea surface temperature from one five-year period to the next (Figures 37 - 48)

The decade 1961 to 1970 was divided into two five-year periods. The monthly mean for each five-year period was computed. Differences of the monthly means for the two five-year periods were analysed and are presented in isopleth charts. Positive/negative values indicate that the mean sea surface temperatures for the five-year period 1966 to 1970 were higher/lower than those for 1961 to 1965. It is noted that the differences are all less than $\pm 2^{\circ}C$.

(9) Interannual variation of the monthly mean sea surface temperature (Figures 49 - 60)

The standard deviations of the one-year monthly mean values about the ten-year monthly mean value were first computed from the formula :-

$$S_{i.v.} = \sqrt{\frac{\Sigma_i \ (m_i - \bar{m})^2}{N - 1}}$$

where $S_{i.v.}$ is the standard deviation of individual one-year means about the ten-year mean : ("i.v." stands for "interannual variation").

m_i is the monthly mean of the year i (1961, ——, 1970)

N is the number of one-year monthly means (normally N = 10), and

$\bar{m}$ is the mean of the N monthly mean i.e. m_i/N.

Results were analysed manually and are presented as isopleth charts.

(10) Departures of one-year monthly means from the ten-year monthly mean in the ten selected one-degree-square areas (Tables 2 - 11)

Departures of individual one-year monthly means from the ten-year monthly mean in each of the ten selected areas were calculated and are tabulated in Tables 2 - 11. The units used are tenths of a degree and where there were no ship reports, the corresponding spaces are left blank.

5. ACKNOWLEDGEMENT

The efforts of the voluntary observers aboard weather observing ships, who have provided the sea surface temperature observations used in this study, are gratefully acknowledged. My sincere appreciation is due to members of the other meteorological services who provided the ship observations on International Maritime Meteorological Punch Cards, to Mr. E.W.K. Chu who has given much encouragement, to Mr. F.C. Lam and Mr. K.L. Tang who have contributed to part of the data processing work, and particularly to Mr. C.Y. Lam who has given valuable guidance, advice and suggestions which made this publication possible.

6. REFERENCES

1.	James, R.W., and Fox, P.T.	1972	Comparative sea surface temperature measurements. Reports on Marine Science Affairs No. 5, W.M.O. - No. 336.
2.	Royal Observatory	1970 - 1979	Annual Marine Climatological Summaries for the years 1961 to 1966 (in annual volumes)
3.	W.M.O.	1977	Guide to Marine Meteorological Services. W.M.O. - No. 471.

Table 1 Temporal distribution of ships' reports in the ten selected areas

Year \ Area	24N 119E	21N 114E	20N 119E	18N 107E	15N 116E	11N 101E	10N 111E	5N 107E	1N 102E	1N 104E
1961	466	288	261	2	1 380	195	951	449	25	90
1962	425	265	327	2	1 511	190	1 186	494	35	137
1963	496	303	182	1	1 836	101	1 569	643	78	233
1964	450	308	632	6	1 503	169	1 462	628	86	363
1965	683	460	688	848	1 508	235	1 555	372	95	294
1966	702	478	814	11 099	1 435	246	1 573	721	113	266
1967	769	696	898	23 590	1 525	237	1 938	764	136	297
1968	484	311	354	2 532	727	223	952	633	80	257
1969	401	302	345	418	722	169	852	657	93	202
1970	225	187	131	35	263	84	365	395	44	118

Table 2 Departures of one-year monthly means from the ten-year monthly mean in the selected one-degree square area northeast of 24N 119E (In units of 0.1°C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	173	165	180	212	239	261	277	278	271	250	226	195
1961	010	15	9	5	-4	12	2	0	4	3	8	16
1962	-1	15	18	-1	-1	0	2	-1	3	0	-3	-11
1963	-1	5	22	7	11	2	-3	5	4	5	12	15
1964	12	0	-8	8	0	2	8	2	6	6	-11	-23
1965	-3	15	-8	0	-2	-3	7	-10	-5	-3	5	6
1966	15	29	23	5	-5	8	3	7	-6	4	12	8
1967	-15	-19	9	0	8	-3	-5	7	9	-6	-10	-17
1968	-6	-41	-3	4	-1	-16	-12	-5	-11	-6	1	20
1969	21	-4	-32	-14	4	-12	1	-5	-4	-3	-3	-12
1970	-16	-14	-30	-16	-13	5	-1	2	3	-2	-12	-6

Table 3 Departures of one-year monthly means from the ten-year monthly mean in the selected one-degree square area northeast of 21N 114E (In units of 0.1°C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	207	204	217	239	271	282	288	289	282	269	249	225
1961	-3	3	-1	-2	-21	1	0	-4	-3	-3	8	8
1962	-4	-11	-6	-16	7	3	5	1	-4	1	-7	-12
1963	-4	-7	-5	-9	9	5	-3	-1	1	1	1	-7
1964	13	-2	-1	18	-7	-4	-1	-1	-2	1	-9	-5
1965	-6	12	9	15	-6	-6	-10	3	0	4	14	11
1966	5	7	26	12	-1	-1	1	5	2	7	14	9
1967	-4	5	-7	-7	12	3	5	-4	3	-1	-3	-4
1968	-19	-19	-11	-7	-6	0	0	1	-8	-4	-4	11
1969	22	9	-12	-6	12	-2	3	1	5	-1	-5	-9
1970	-4	5	3	-2	3	5	4	-1	2	-7	-8	-7

Table 4 Departures of one-year monthly means from the ten-year monthly mean in the selected one-degree square area northeast of 20N 119E (In units of 0.1°C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	236	237	244	261	283	289	290	289	284	277	263	247
1961	2	0	0	-3	-3	12	-5	0	-3	2	3	1
1962	-8	-7	-1	0	6	3	1	-3	-2	-2	-1	-4
1963	-9	-6	-5	-13	-7	-9	-9	-2	3	-2	1	-1
1964	4	1	-3	0	-5	-5	-1	-7	1	4	1	-7
1965	1	8	-4	8	3	-7	-8	0	7	-2	7	8
1966	15	10	12	12	-3	-6	3	8	-5	-1	6	7
1967	6	-2	-4	-5	1	2	6	3	4	2	-9	-10
1968	-8	-6	-4	-1	-2	6	8	2	-5	-5	-10	-3
1969	7	8	4	1	8	-3	8	2	2	4	0	-4
1970	-9	-4	1	-3	-2	7	0	-1	0	-4	-2	9

Table 5 Departures of one-year monthly means from the ten-year monthly mean in the selected one-degree square area northeast of 18N 107E (In units of 0.1°C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	240	228	227	258	280	295	300	299	293	287	272	254
1961									2			
1962	-20									-19		
1963									-15			
1964		-1			0	5	0				3	
1965			6	-1	-16	-13	-8	0	1	1	5	5
1966	12	18	16	9	0	1	1	2	10	3	6	1
1967	-6	-11	-5	-15	-2	-4	6	-2	-6	-9	-9	-3
1968	4	-28	-26	-8	0	5	0	1	2	10		2
1969	11	20	10	1	+16	3	-2	0	5	15	-2	-5
1970				12								

Table 6 Departures of one-year monthly means from the ten-year monthly mean in the selected one-degree square area northeast of 15N 116E (In units of 0.1°C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	253	254	265	281	295	292	288	288	288	285	276	265
1961	1	0	3	-4	-11	-5	-6	-5	-6	-4	1	-1
1962	0	-0	-5	-2	4	0	-4	-6	-3	2	-2	-5
1963	-10	-14	-12	-10	-3	-7	-4	0	0	0	5	4
1964	11	4	-4	3	0	-1	-3	0	0	0	-3	
1965	-11	-7	-4	1	5	-6	-5	1	2	3	8	6
1966	10	12	14	10	-1	6	5	4	1	4	6	9
1967	6	0	0	4	2	-1	5	-2	1	-3	-8	-10
1968	-7	-3	-11	-2	-2	9	1	5	0	1	-4	3
1969	11	9	8	-1	6	5	8	5	4	4	-1	-7
1970	-10	6	10	4	4	3	5	0	0	-8	0	4

Table 7 Departures of one-year monthly means from the ten-year monthly mean in the selected one-degree square area northeast of 11N 101E (In units of 0.1°C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	275	276	287	296	300	291	286	286	284	286	285	277
1961	0	4	1	-4	-2	1	-3	-4	-2	-7	-2	1
1962	-4	-10	-10	1	-2	-1	-1	-2	-6	1	-2	-7
1963	-8	-4	-12	-10	2	-5	-2	-4	3	-3	1	10
1964	7	7	-1	1	-4	-3	3	0	4	1	-5	-7
1965	-12	-4	-8	-6	-2	-5	-1	5	-1	0	4	4
1966	10	6	10	6	2	3	-2	-3	-2	0	7	5
1967	2	2	4	1	1	2	4	-3	3	-1	-3	-4
1968	-4	-1	0	1	2	2	2	2	-3	3	1	7
1969	13	6	1	7	5	7	6	6	2	9	4	-5
1970	0	-2	12	2	-1	-1	-2	3	5	-3	-4	-4

Table 8 Departures of one-year monthly means from the ten-year monthly mean in the selected one-degree square area northeast of 10N 111E (In units of 0.1°C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	262	262	270	285	296	292	287	285	285	285	280	270
1961	1	1	6	0	-2	-6	-5	-4	-2	-8	1	1
1962	-3	-8	-4	-3	0	-2	-2	-3	-3	0	1	-8
1963	-11	-13	-14	-11	-3	-5	-1	1	-2	-1	3	4
1964	7	8	-1	0	-2	-3	5	1	2	-1	-5	-12
1965	-10	-3	-5	-1	1	-5	-6	3	0	2	8	8
1966	9	11	12	14	0	4	3	4	2	5	5	11
1967	6	2	-4	5	1	1	0	-3	0	-2	-5	-3
1968	-2	-5	-9	-5	0	11	9	-1	0	0	-5	2
1969	10	11	9	4	7	8	2	5	3	10	1	-6
1970	-11	-2	9	-4	-1	-2	-4	1	3	-4	-6	-2

Table 9 Departures of one-year monthly means from the ten-year monthly mean in the selected one-degree square area northeast of 5N 107E (In units of 0.1°C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	261	262	274	287	296	294	288	287	287	286	280	269
1961	1	-2	6	3	-2	-3	0	-2	1	-5	0	1
1962	-2	-8	-5	-6	-3	-1	-4	-2	-4	0	3	-8
1963	-11	-14	-15	-10	-2	-1	1	0	2	1	3	3
1964	10	6	-8	-2	0	-3	4	-1	3	-1	-5	
1965	-11		10		-7	-4	-1	1	-3	7	9	9
1966	8	10	12	13	3	1	3	2	3	3	7	6
1967	2	-2	-8	1	3	-1	-1	-3	-1	-1	-3	-5
1968	-4	-3	-6	-3	3	6	3	0	3	-2	-3	5
1969	11	13	9	6	6	8	2	4	2	8	-1	-6
1970	-6	-3	1	0	3	-3	-3	-2	-2	-7	-10	-9

Table 10 Departures of one-year monthly means from the ten-year monthly mean in the selected one-degree square area northeast of 1N 102E (In units of 0.1°C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	276	278	286	293	300	296	293	294	289	290	289	285
1961	-5	2	5	6	3	-1	-1	6	-19	-4	-3	10
1962	-1	1	1	-6	-7	2	0	-3	2	2	-9	4
1963	-8	-12	-6	-2	2	0	5	-4	-6	-6	10	-4
1964	9	11	2	5	-2	-4	0	1	-4	4	-7	-2
1965	-7	-11	-2	-16	2	1	0	0	1	4	4	0
1966	2	3	9	9	3	0	0	-5	4	2	5	3
1967	8	-2	-3	7	-1	-2	-9	1	5	-1	2	-
1968	-6	4	-10	-2	1	0	7	7	3	6	0	3
1969	11	9	2	14	-5	7	-2	0	1	6	4	0
1970	1	-5	4	-13		-8	3	-4	11	-10	-7	-10

Table 11 Departures of one-year monthly means from the ten-year monthly mean in the selected one-degree square area northeast of 1N 104E (In units of 0.1°C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	272	273	280	290	297	293	289	284	285	288	286	280
1961	4	0	-1	0	2	-3	-5	-3	-4	-5	5	-4
1962	-3	-6	-3	-1	0	-7	-1	-1	1	-4	-6	-4
1963	6	-13	-9	2	4	7	4	0	0	-3	4	3
1964	10	10	-2	1	2	-1	1	1	1	1	-4	-6
1965	-11	-1	-1	-11	-6	-3	-2	1	4	0	1	6
1966	2	3	9	9	6	2	2	4	6	4	11	5
1967	2	-2	-7	-3	-5	2	-5	-1	-2	0	-1	-5
1968	-5	-2	-3	2	1	4	0	7	2	-1	0	0
1969	3	10	9	2	1	2	5	-3	3	3	-5	-2
1970	-4	-2	8	-1	-2	-4	-3	-1	-9	0	-4	2

Figure 1. Spatial distribution of ships' reports.

(Figures in thousands per one-degree square)

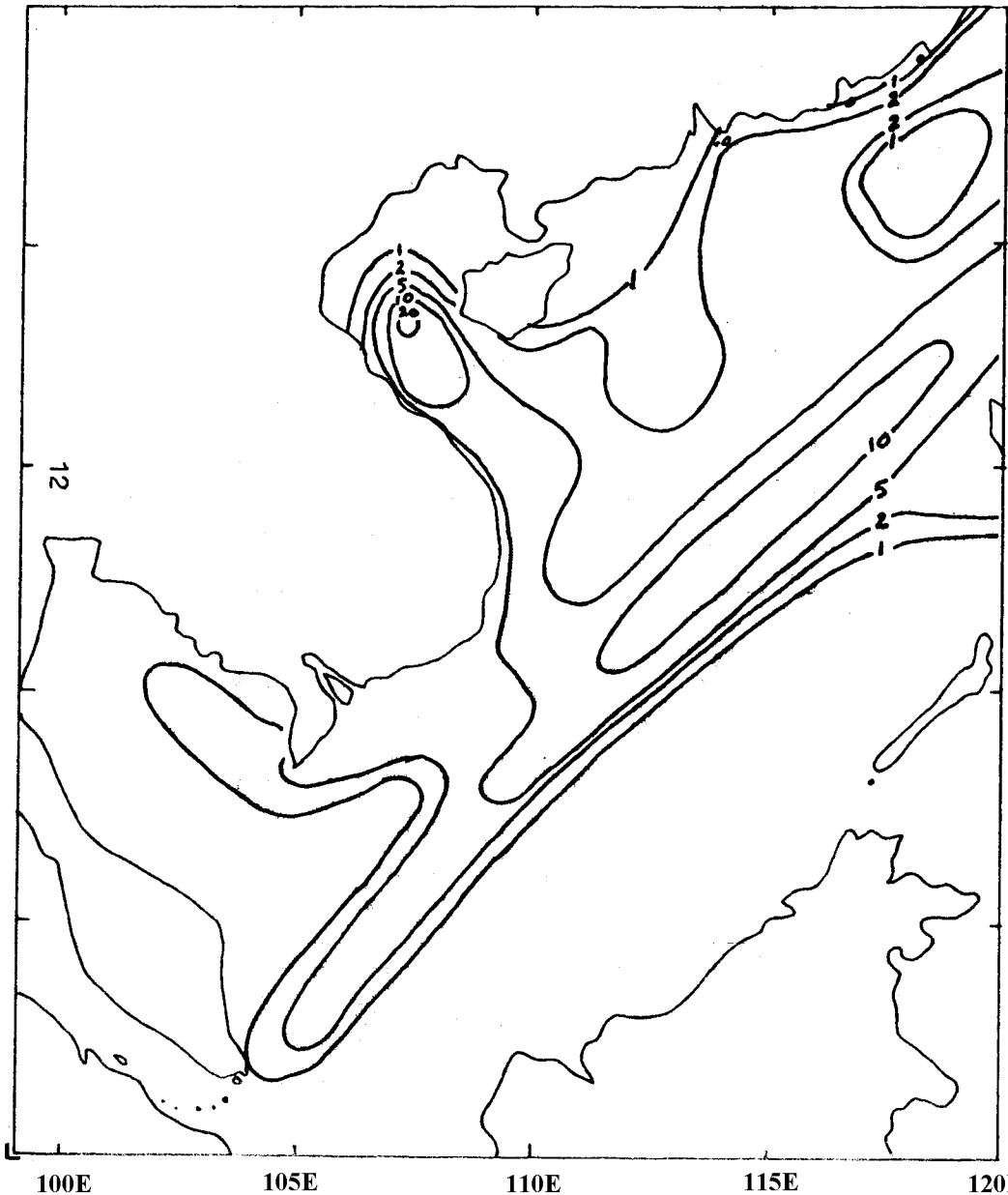


Figure 2. The location of the ten selected areas.

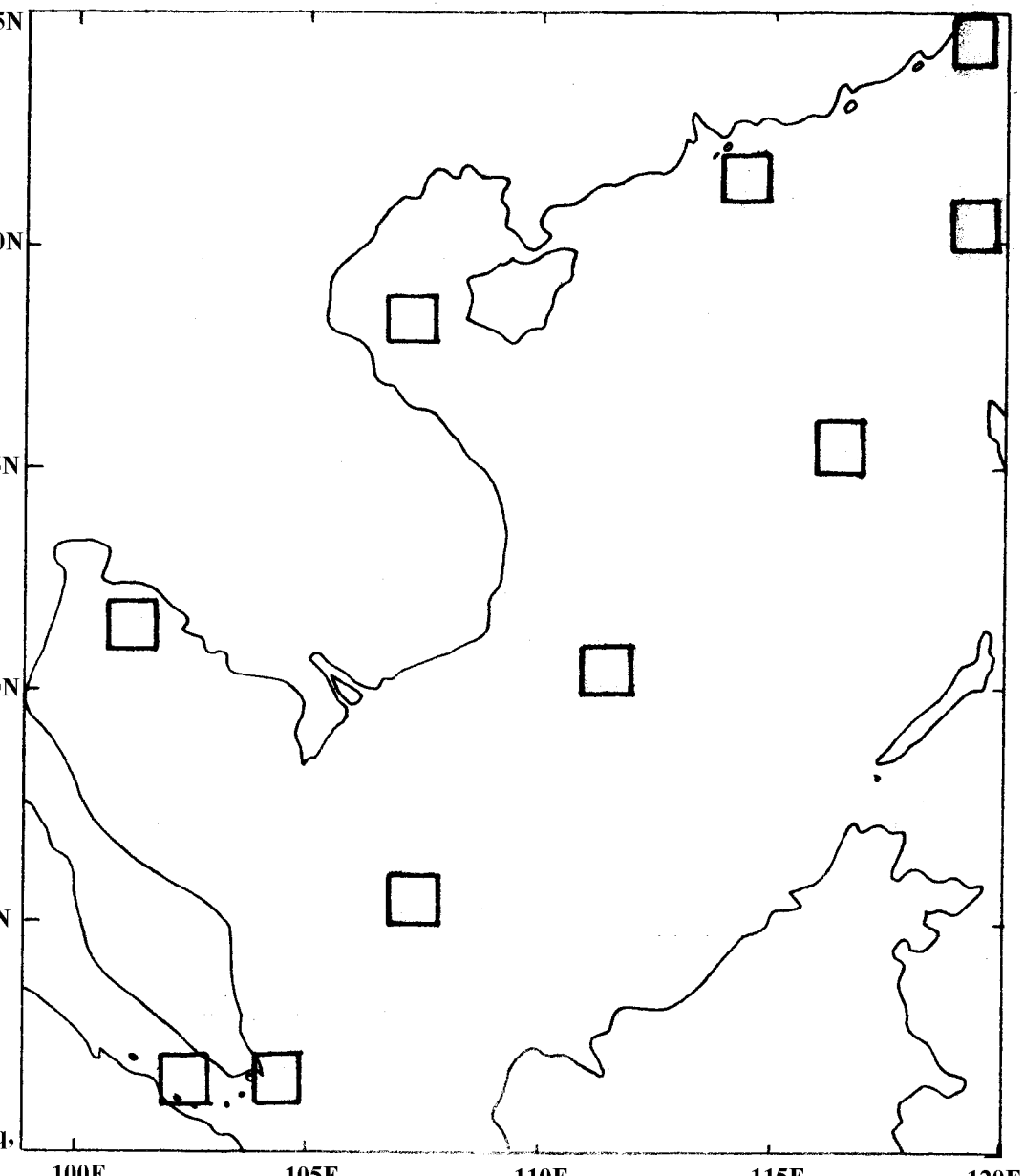


Figure 3(a). Ten-year mean sea surface temperatures in the South China Sea for the first ten-day period of January.

Figure 3(b). Ten-year mean sea surface temperatures in the South China Sea for the second ten-day period of January.

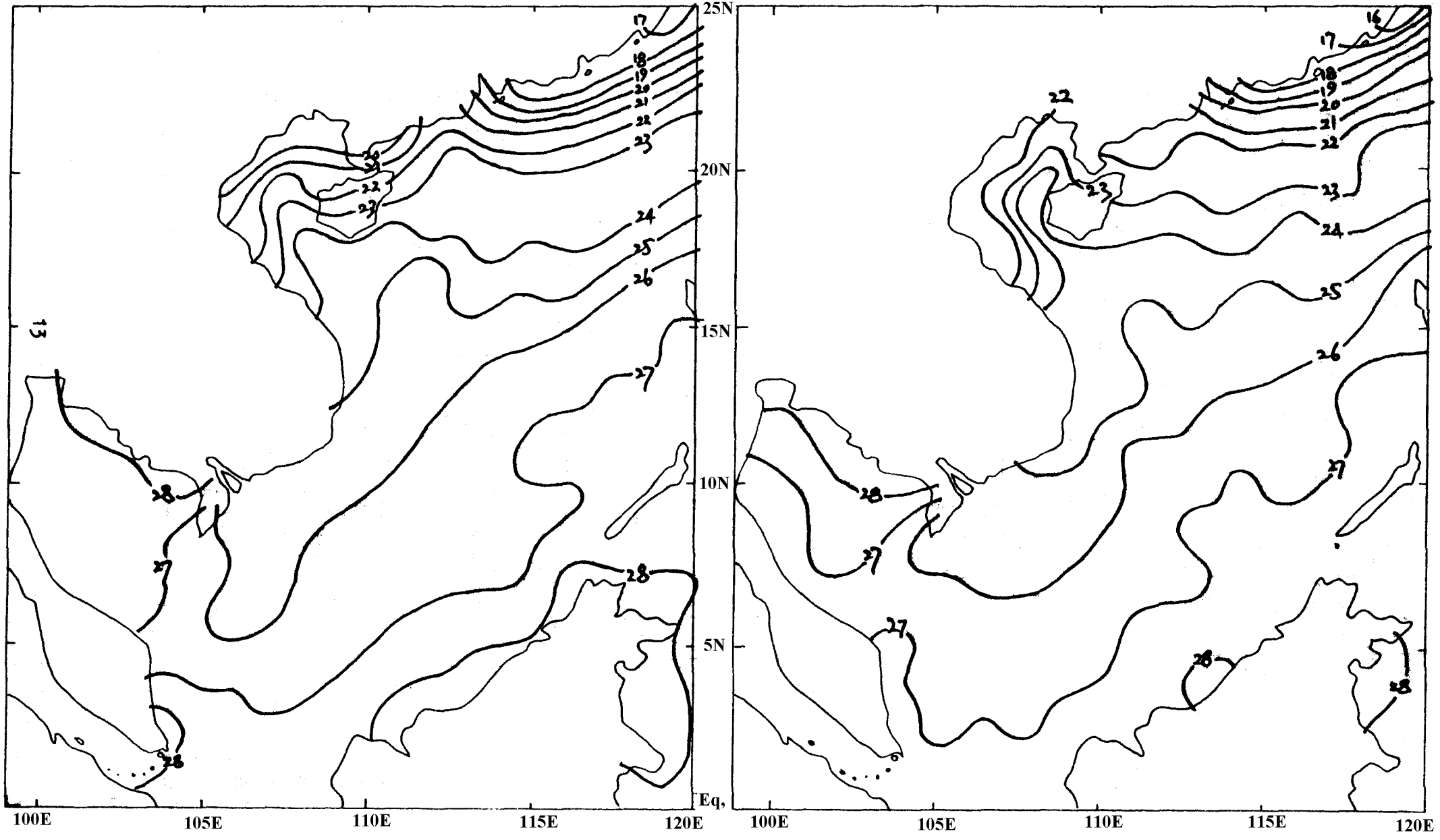


Figure 3(c). Ten-year mean sea surface temperatures in the South China Sea for the third ten-day period of January.

Figure 3(d). Ten-year monthly mean sea surface temperatures in the South China Sea for January.

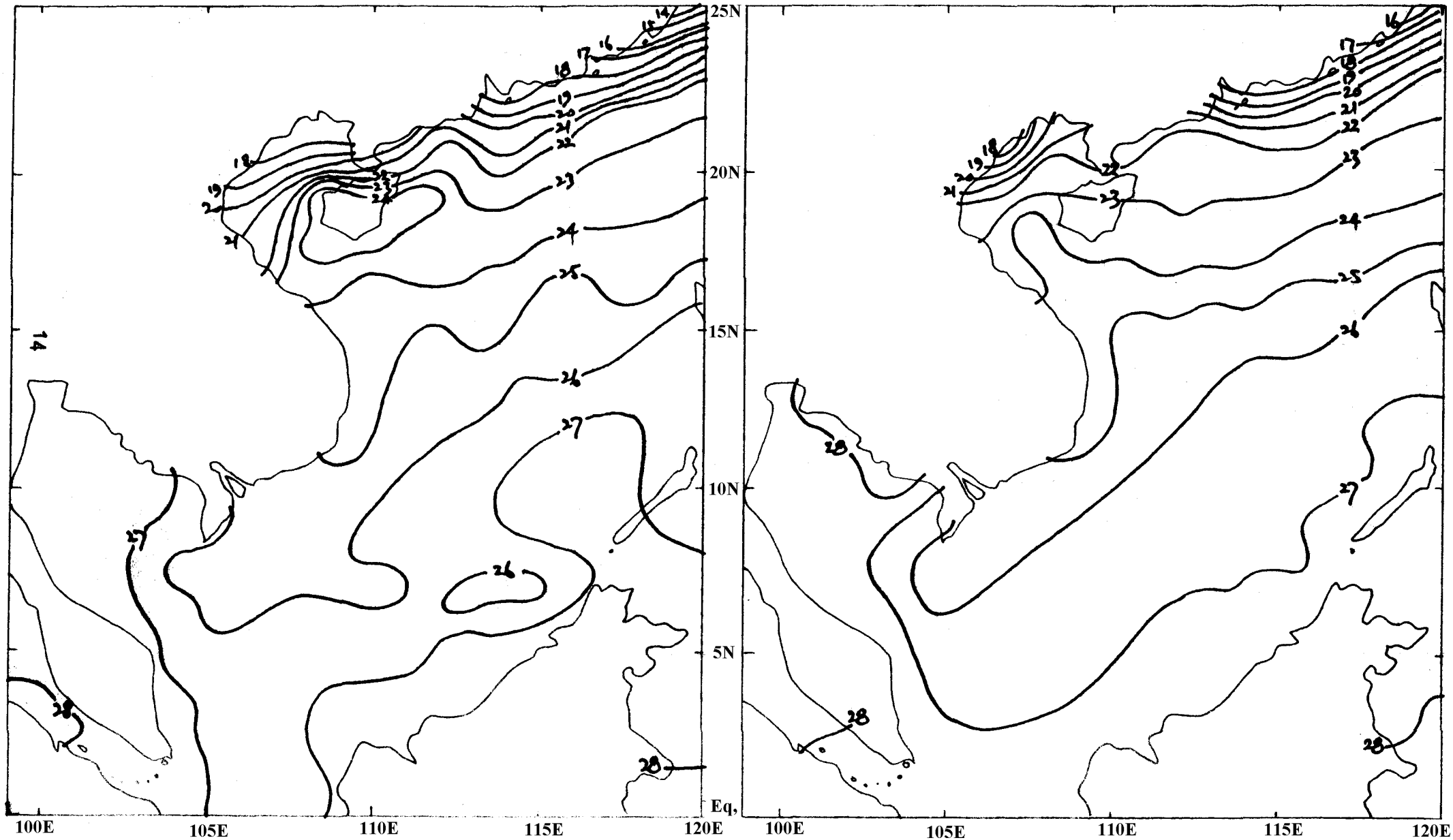


Figure 4(a). Ten-year mean sea surface temperatures in the South China Sea for the first ten-day period of February.

Figure 4(b). Ten-year mean sea surface temperatures in the South China Sea for the second ten-day period of February.

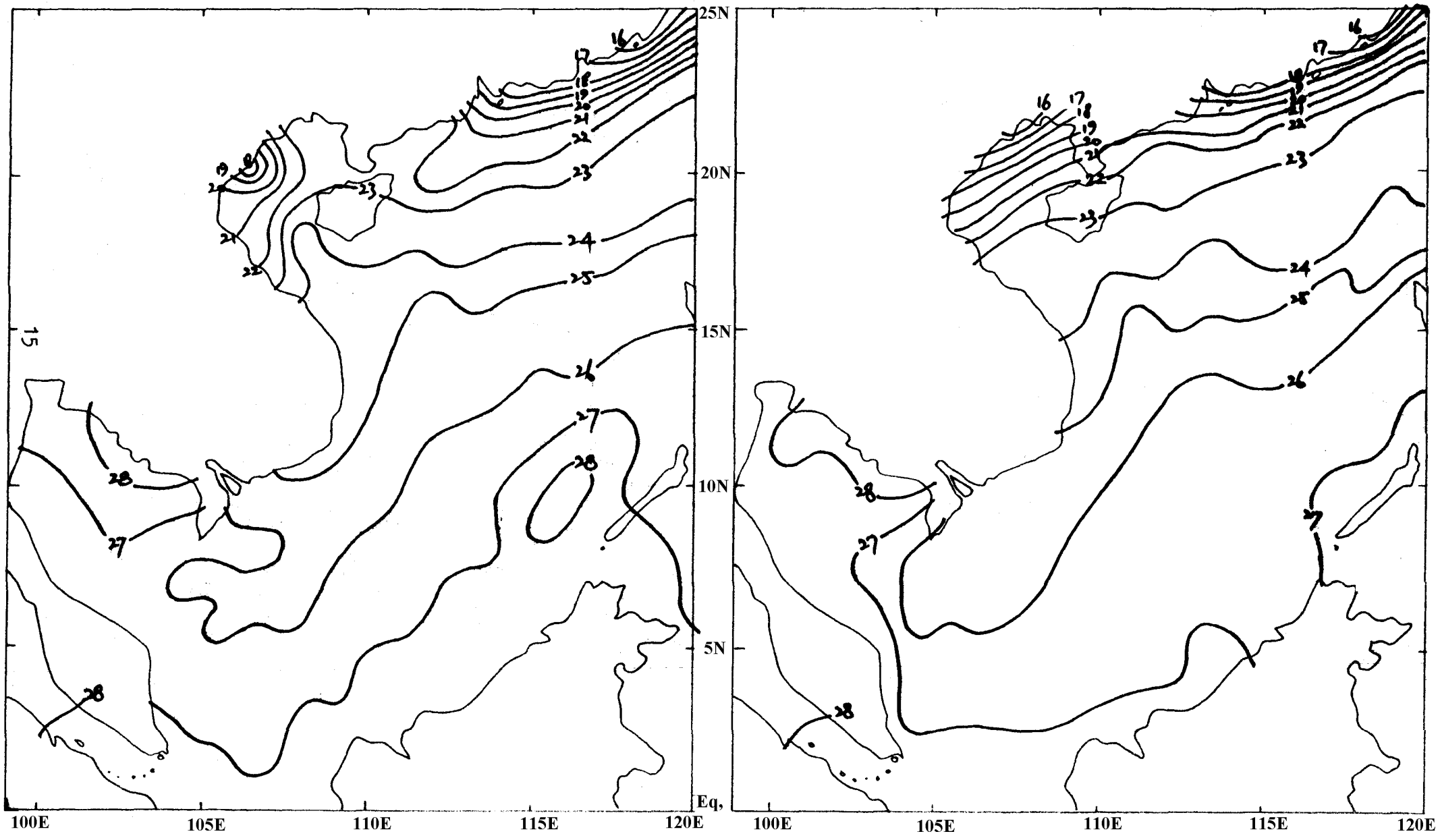


Figure 4(c). Ten-year mean sea surface temperatures in the South China Sea for the third ten-day period of February.

Figure 4(d). Ten-year monthly mean sea surface temperatures in the South China Sea for February.

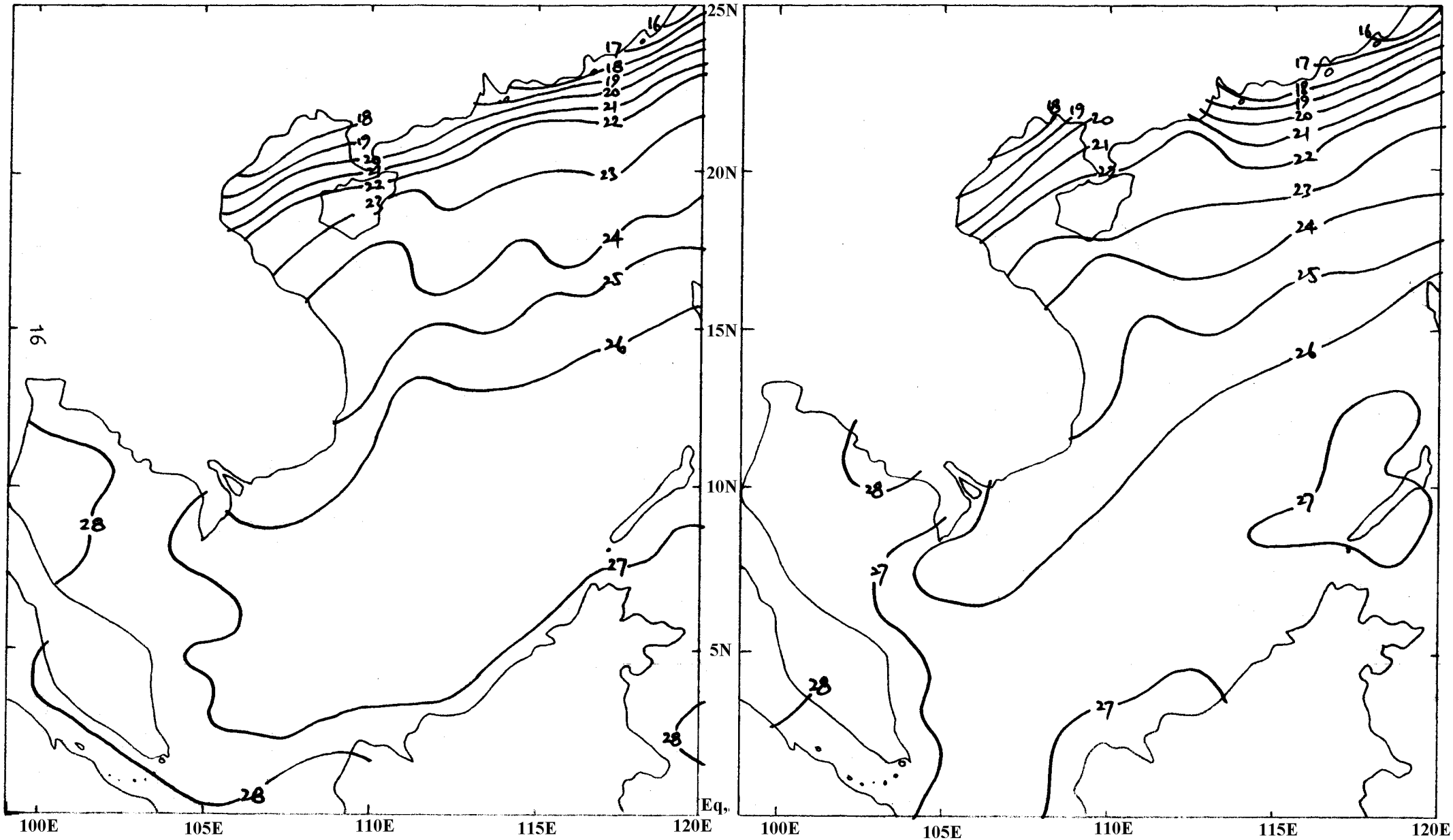


Figure 5(a). Ten-year mean sea surface temperatures in the South China Sea for the first ten-day period of March.

Figure 5(b). Ten-year mean sea surface temperatures in the South China Sea for the second ten-day period of March.

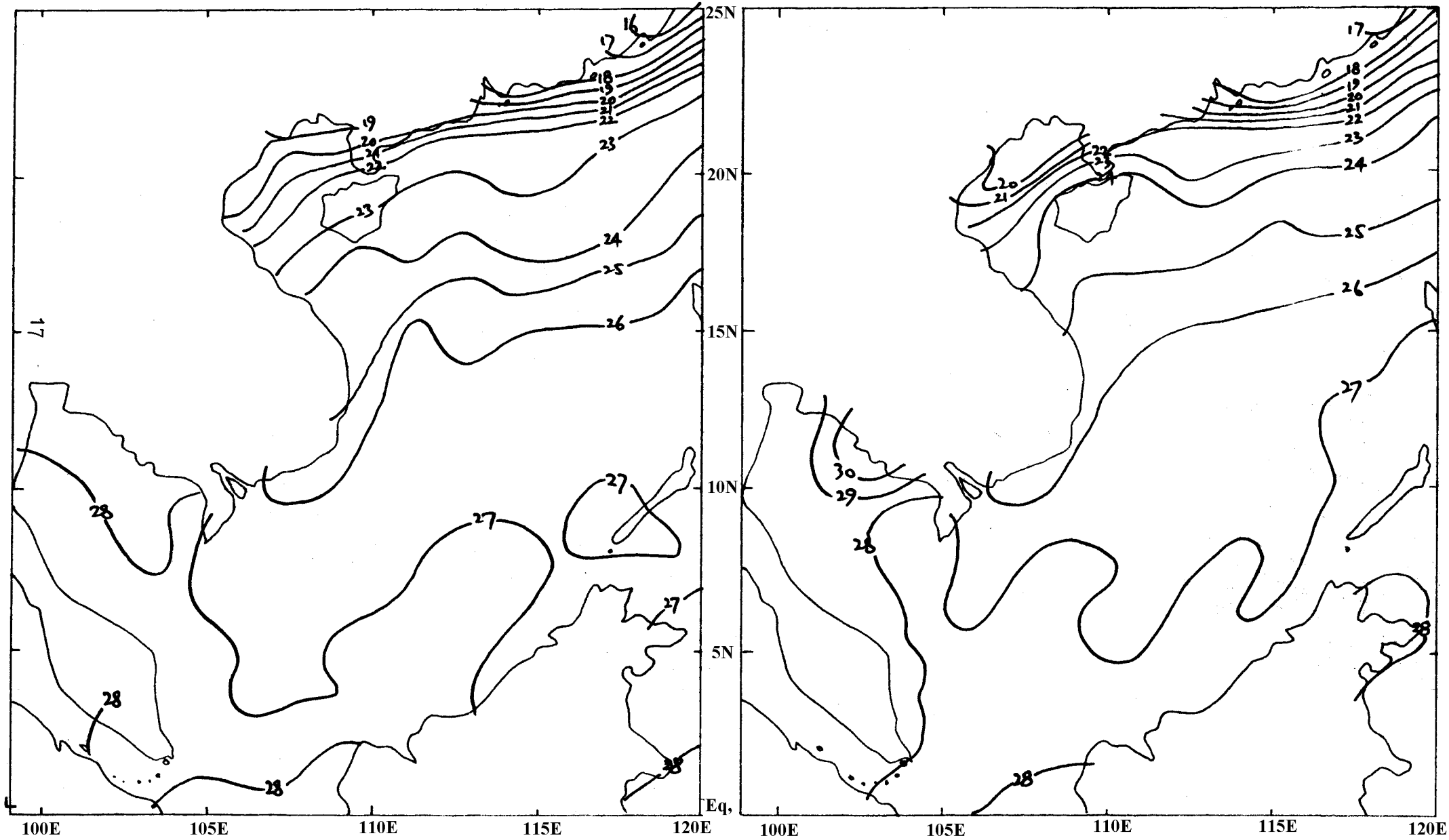


Figure 5(c). Ten-year mean sea surface temperatures in the South China Sea for the third ten-day period of March.

Figure 5(d). Ten-year monthly mean sea surface temperatures in the South China Sea for March.

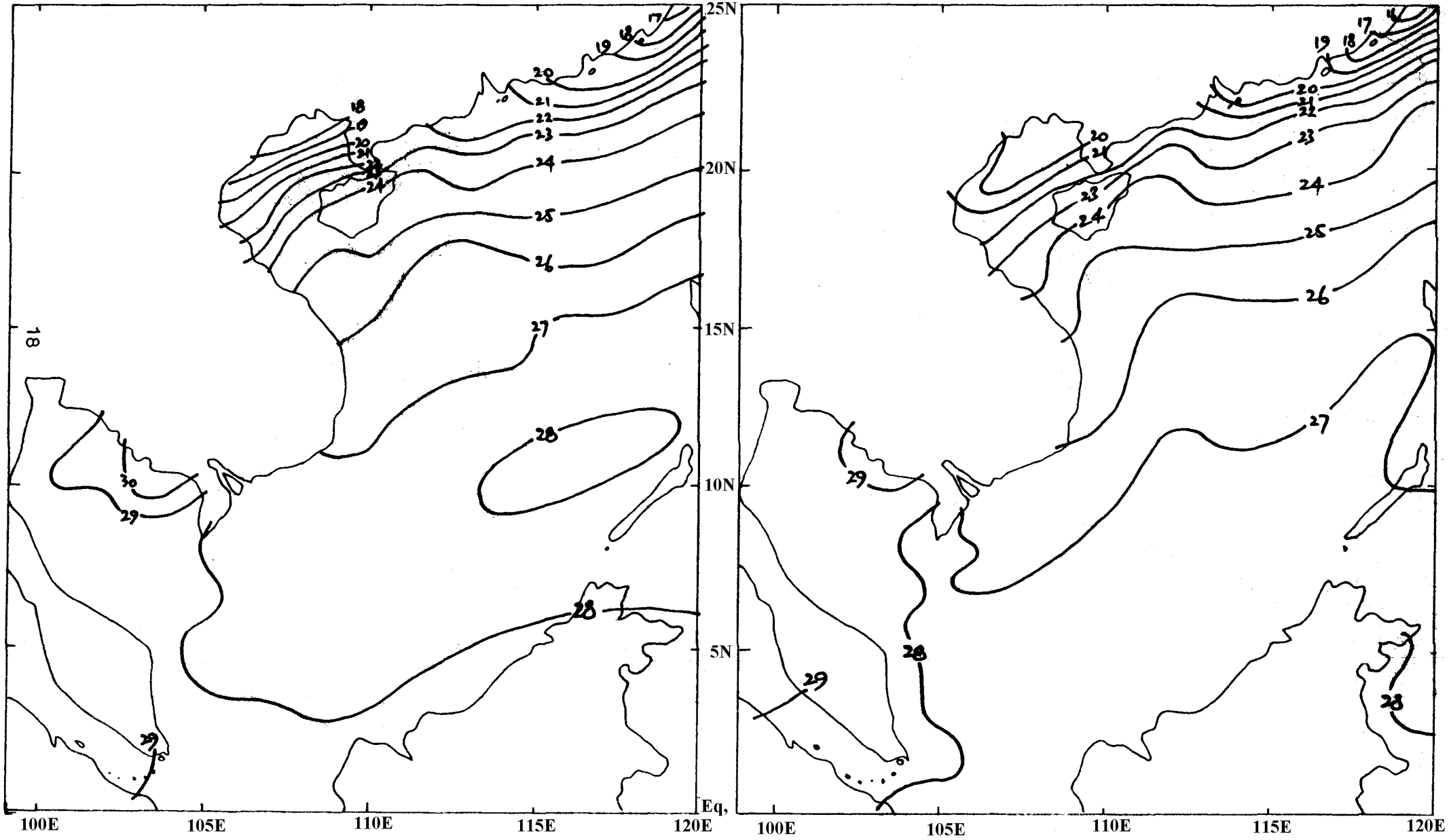


Figure 6(a). Ten-year mean sea surface temperatures in the South China Sea for the first ten-day period of April.

Figure 6(b). Ten-year mean sea surface temperatures in the South China Sea for the second ten-day period of April.

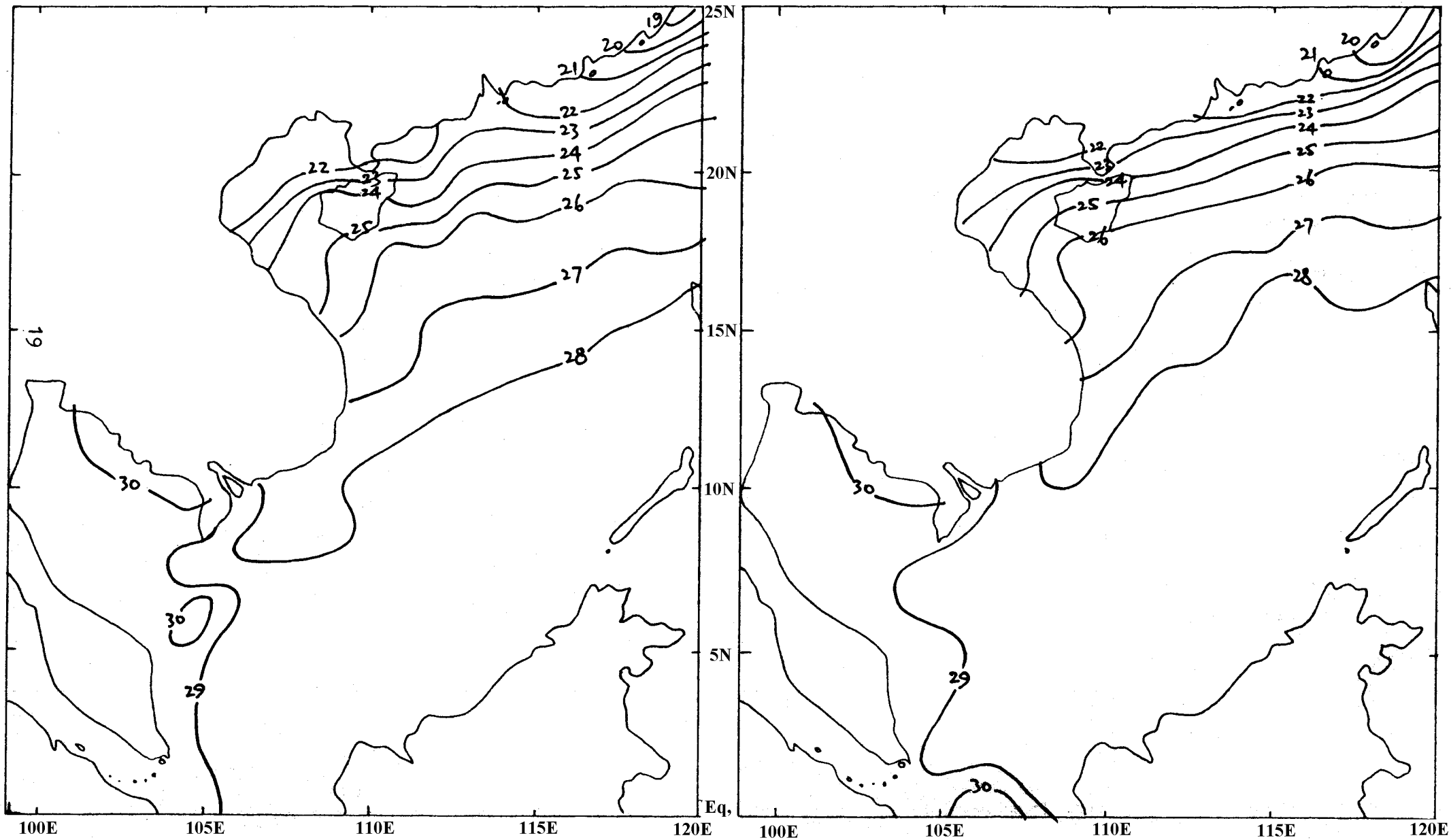


Figure 6(c). Ten-year mean sea surface temperatures in the South China Sea for the third ten-day period of April.

Figure 6(d). Ten-year monthly mean sea surface temperatures in the South China Sea for April.

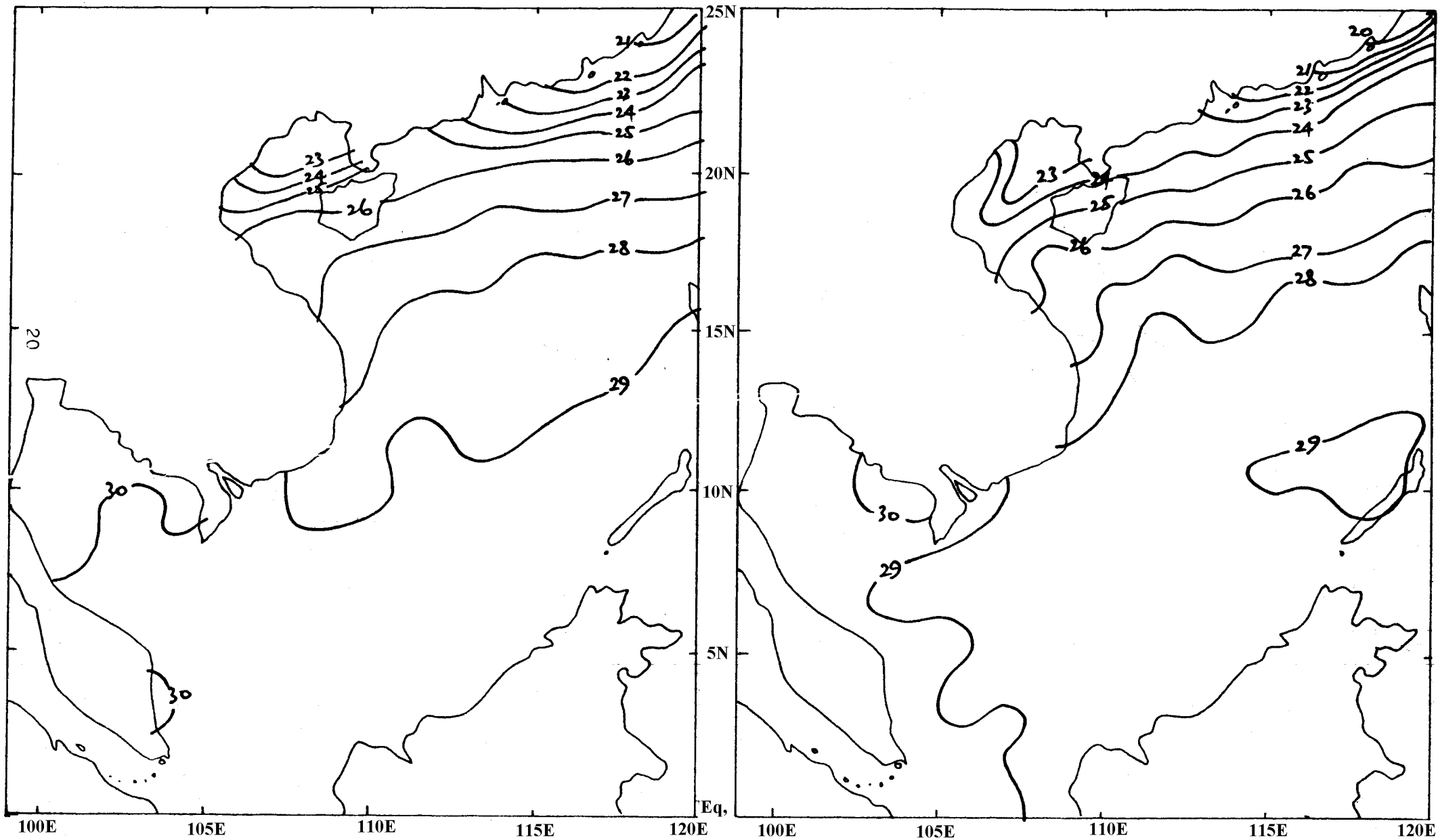


Figure 7(a). Ten-year mean sea surface temperatures in the South China Sea for the first ten-day period of May.

Figure 7(b). Ten-year mean sea surface temperatures in the South China Sea for the second ten-day period of May.

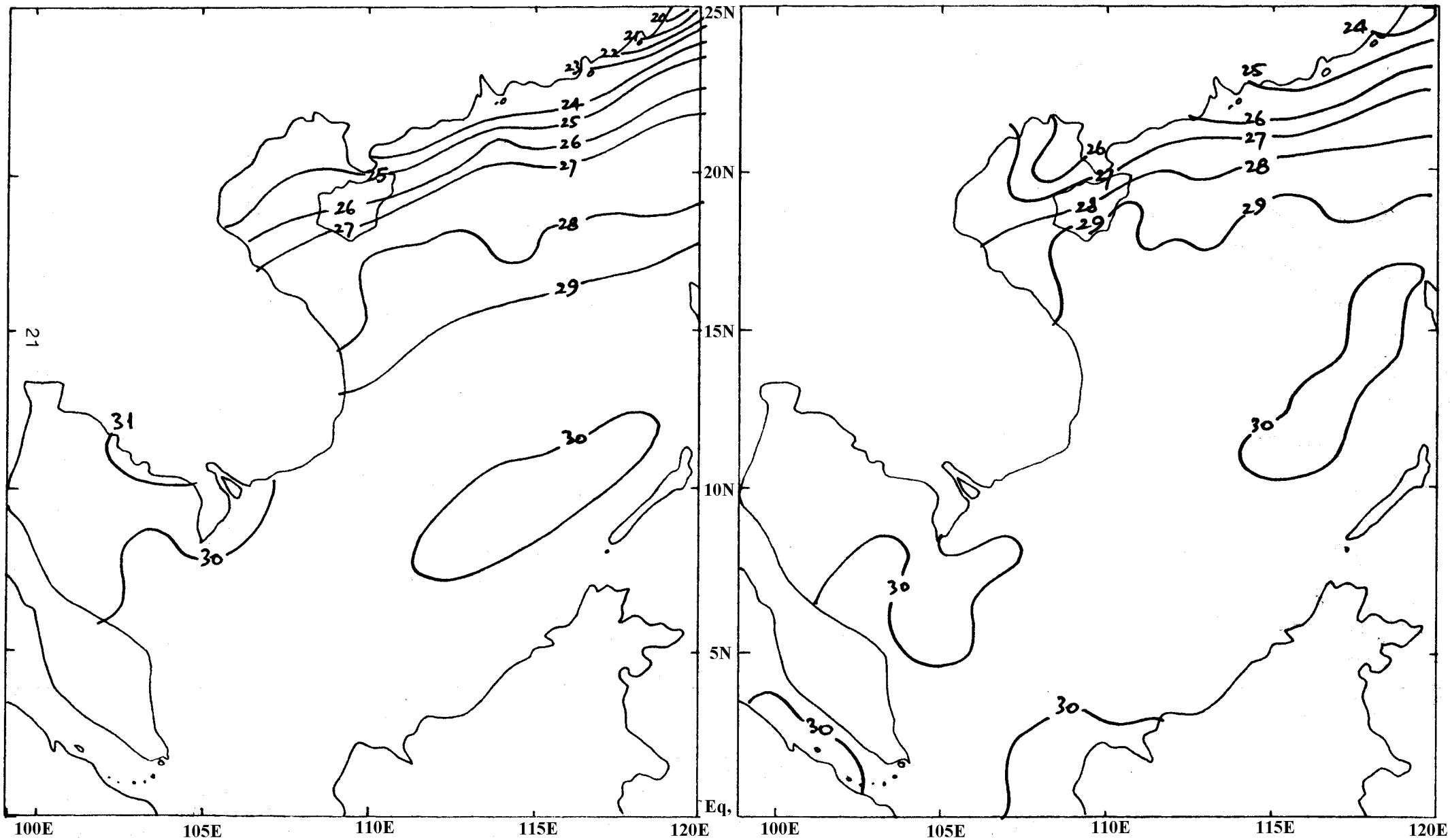


Figure 7(c). Ten-year mean sea surface temperatures in the South China Sea for the third ten-day period of May.

Figure 7(d). Ten-year monthly mean sea surface temperatures in the South China Sea for May.

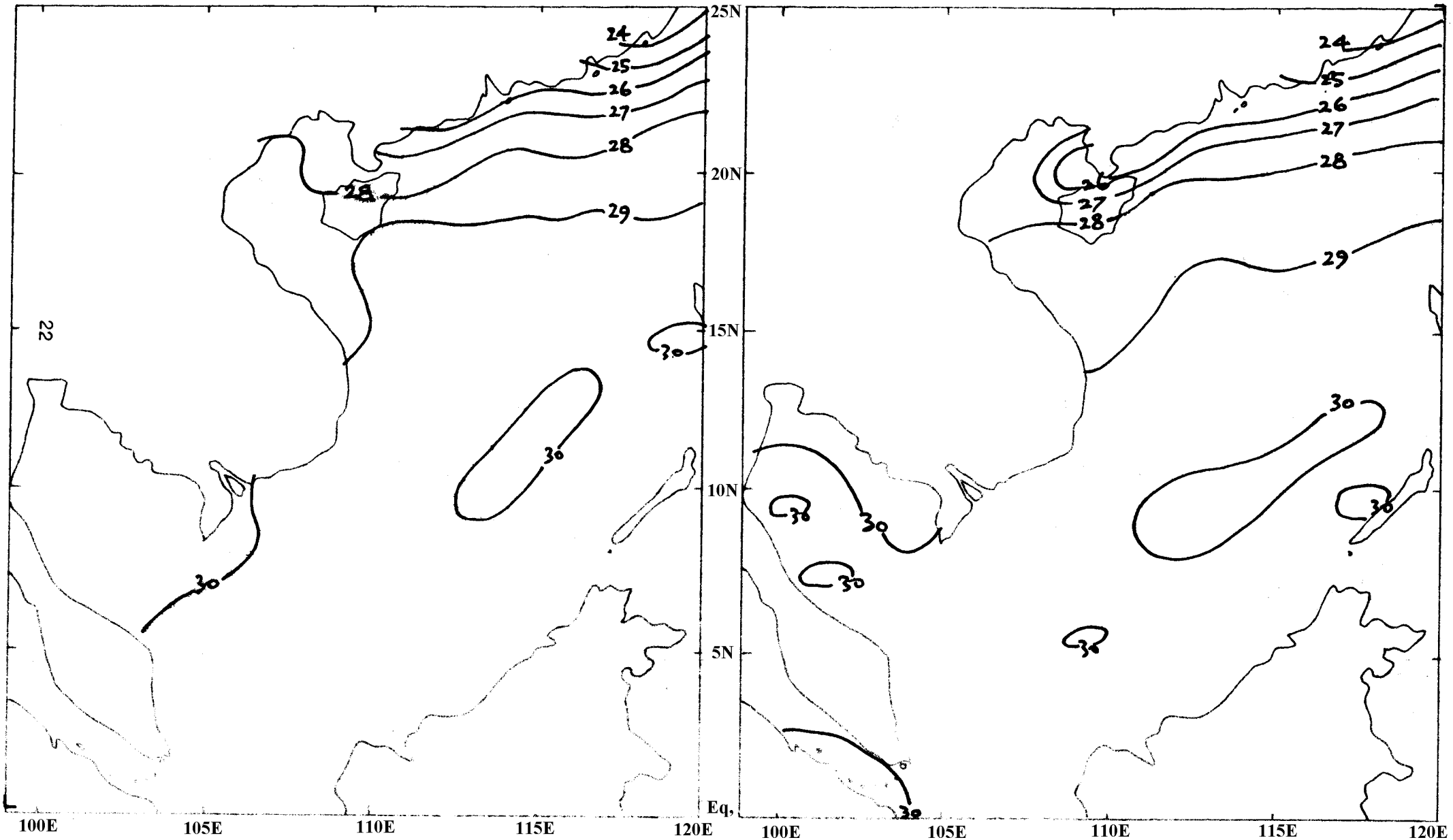


Figure 8(a). Ten-year mean sea surface temperatures in the South China Sea for the first ten-day period of June.

Figure 8(b). Ten-year mean sea surface temperatures in the South China Sea for the second ten-day period of June.

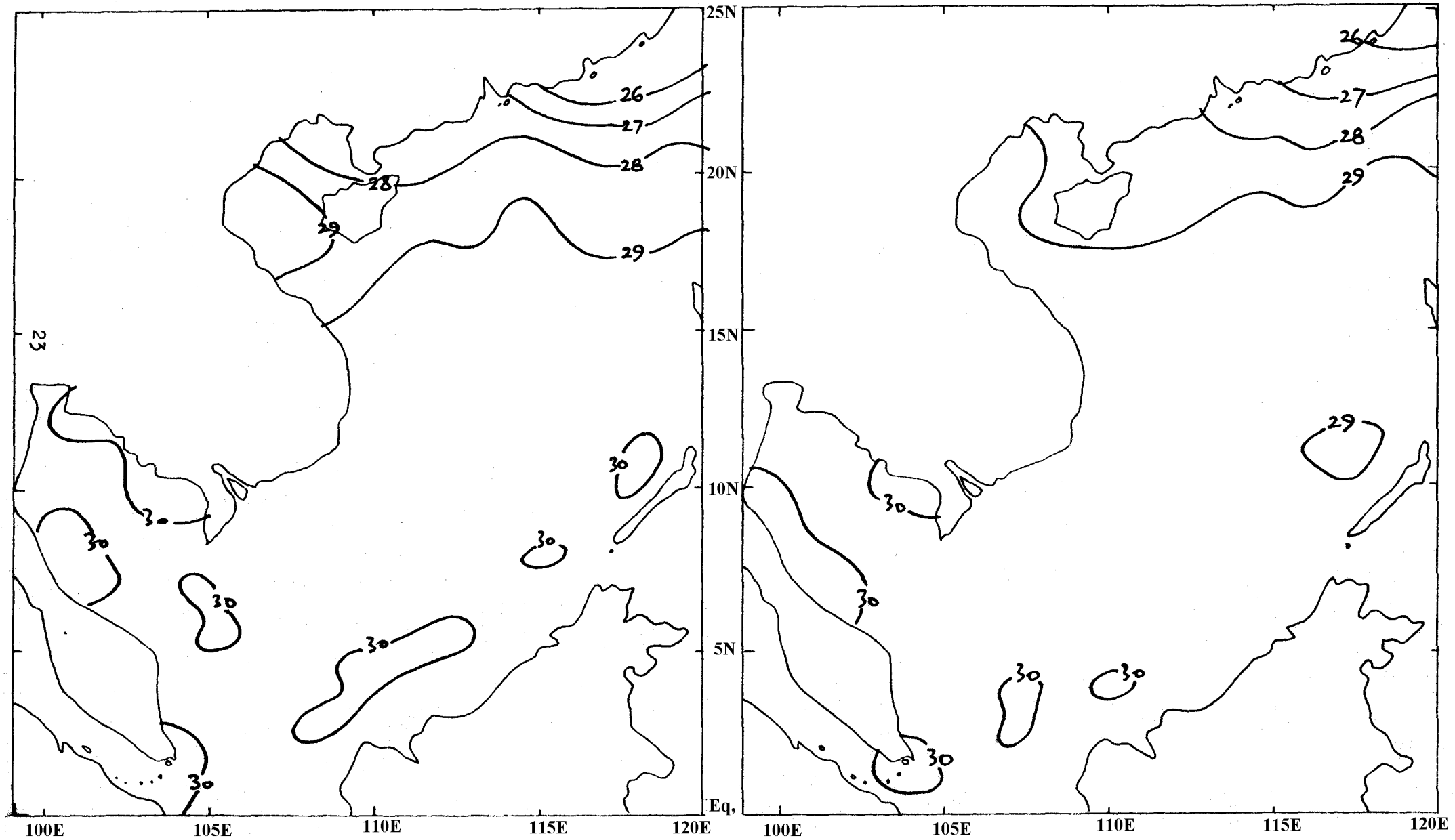


Figure 8(c). Ten-year mean sea surface temperatures in the South China Sea for the third ten-day period of June.

Figure 8(d). Ten-year monthly mean sea surface temperatures in the South China Sea for June.

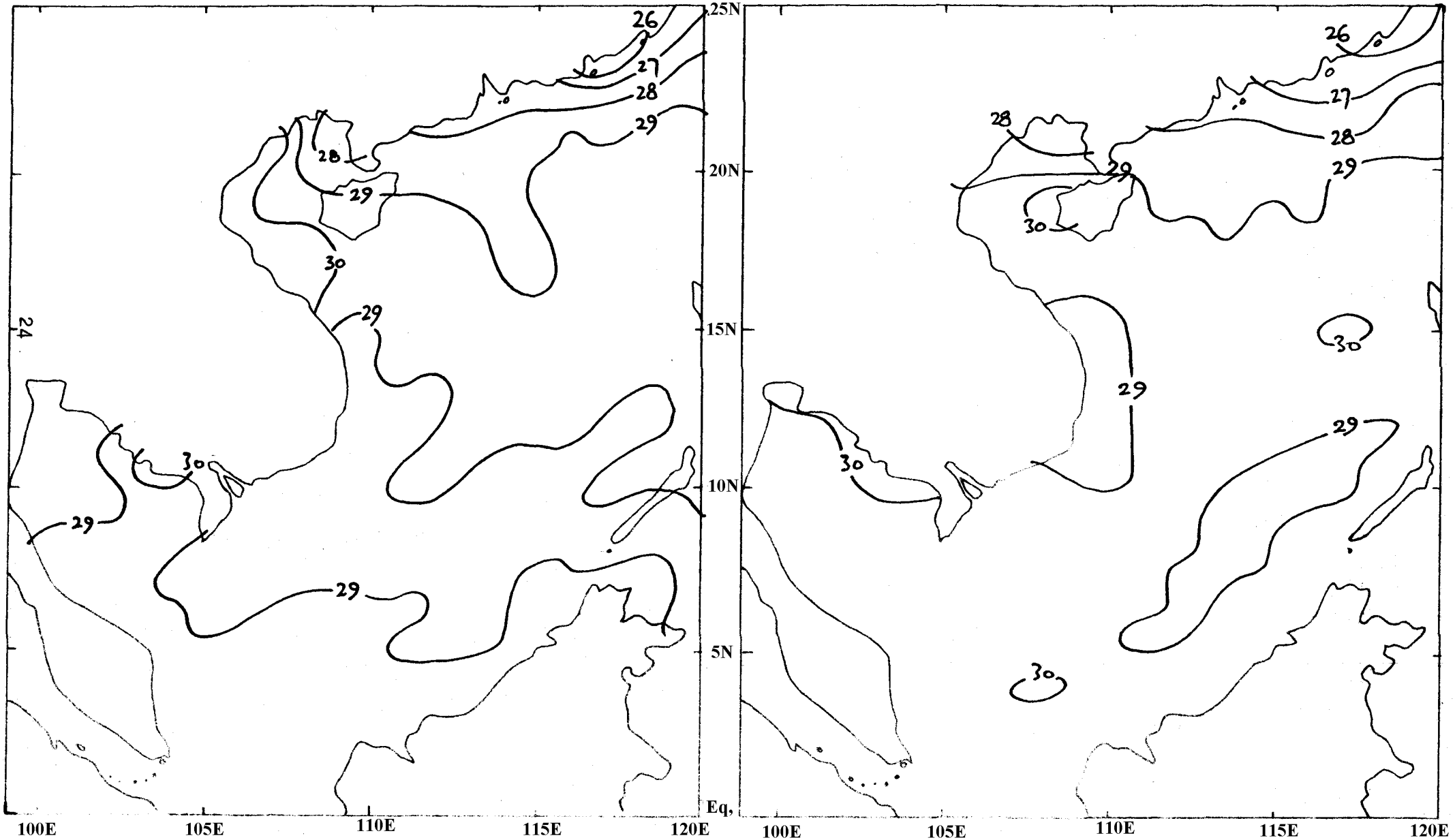


Figure 9(a). Ten-year mean sea surface temperatures in the South China Sea for the first ten-day period of July.

Figure 9(b). Ten-year mean sea surface temperatures in the South China Sea for the second ten-day period of July.

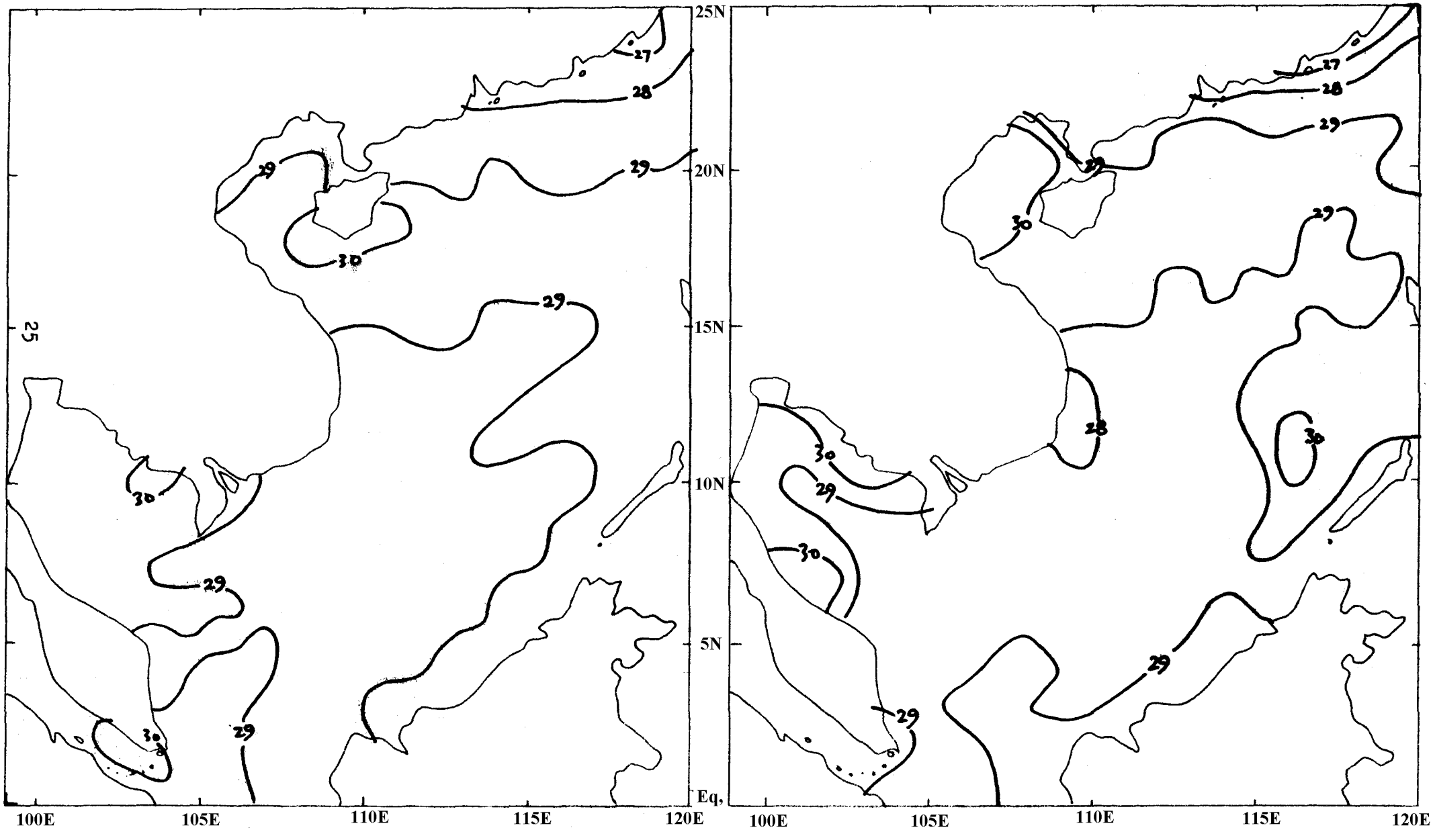


Figure 9(c). Ten-year mean sea surface temperatures in the South China Sea for the third ten-day period for July.

Figure 9(d). Ten-year monthly mean sea surface temperatures in the South China Sea for July.

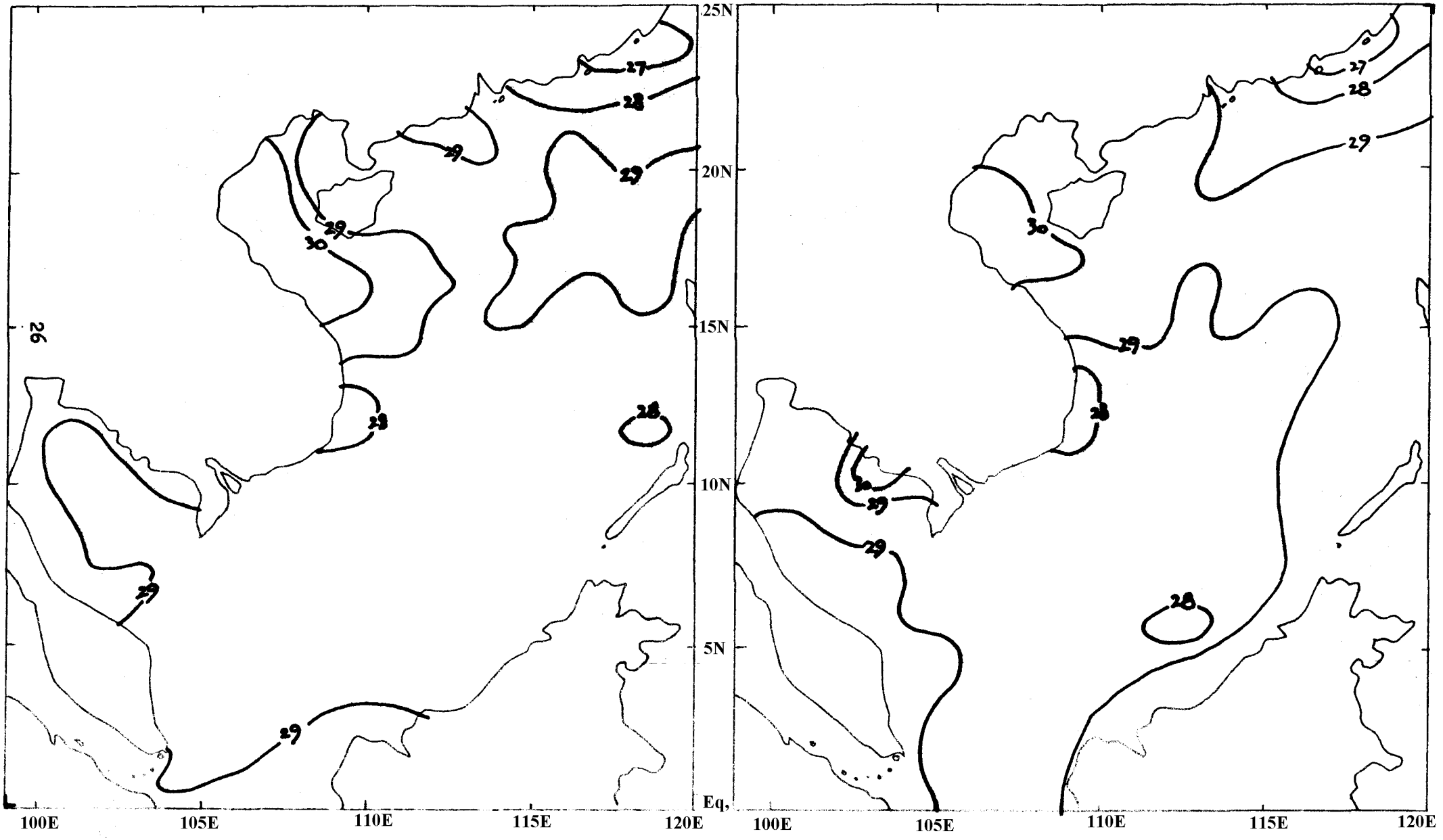


Figure 10(a). Ten-year mean sea surface temperatures in the South China Sea for the first ten-day period of August.

Figure 10(b). Ten-year mean sea surface temperatures in the South China Sea for the second ten-day period of August.

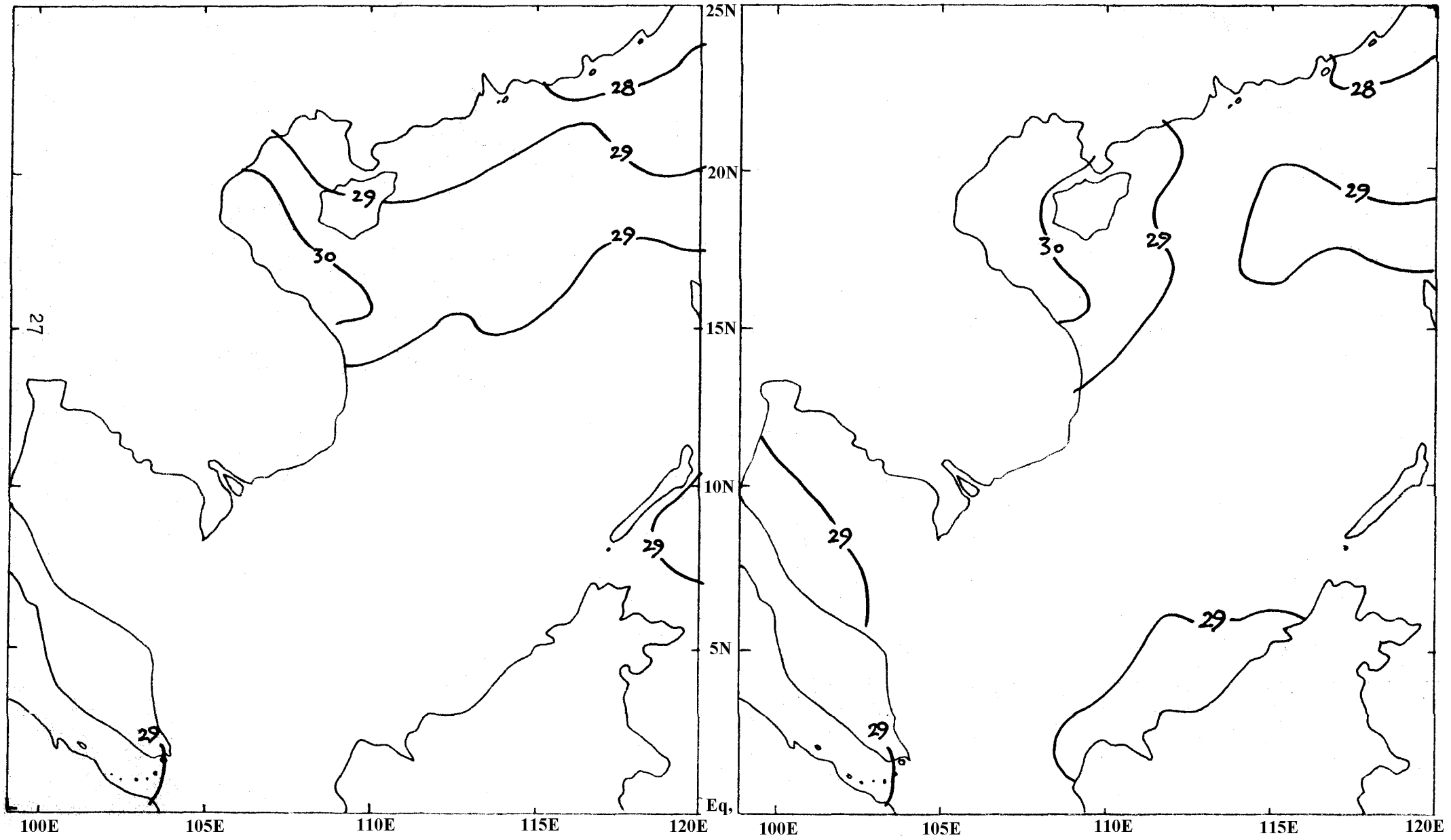


Figure 10(c). Ten-year mean sea surface temperatures in the South China Sea for the third ten-day period of August.

Figure 10(d). Ten-year monthly mean sea surface temperatures in the South China Sea for August.

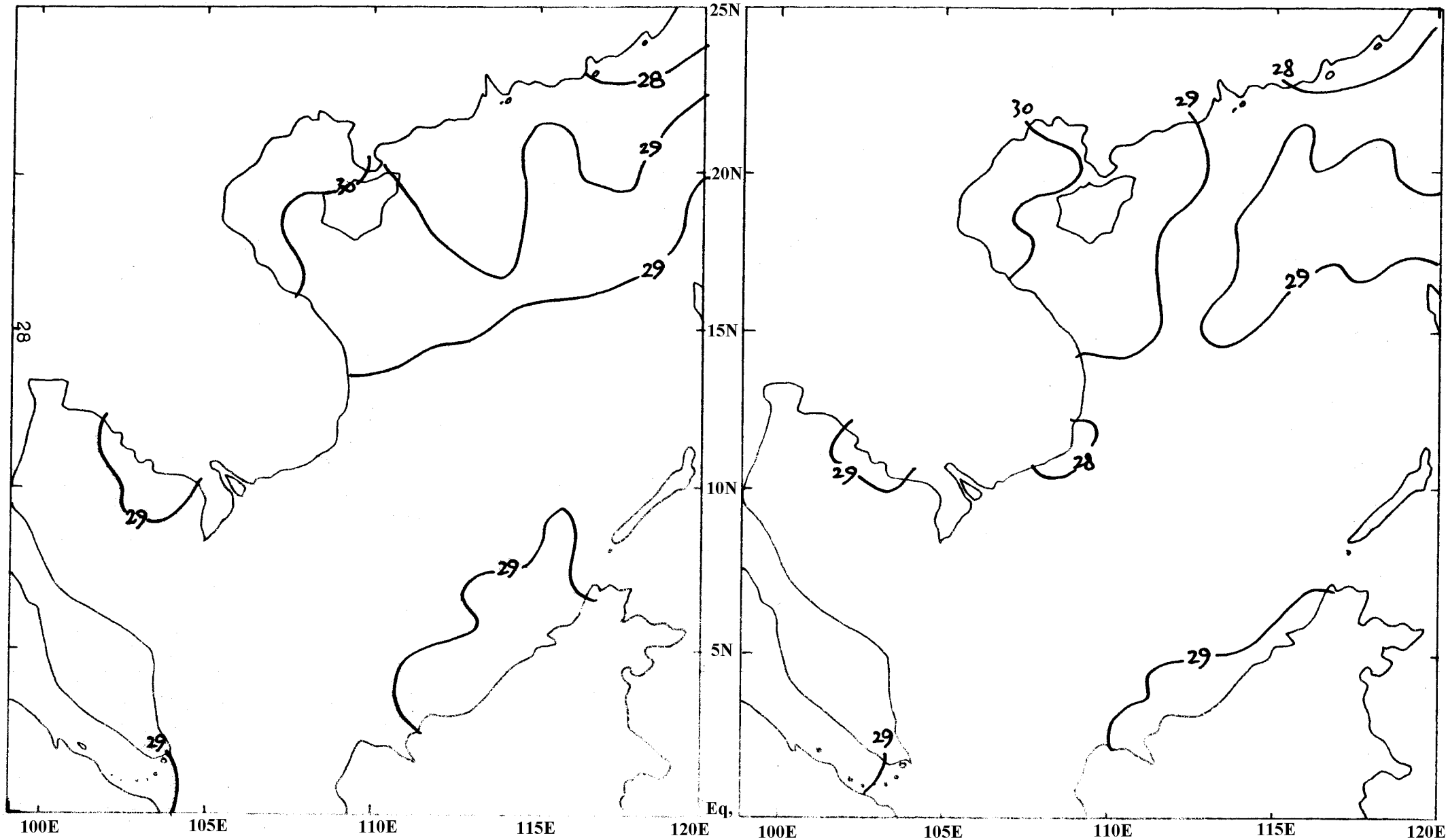


Figure 11(a). Ten-year mean sea surface temperatures in the South China Sea for the first ten-day period of September.

Figure 11(b). Ten-year mean sea surface temperatures in the South China Sea for the second ten-day period of September.

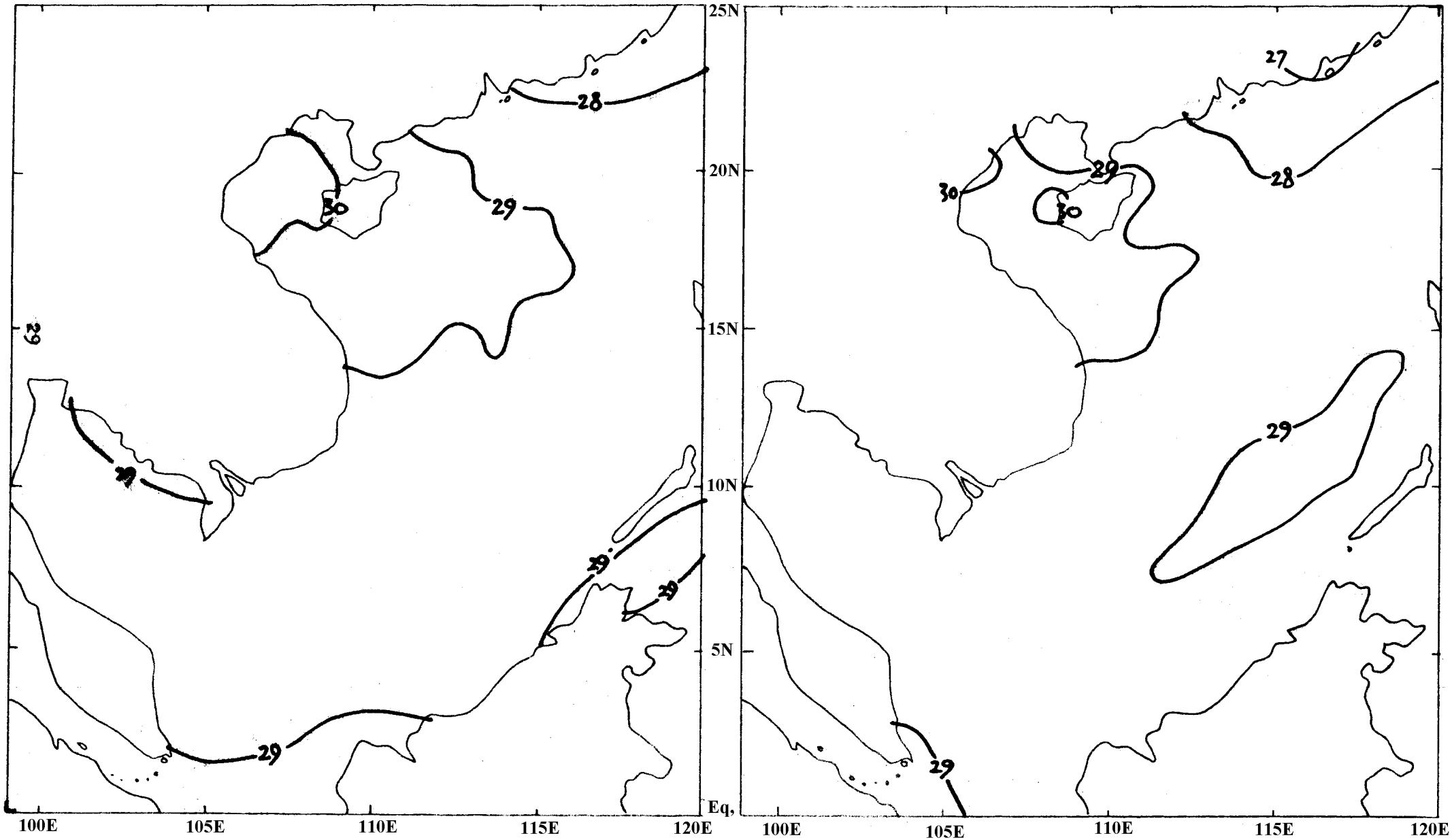


Figure 11(c). Ten-year mean sea surface temperatures in the South China Sea for the third ten-day period of September.

Figure 11(d). Ten-year monthly mean sea surface temperatures in the South China Sea for September.

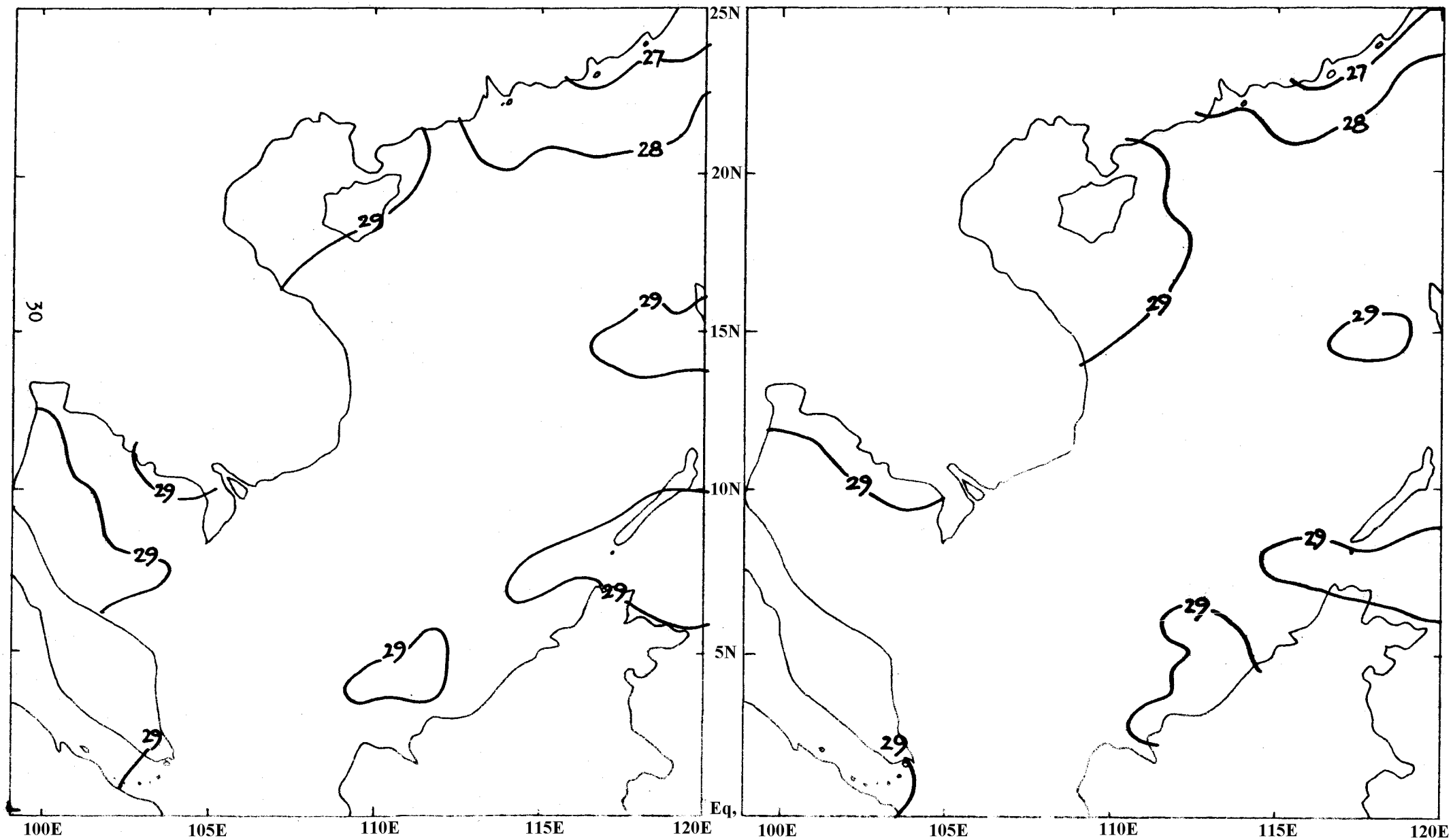


Figure 12(a). Ten-year mean sea surface temperatures in the South China Sea for the first ten-day period of October.

Figure 12(b). Ten-year mean sea surface temperatures in the South China Sea for the second ten-day period of October.

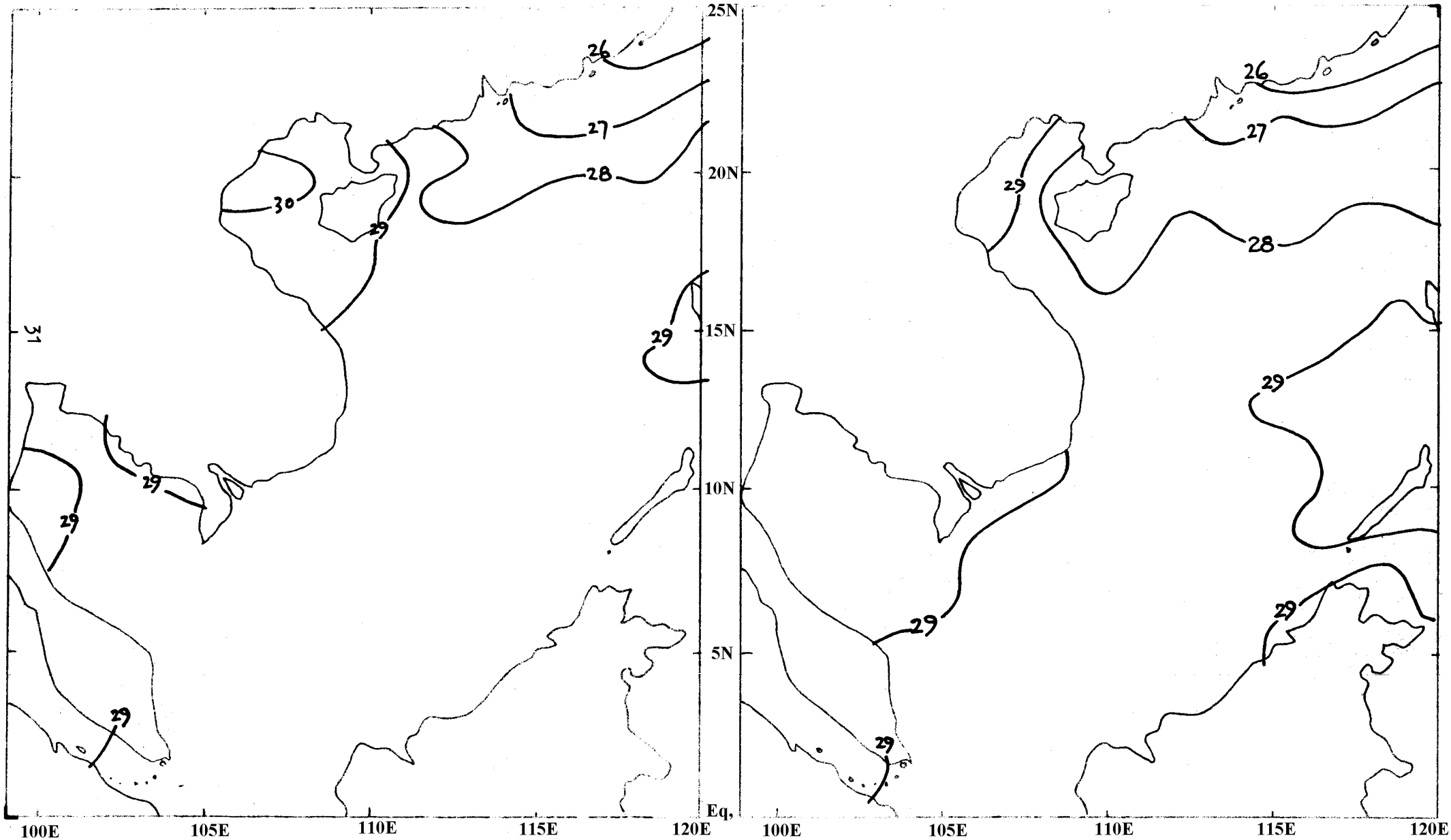


Figure 12(c). Ten-year mean sea surface temperatures in the South China Sea for the third ten-day period of October.

Figure 12(d). Ten-year monthly mean sea surface temperatures in the South China Sea for October.

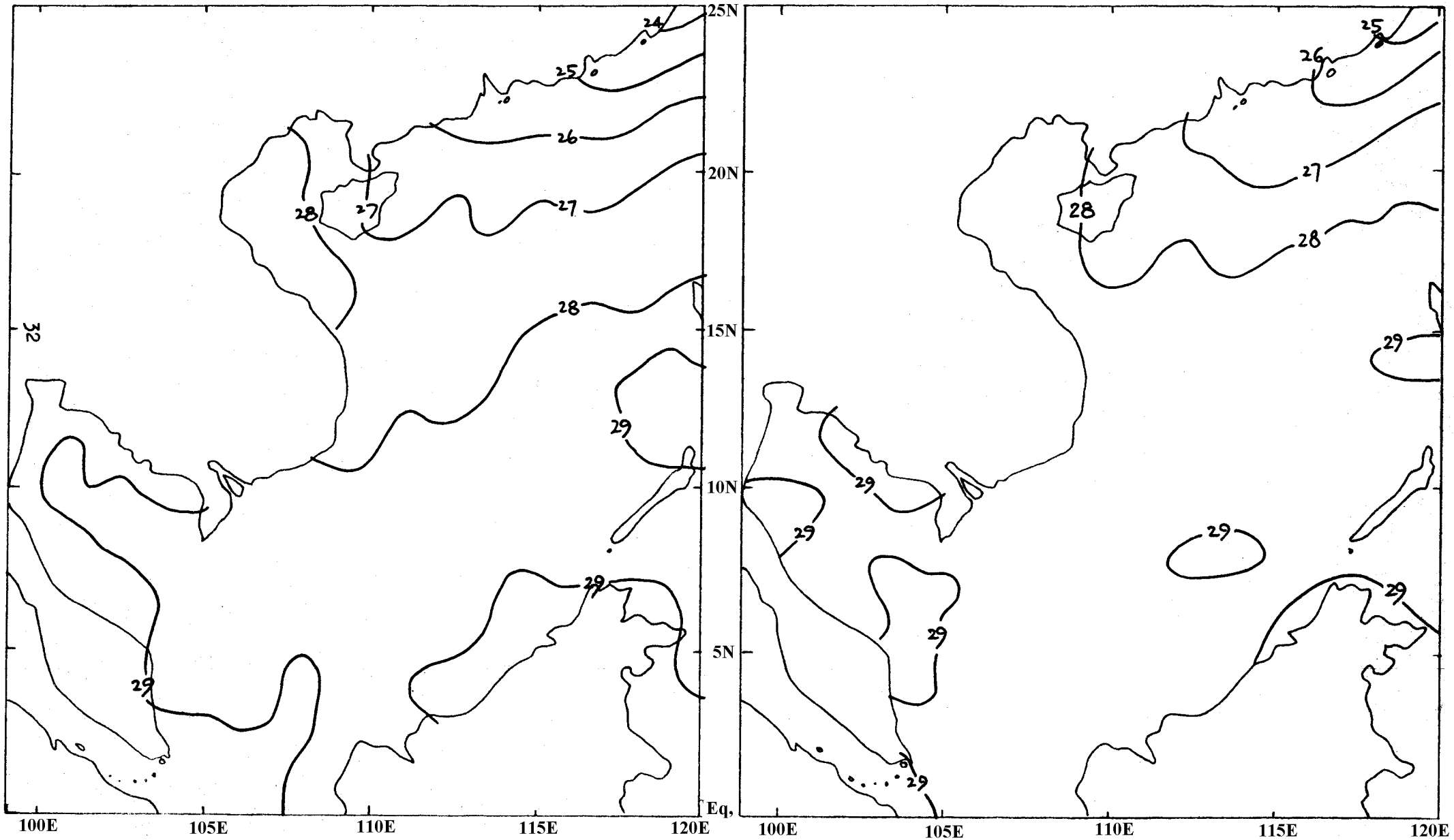


Figure 13(a). Ten-year mean sea surface temperatures in the South China Sea for the first ten-day period of November.

Figure 13(b). Ten-year mean sea surface temperatures in the South China Sea for the second ten-day period of November.

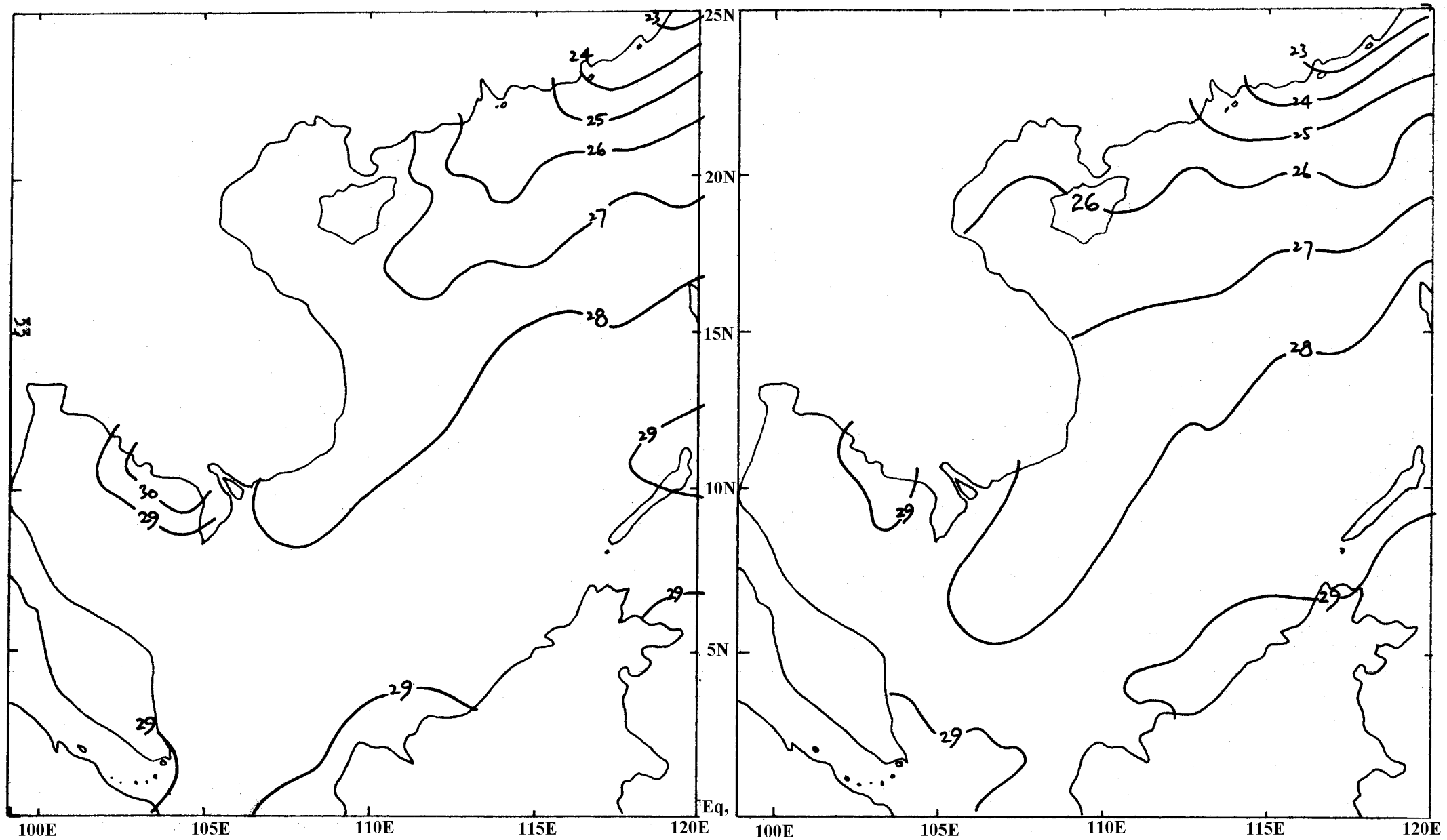


Figure 13(c). Ten-year mean sea surface temperatures in the South China Sea for the third ten-day period of November.

Figure 13(d). Ten-year monthly mean sea surface temperatures in the South China Sea for November.

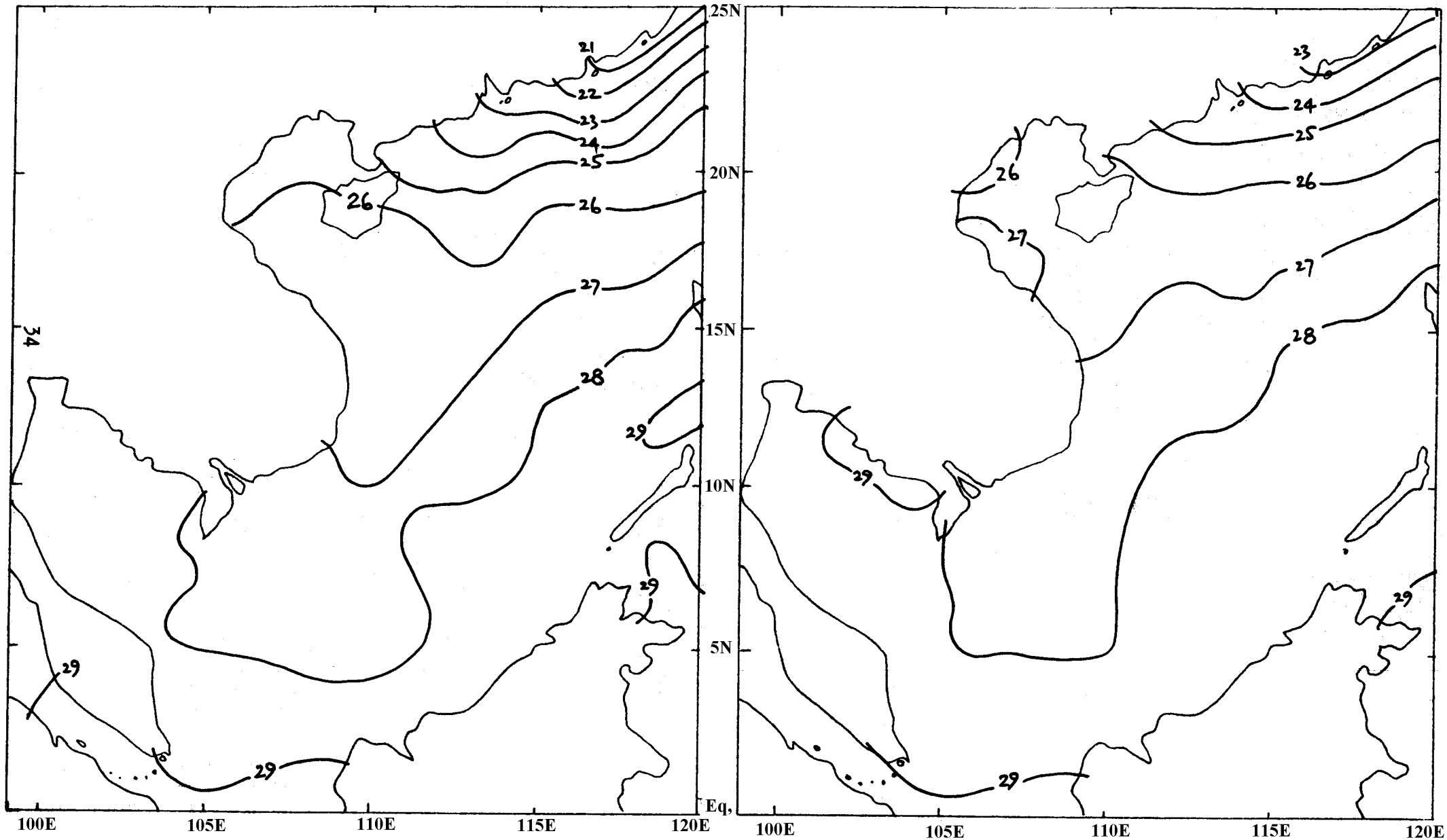


Figure 14(a). Ten-year mean sea surface temperatures in the South China Sea for the first ten-day period of December.

Figure 14(b). Ten-year mean sea surface temperatures in the South China Sea for the second ten-day period of December.

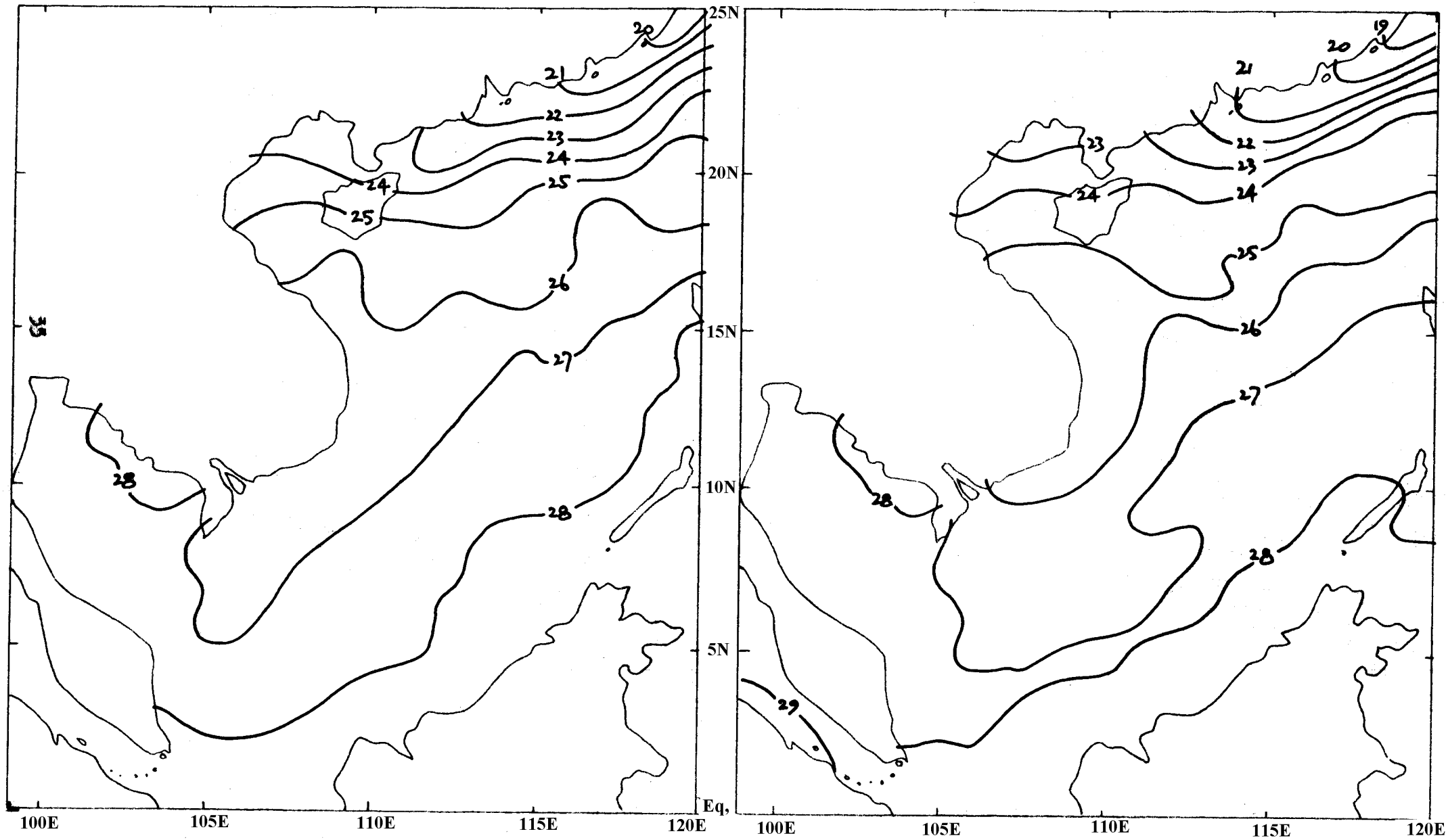


Figure 14(c). Ten-year mean sea surface temperatures in the South China Sea for the third ten-day period of December.

Figure 14(d). Ten-year monthly mean sea surface temperatures in the South China Sea for December.

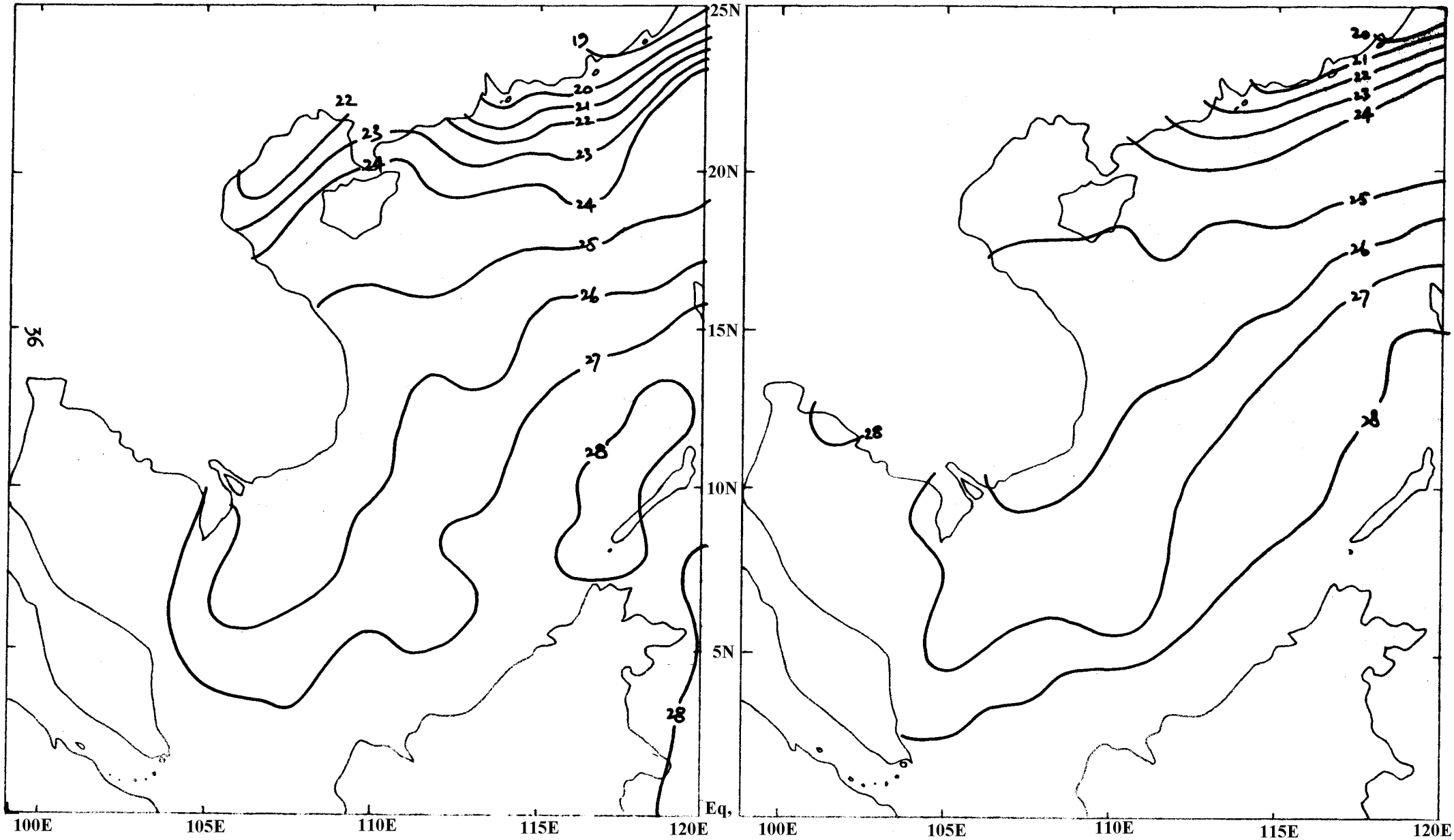


Figure 15. Ten-year seasonal mean sea surface temperatures in the South China Sea for March to May.

Figure 16. Ten-year seasonal mean sea surface temperatures in the South China Sea for June to August.

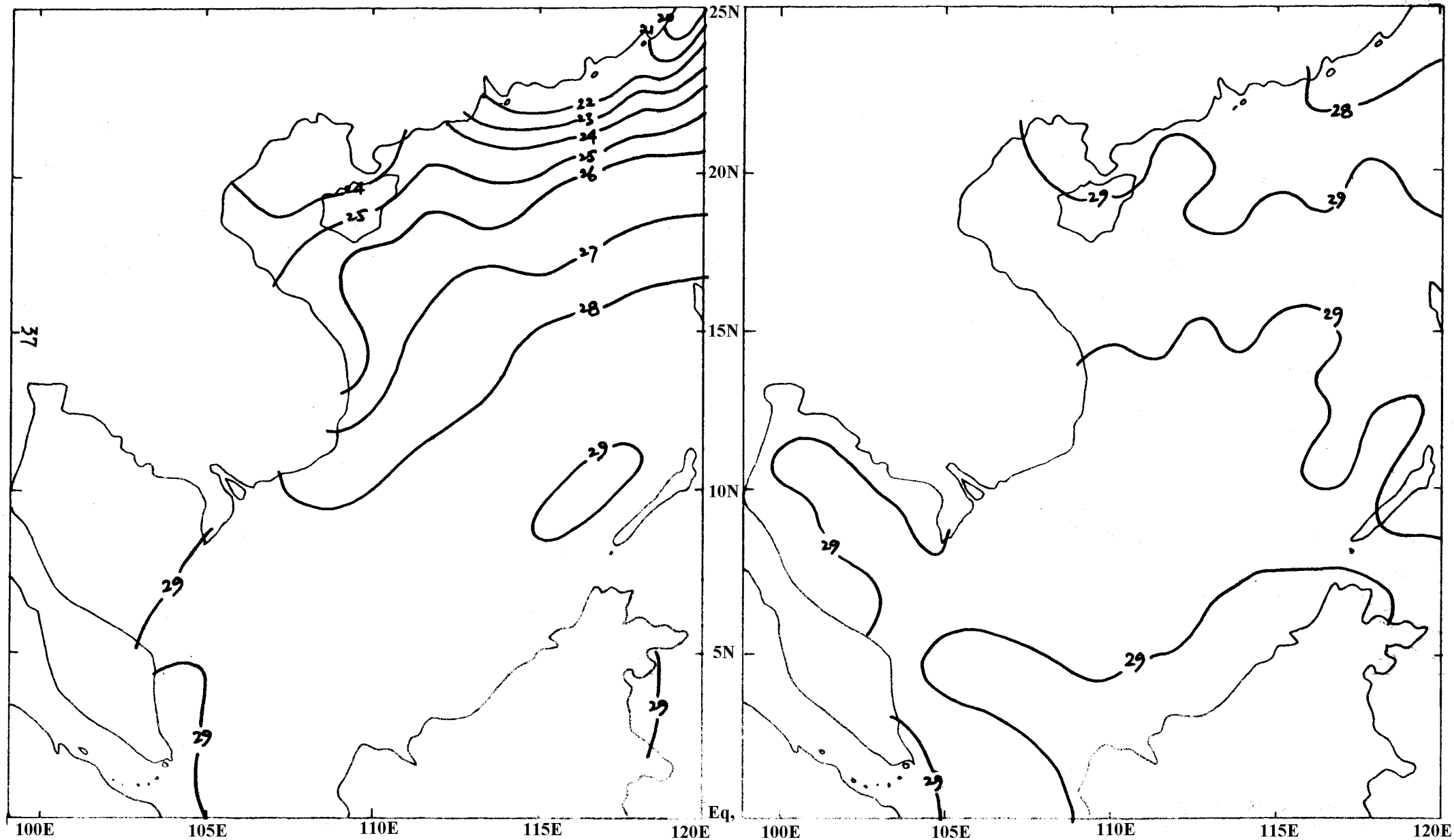


Figure 17. Ten-year seasonal mean sea surface temperatures in the South China Sea for September to November.

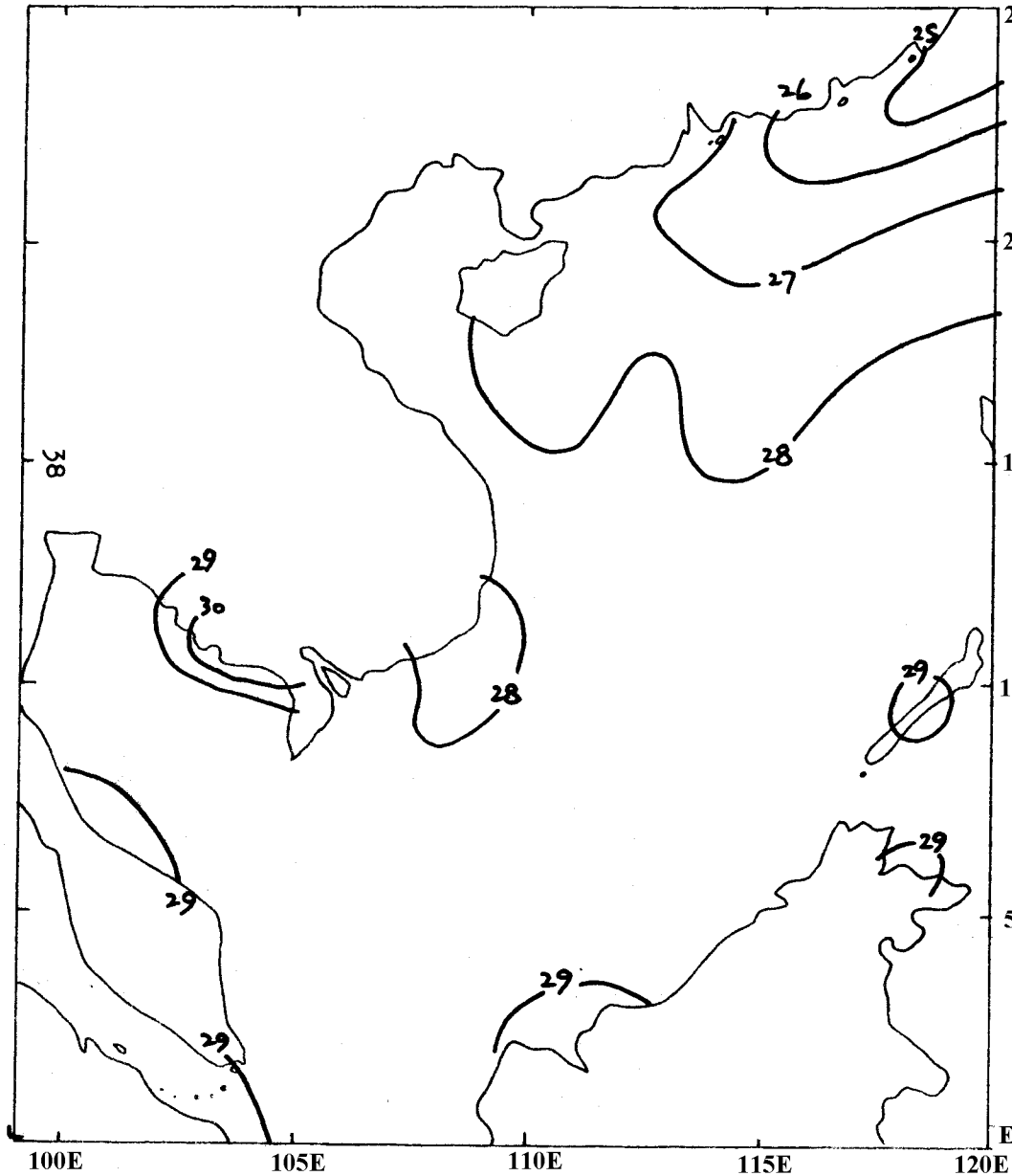


Figure 18. Ten-year seasonal mean sea surface temperatures in the South China Sea for December to February.

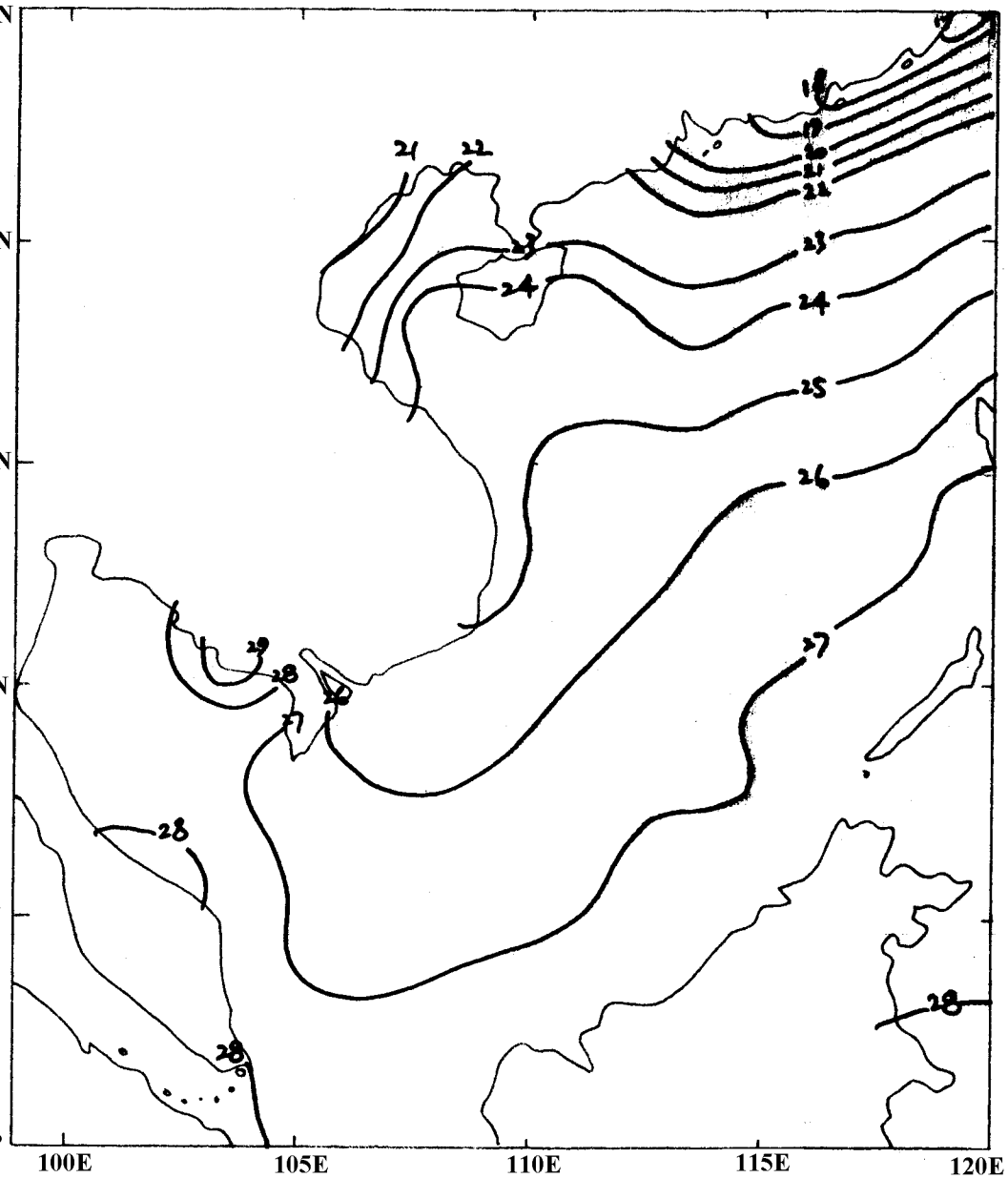


Figure 19. Ten-year annual mean **sea surface temperatures** in the South China Sea.

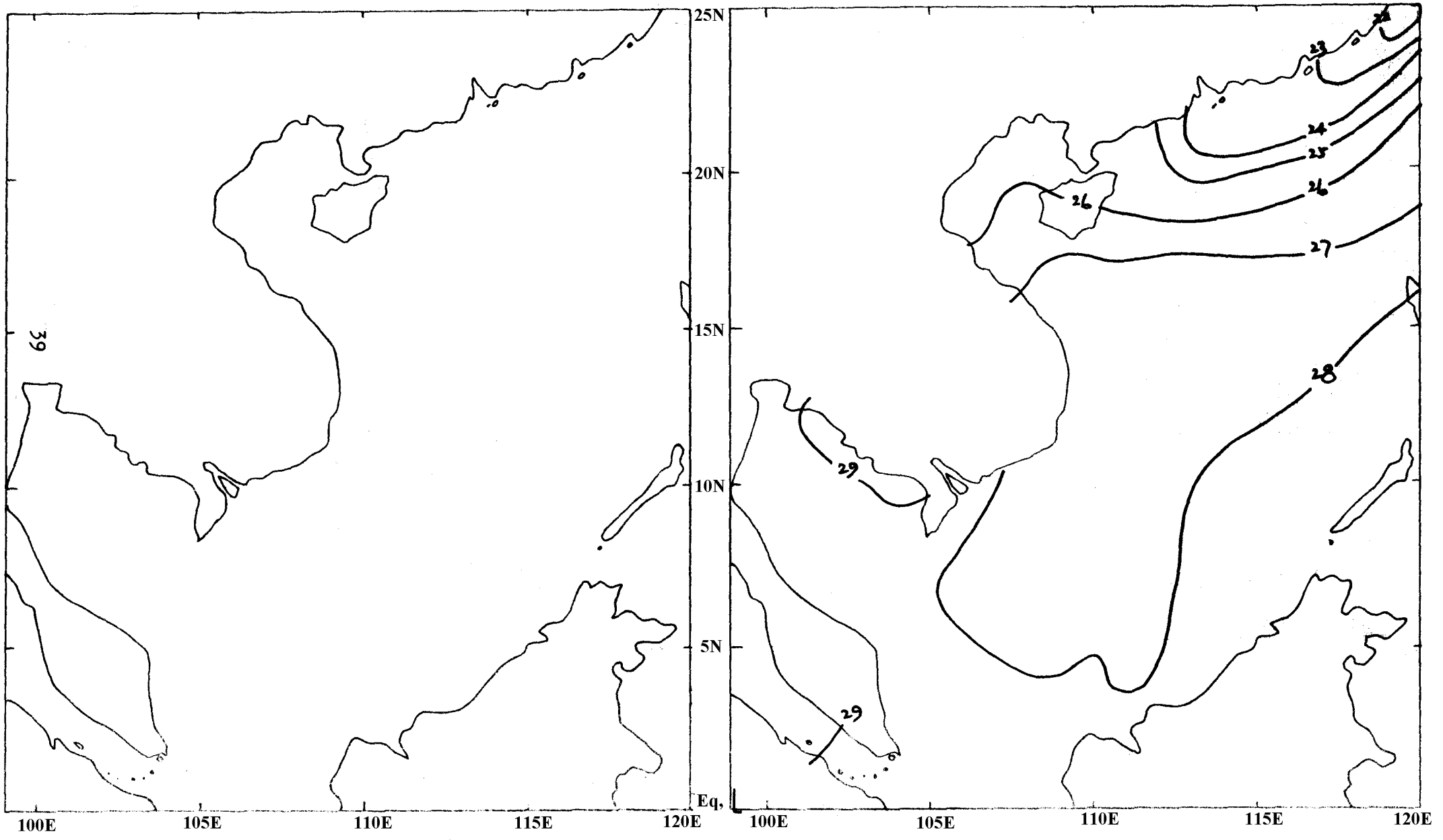


Figure 20. Mean monthly positions of the 28°C isotherms.

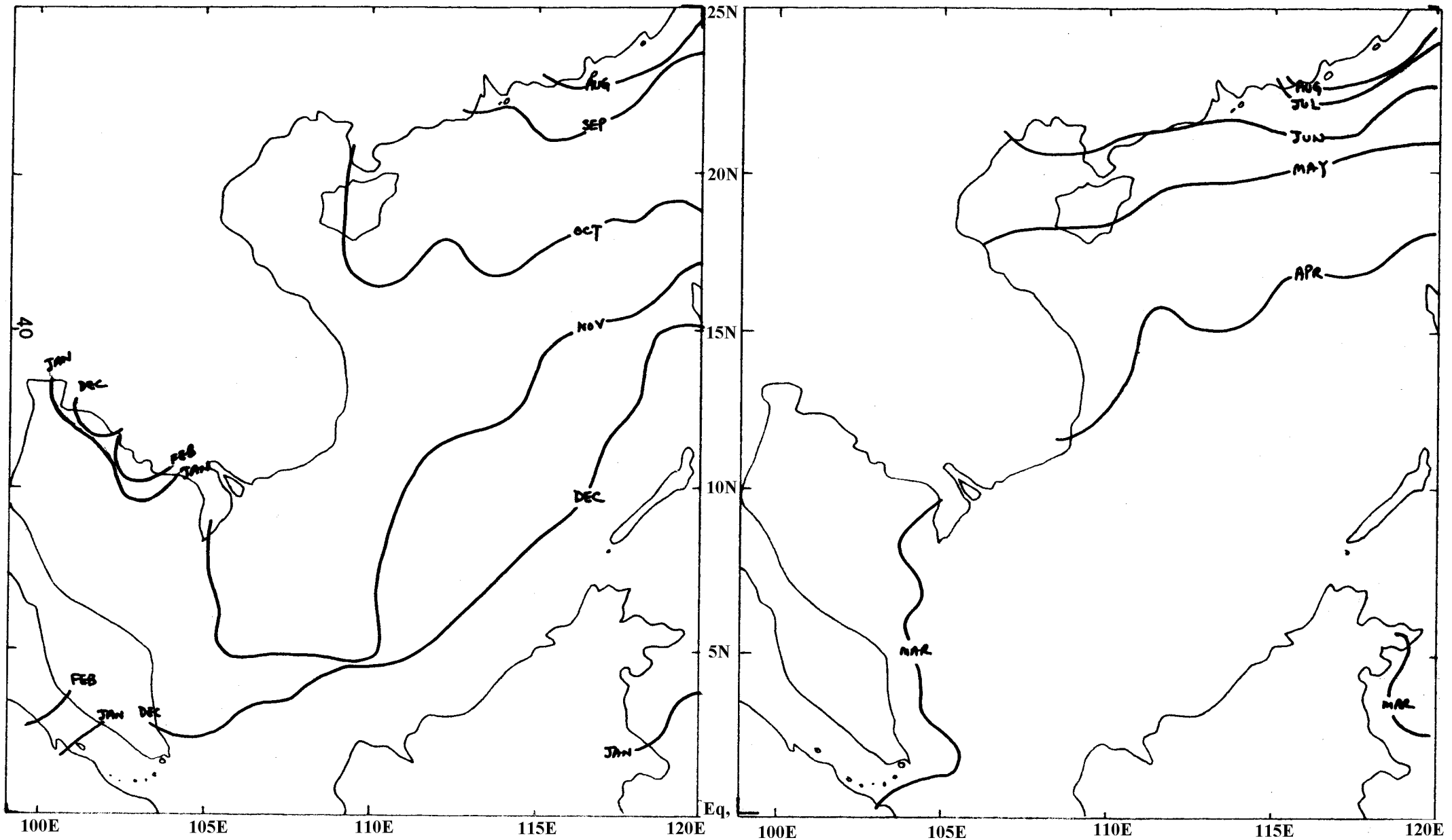


Figure 21. Mean monthly positions of the 26°C isotherms.

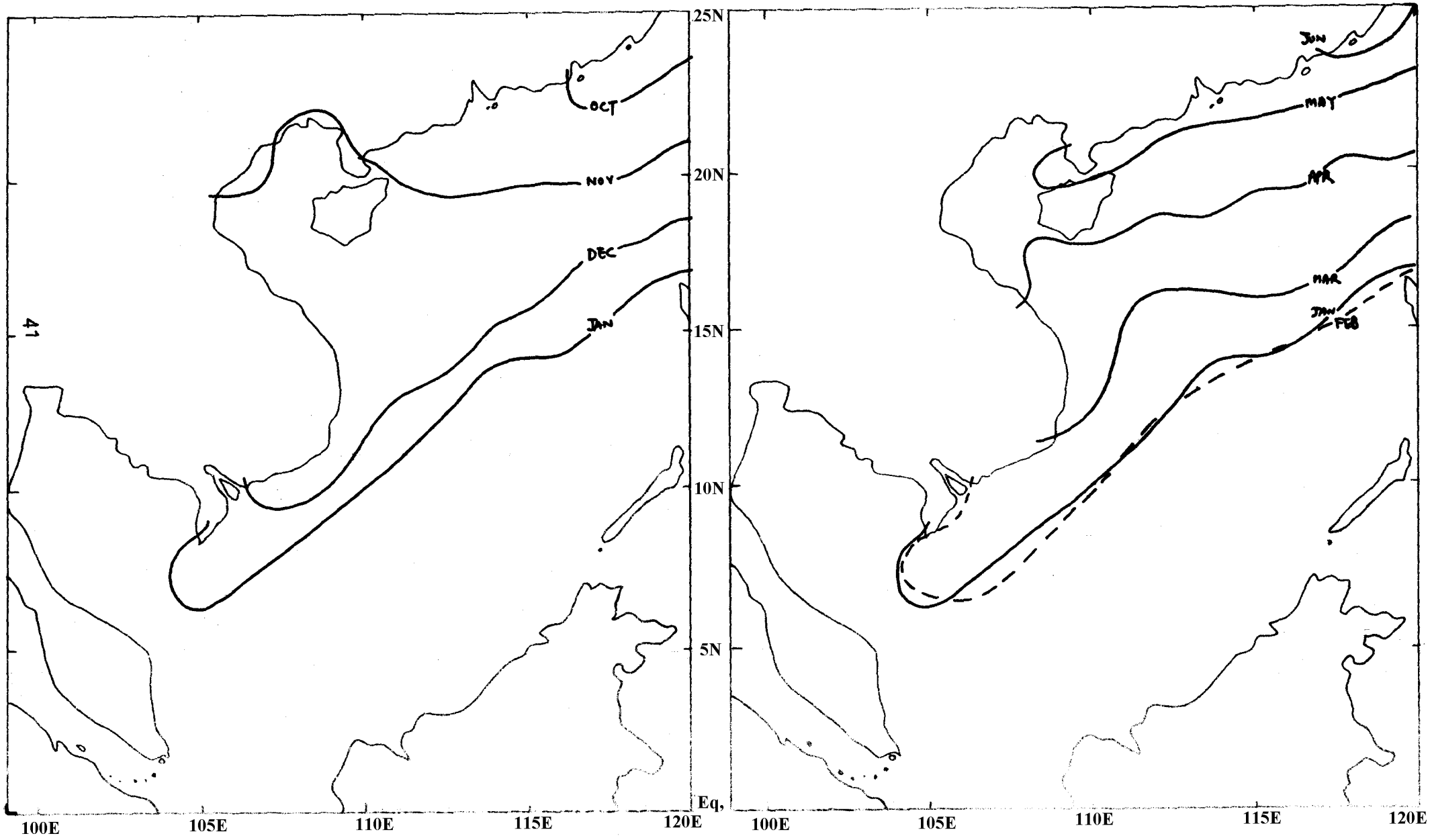


Figure 22. Mean monthly positions of the 24°C isotherms.

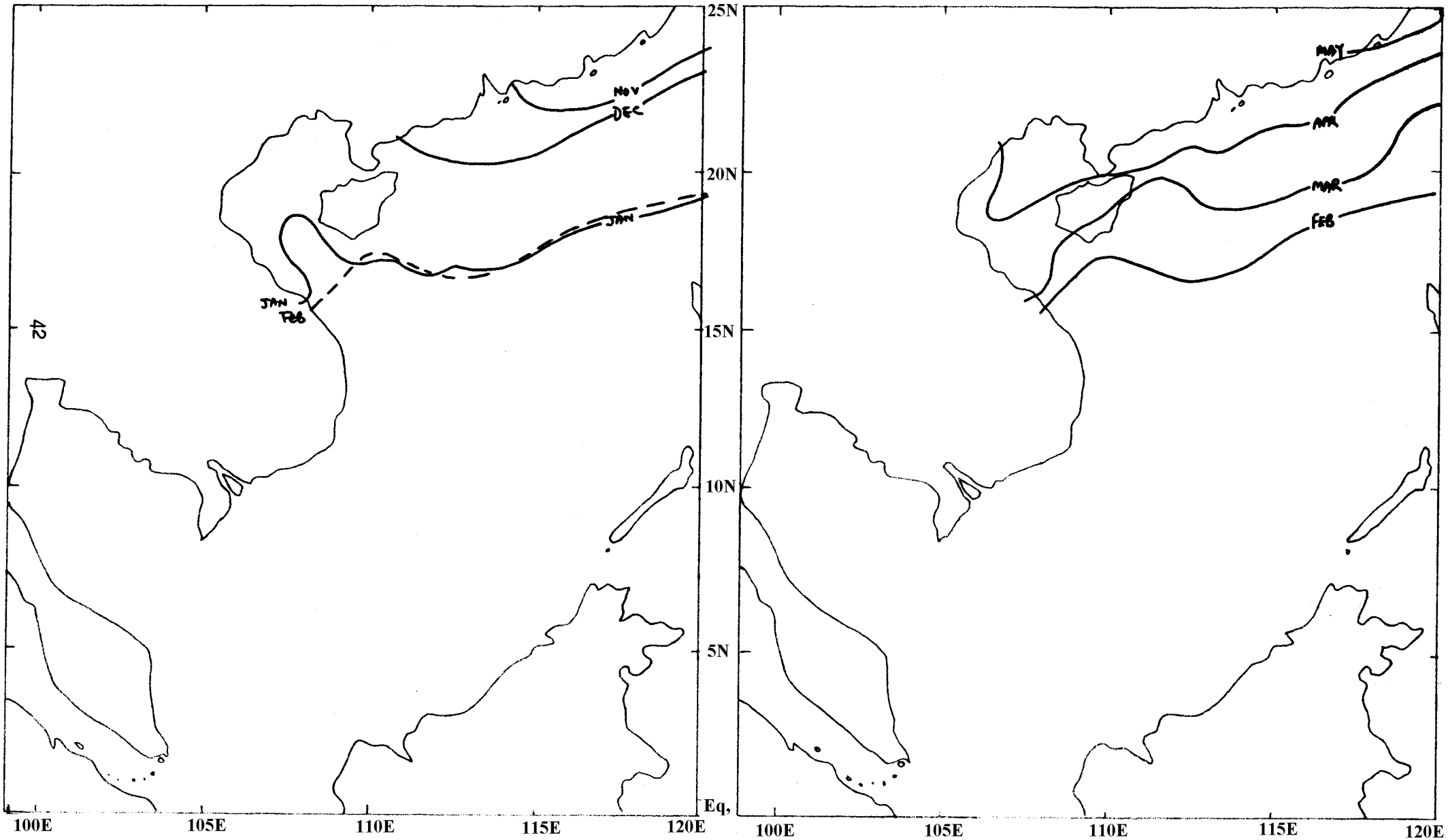


Figure 23. Mean monthly positions of the 20° isotherms.

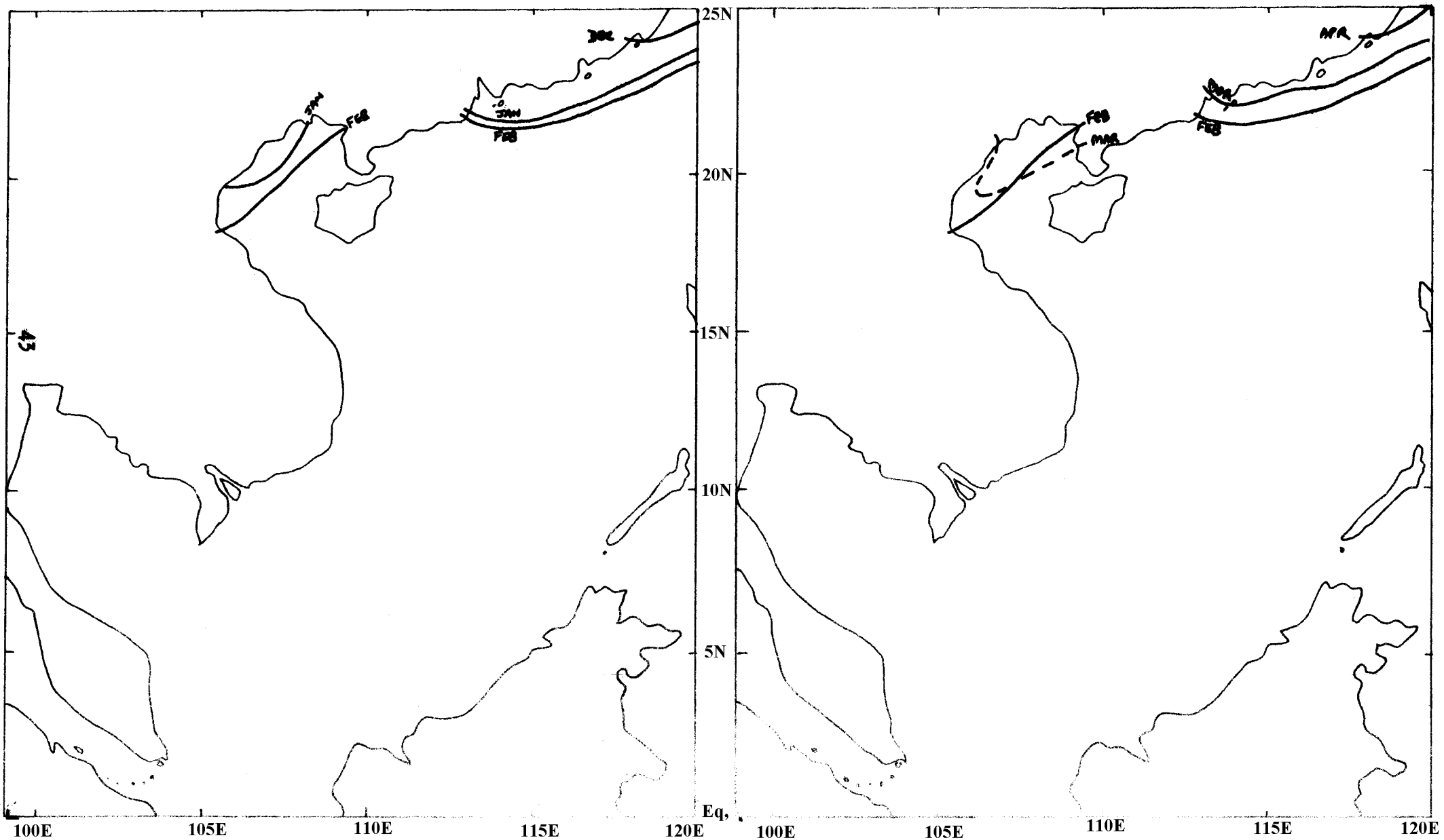


Figure 24. Mean monthly positions of the 16°C isotherms.

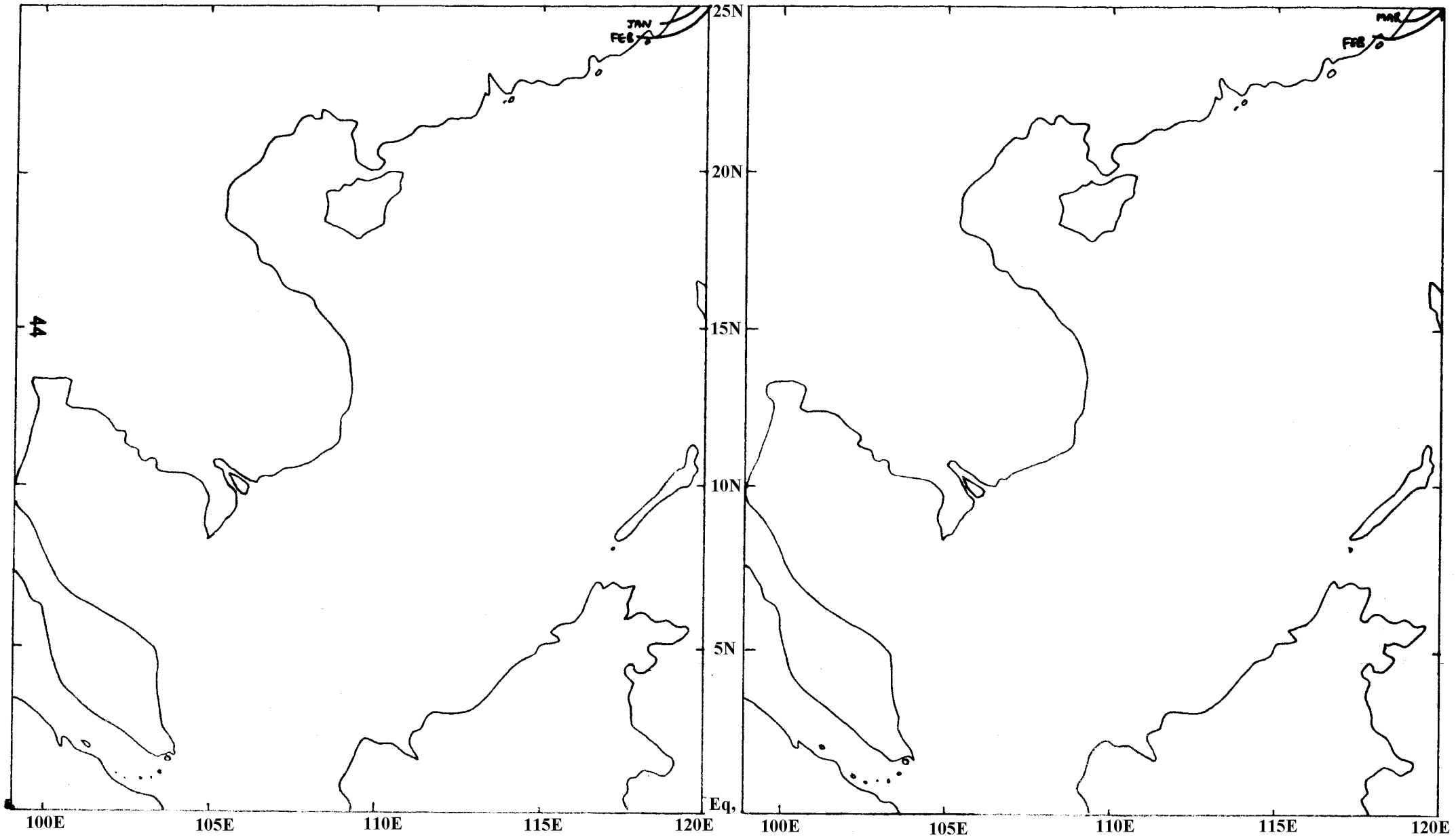


Figure 25. Mean month-to-monthvariation (February-January).

Figure 26. Mean month-to-month variation (March - February)

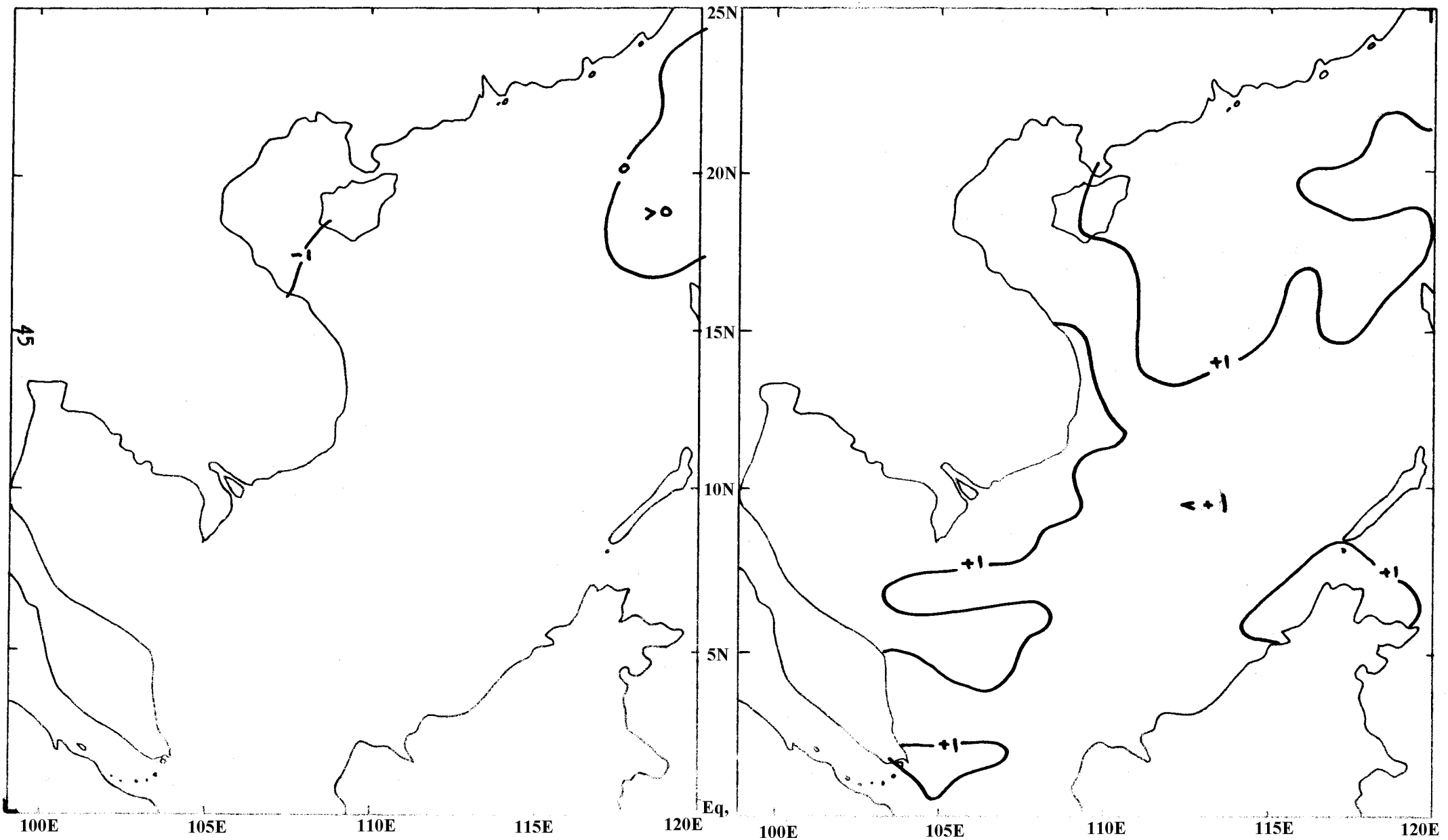


Figure 27. Mean month-to-month variation (April - March).

Figure 28. Mean month-to-month variation (May - April).

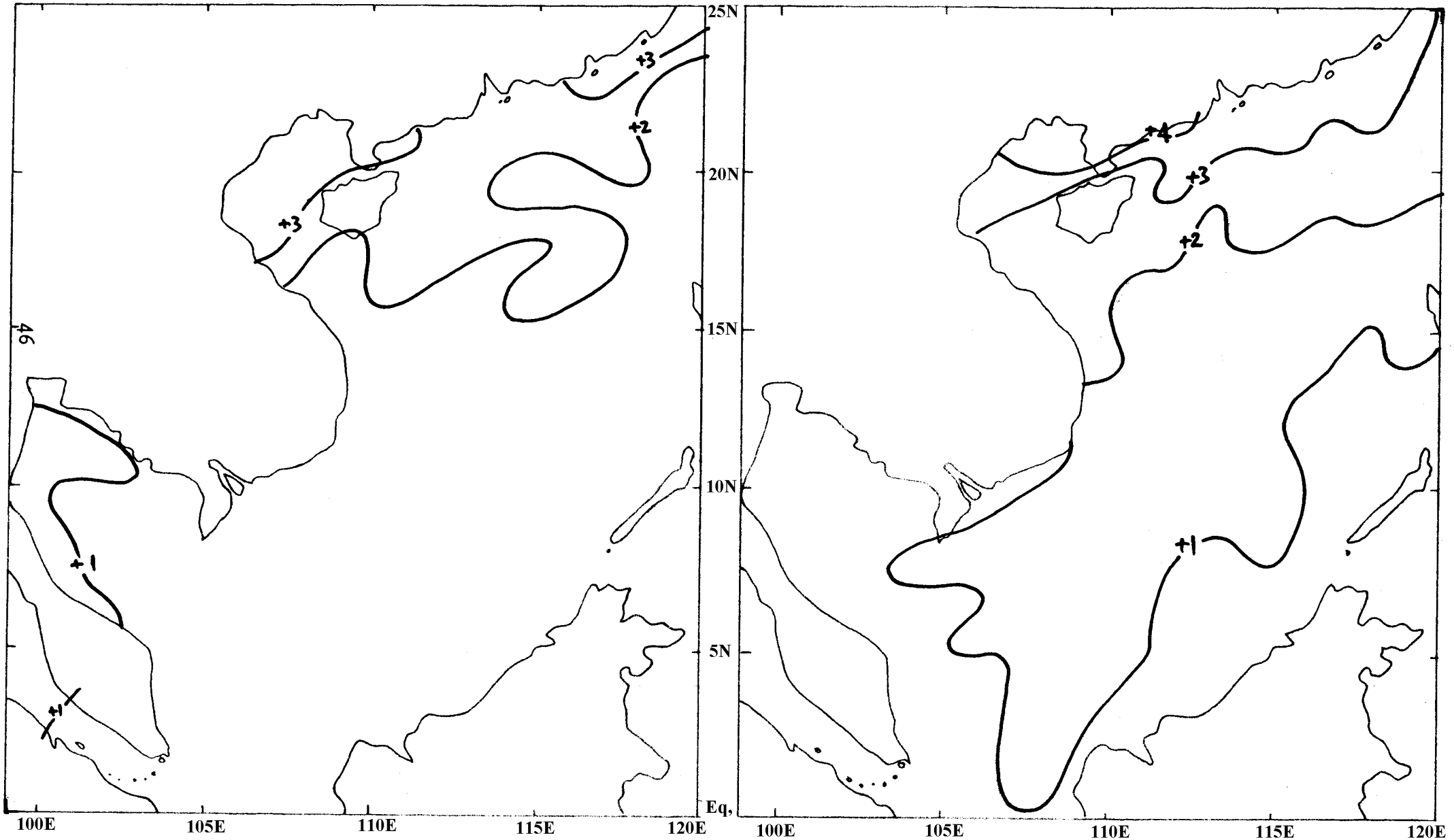


Figure 29. Mean month-to-month variation (June - May).

Figure 30. Mean month-to-month variation (July - June).

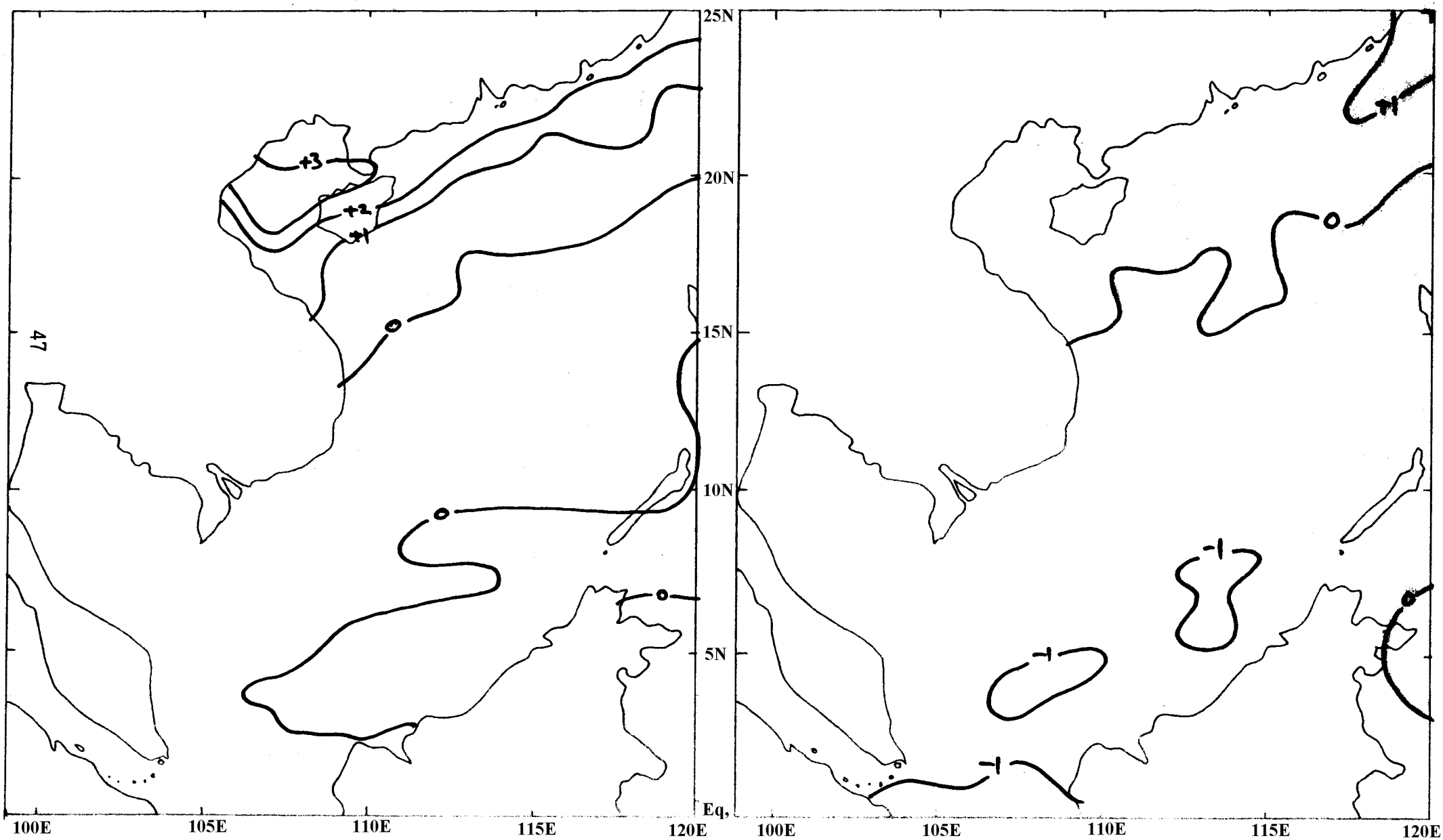


Figure 31. Mean month-to-month variation (August - July).

Figure 32. Mean month-to-month variation (September - August).

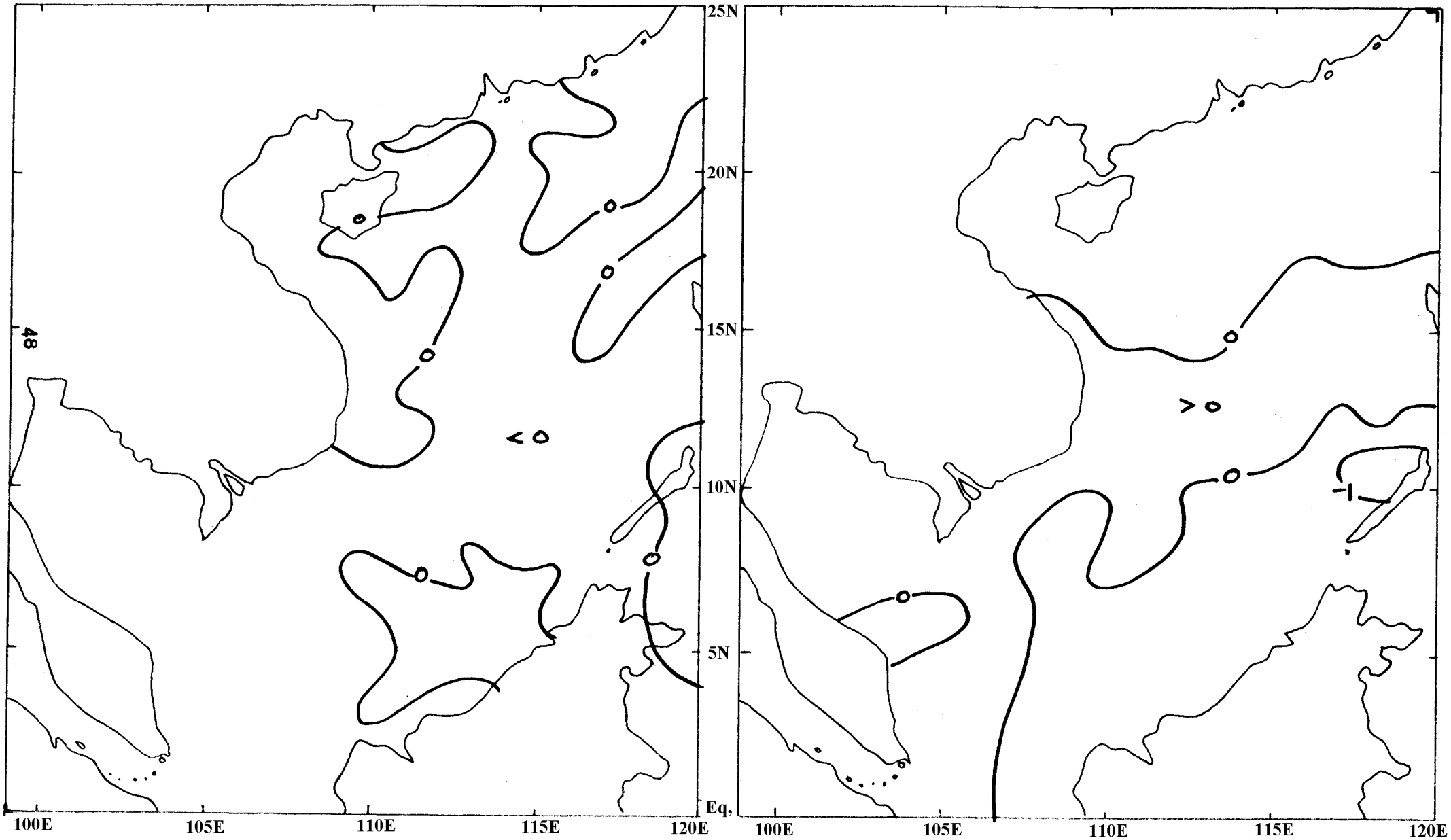


Figure 33. Mean month-to-month variation (October - September). Figure 34. Mean month-to-month variation (November - October).

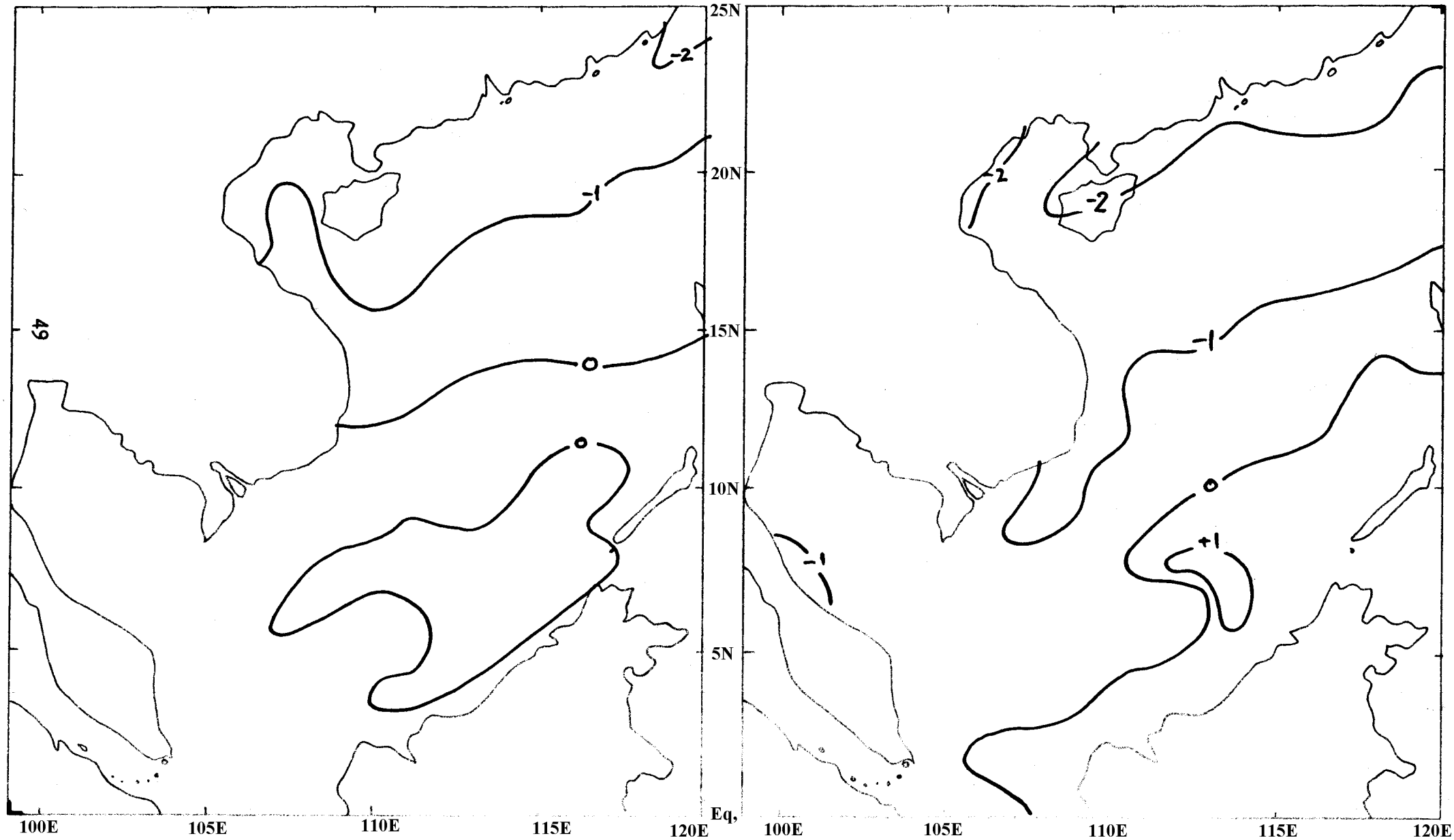


Figure 35. Mean month-to-month variation (December - November). **Figure 36.** Mean month-to-month variation (January - December).

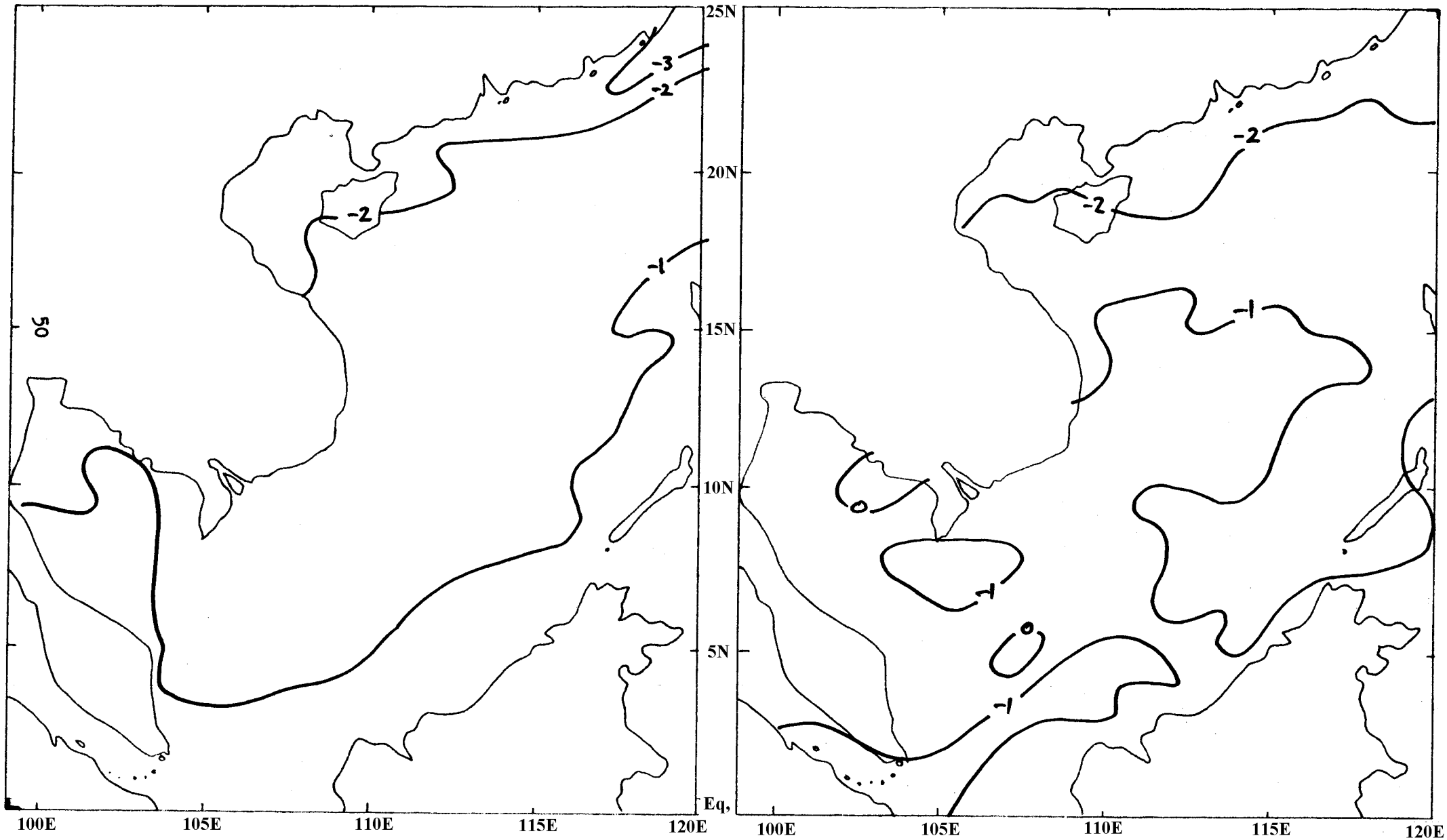


Figure 37. Changes in sea surface temperature from one five-year period to the next for January.

Figure 38. Changes in sea surface temperature from one five-year period to the next for February.

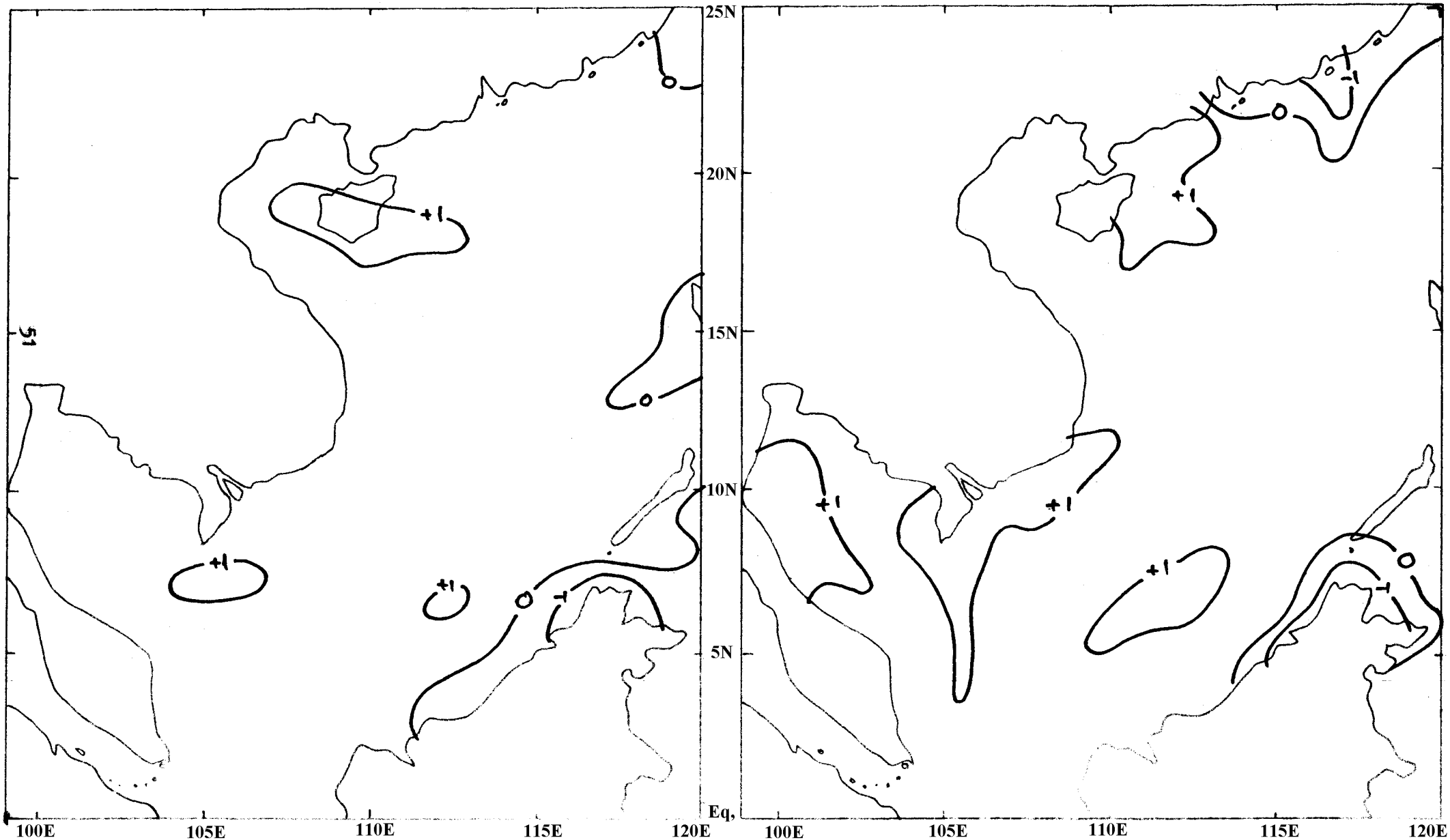


Figure 39. Changes in sea surface temperature from one five-year period to the next for March.

Figure 40. Changes in sea surface temperature from one five-year period to the next for April.

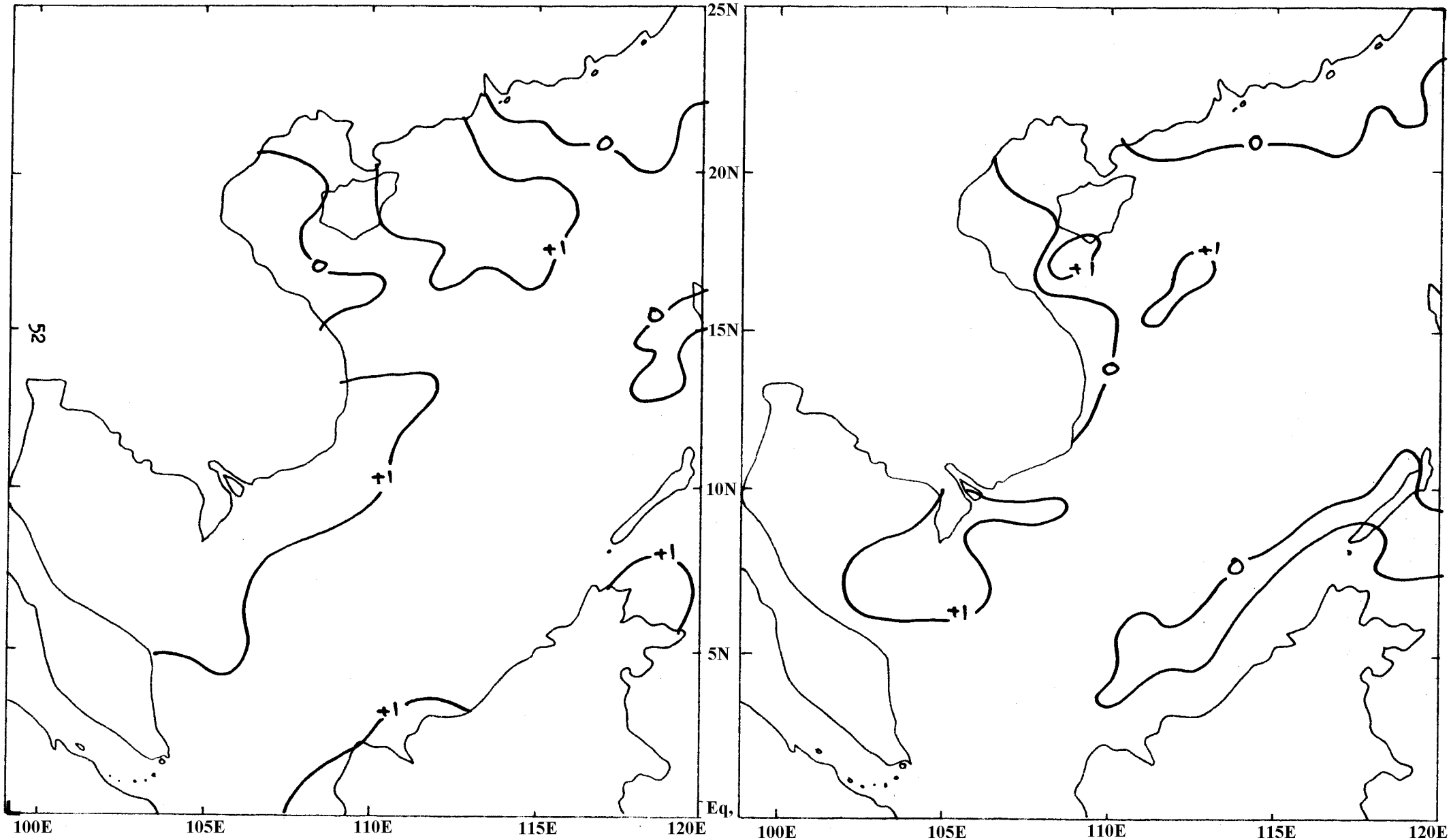


Figure 41. Changes in sea surface temperature from one five-year period to the next for May.

Figure 42. Changes in sea surface temperature from one five-year period to the next for June.

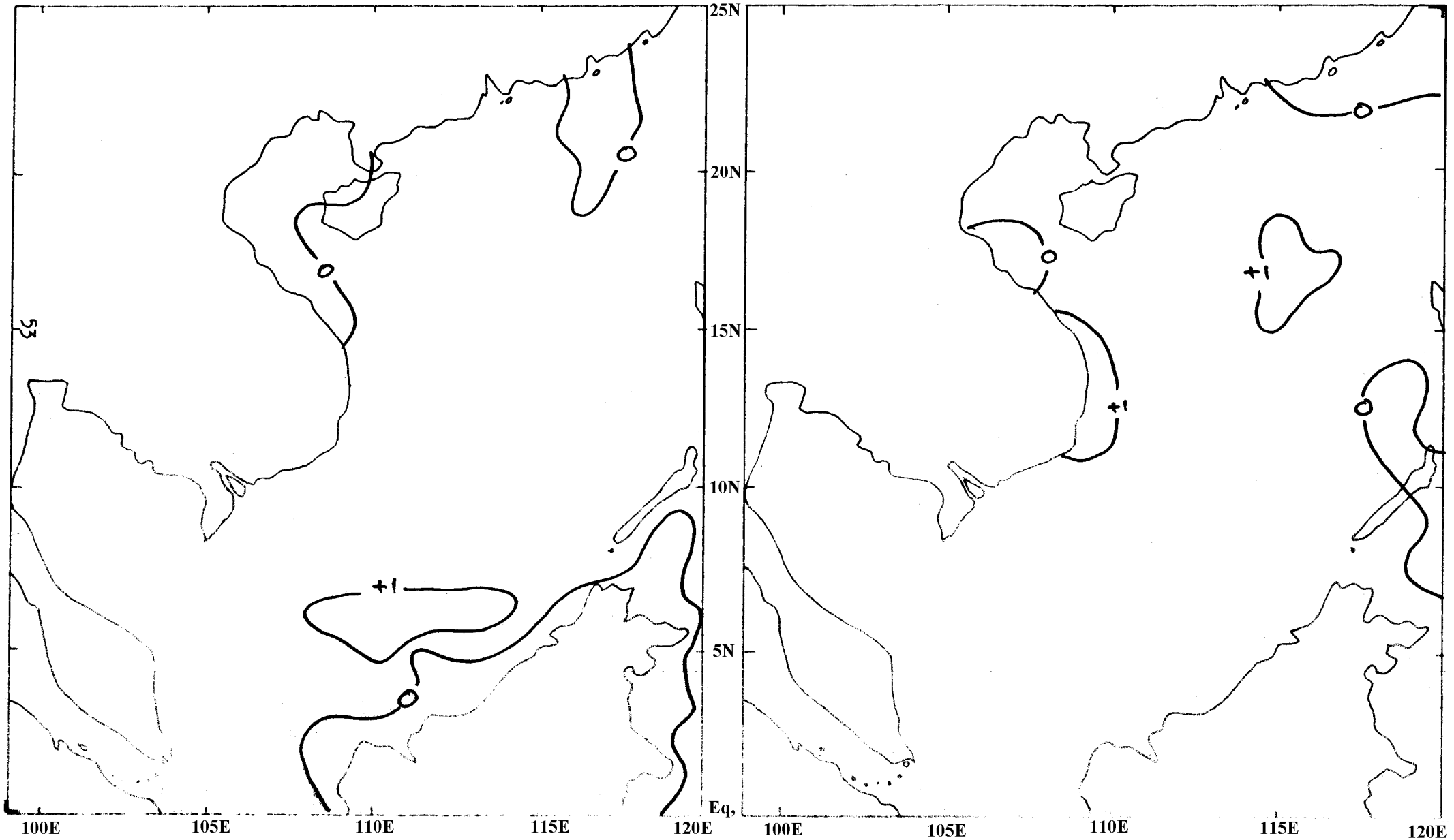
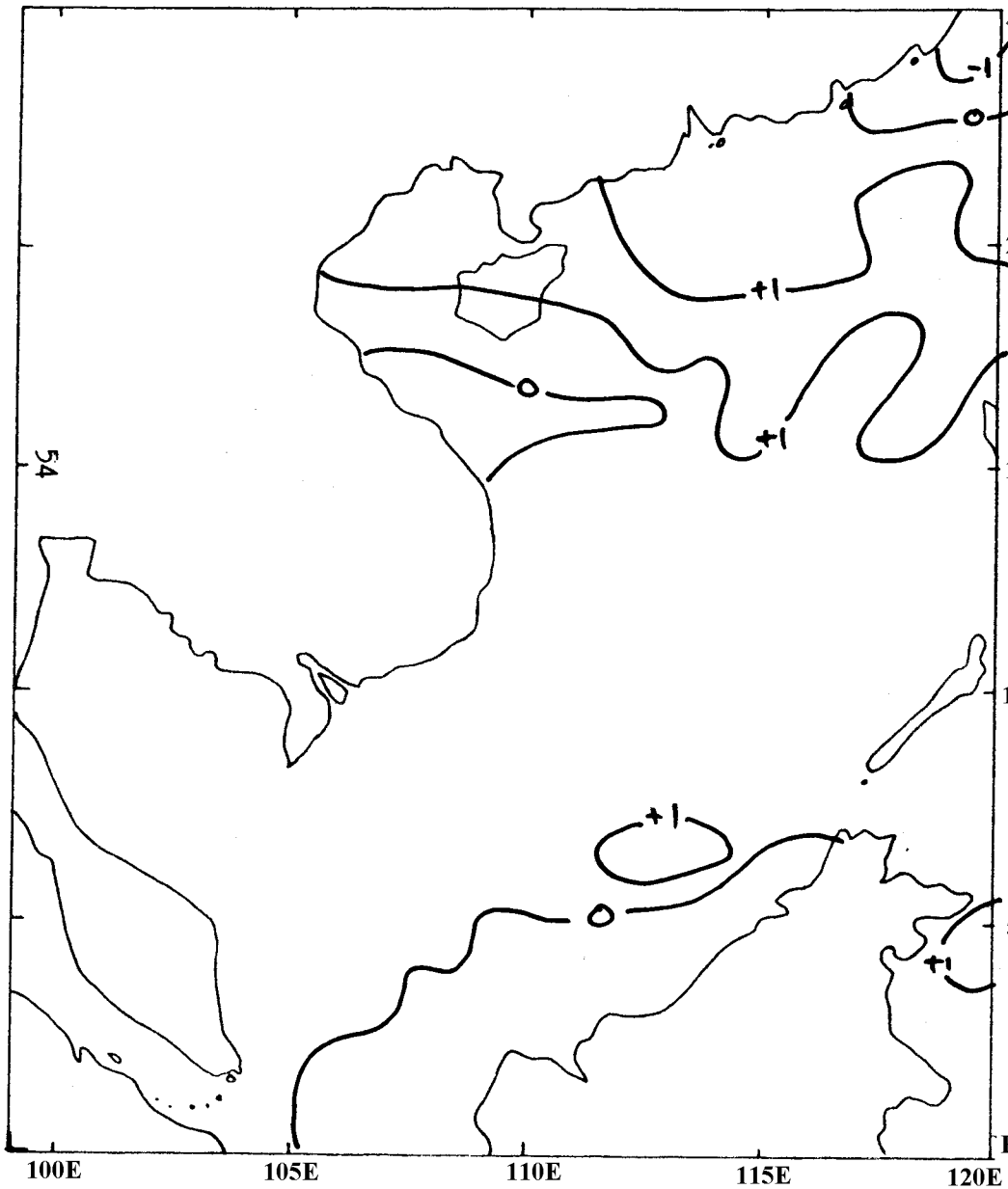


Figure 43. Changes in sea surface temperature from one five-year period to the next for July.

Figure 44. Changes in sea surface temperature from one five-year period to the next for August.



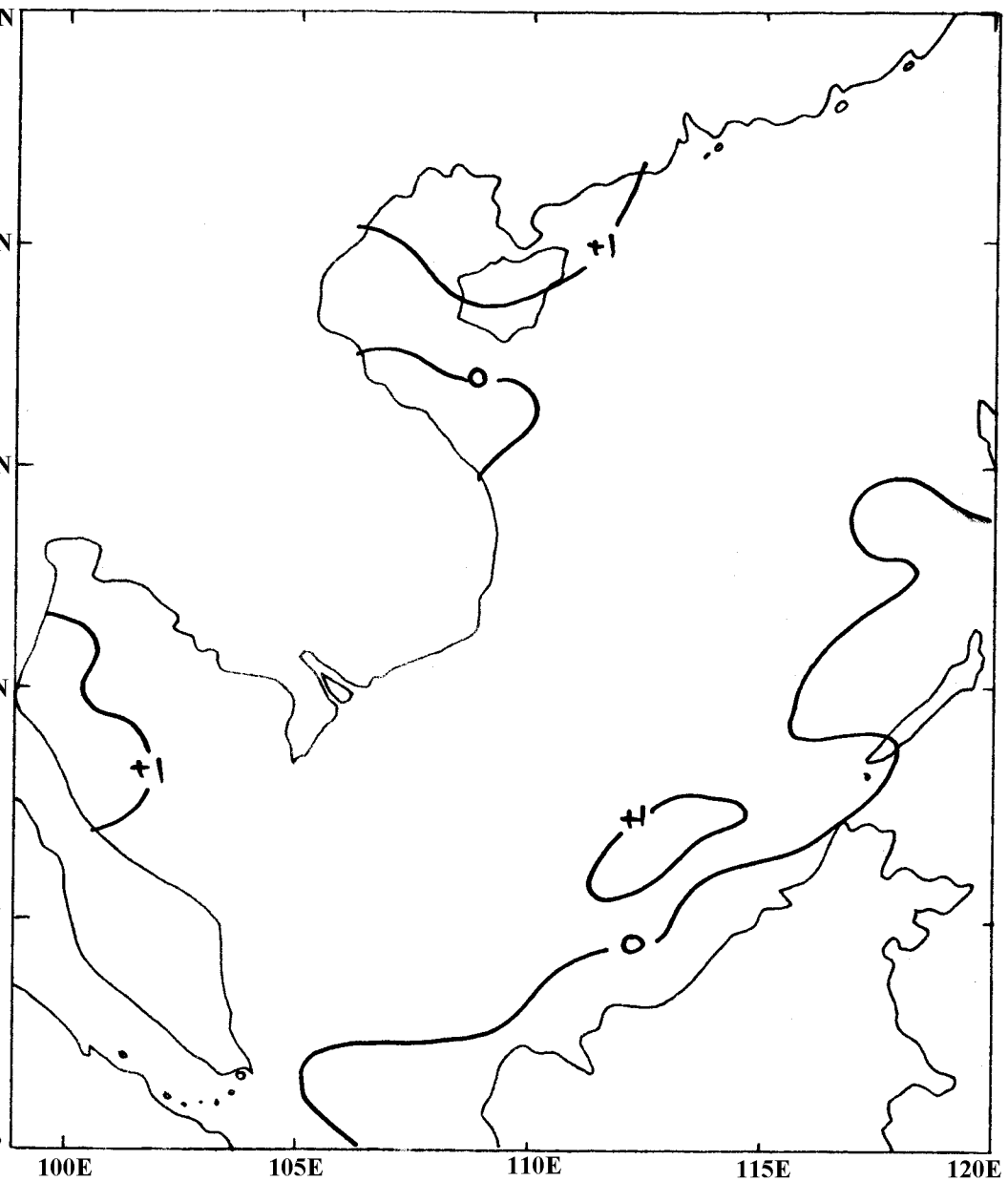


Figure 45. Changes in sea surface temperature from one five-year period to the next for September.

Figure 46. Changes in sea surface temperature from one five-year period to the next for October.

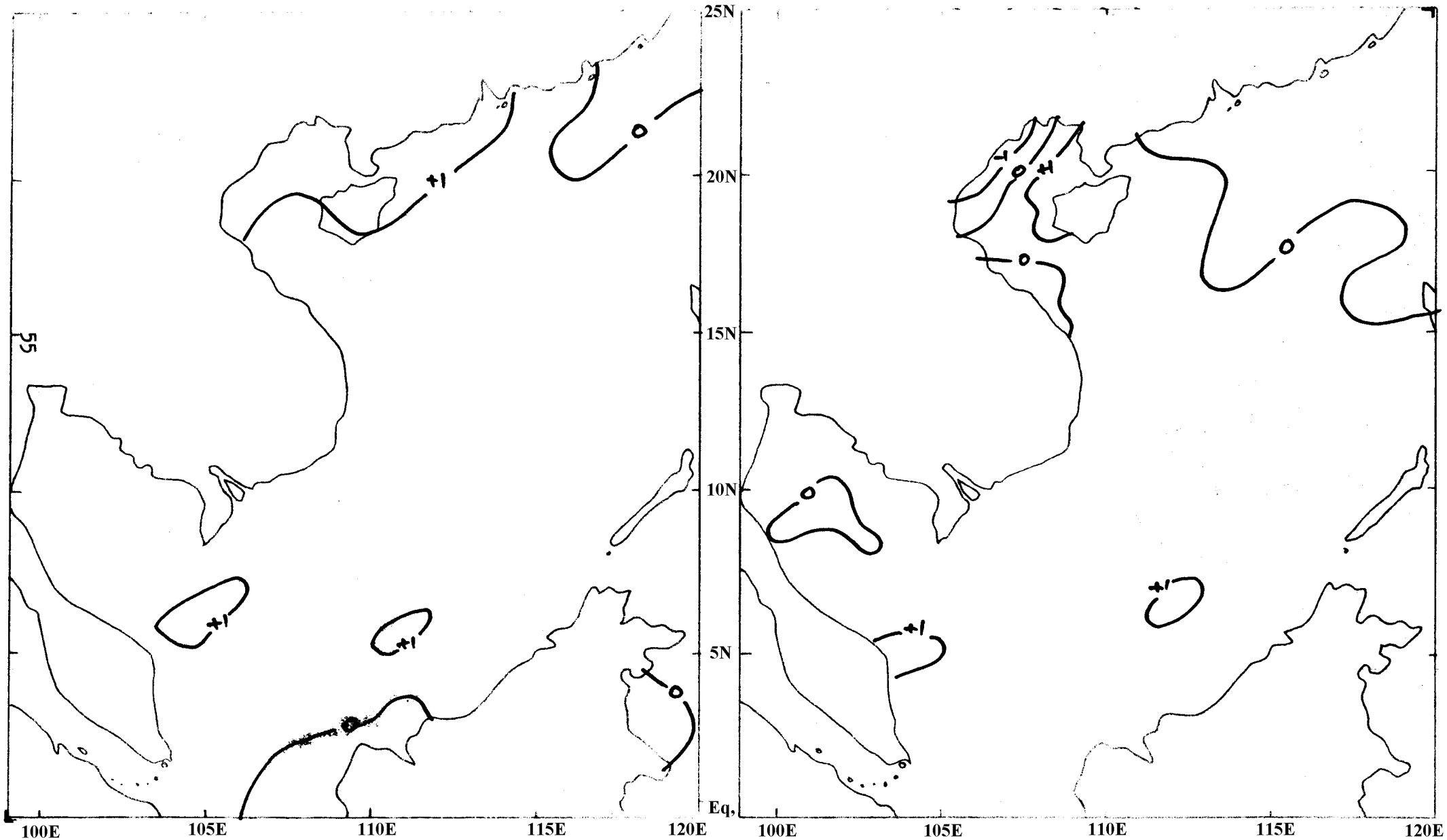


Figure 47. Changes in sea surface temperature from one five-year period to the next for November.

Figure 48. Changes in sea surface temperature from one five-year period to the next for December.

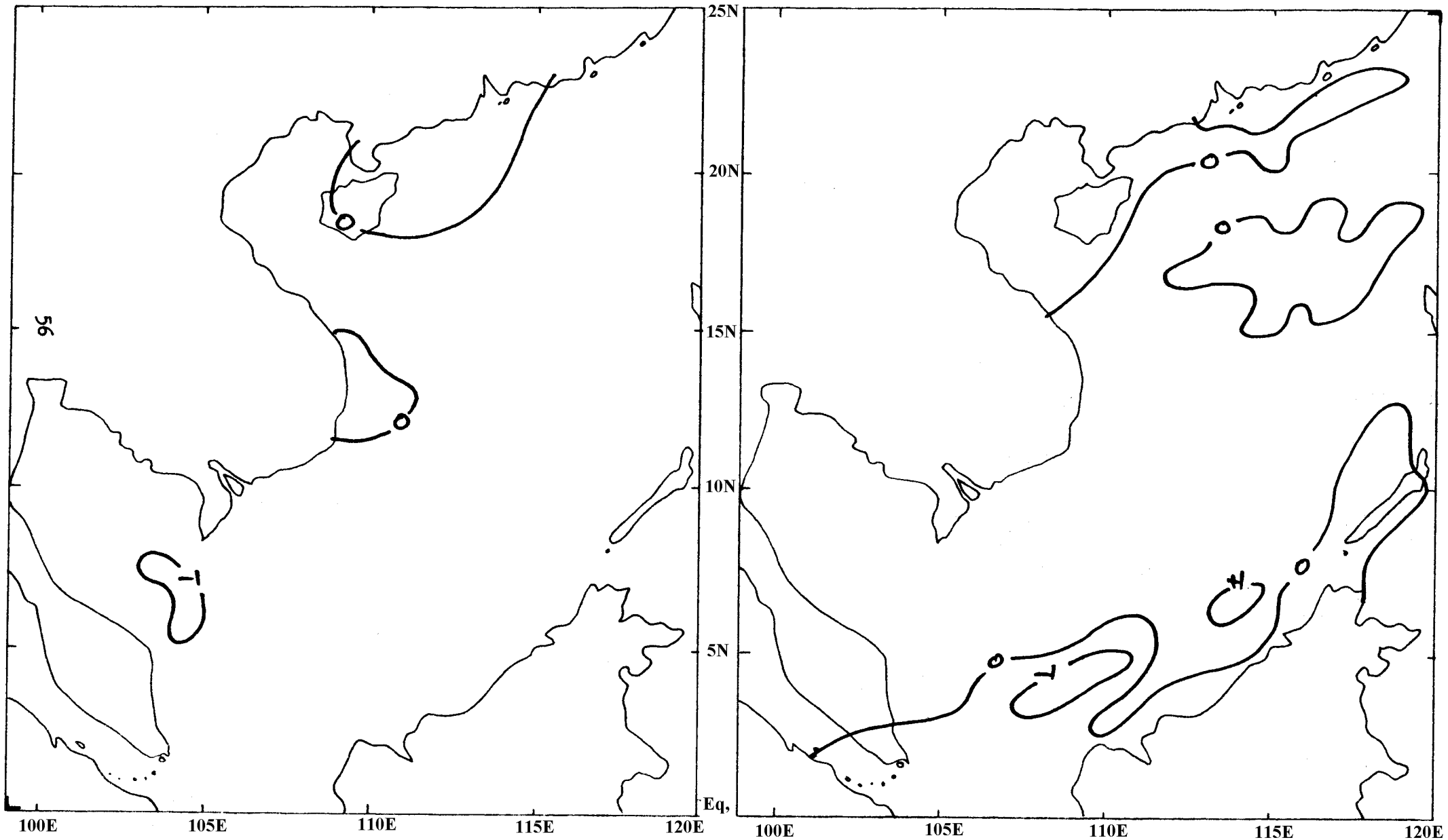


Figure 49. Interannual variation of the monthly mean sea surface temperature for January.

Figure 50. Interannual variation of the monthly mean sea surface temperature for February.

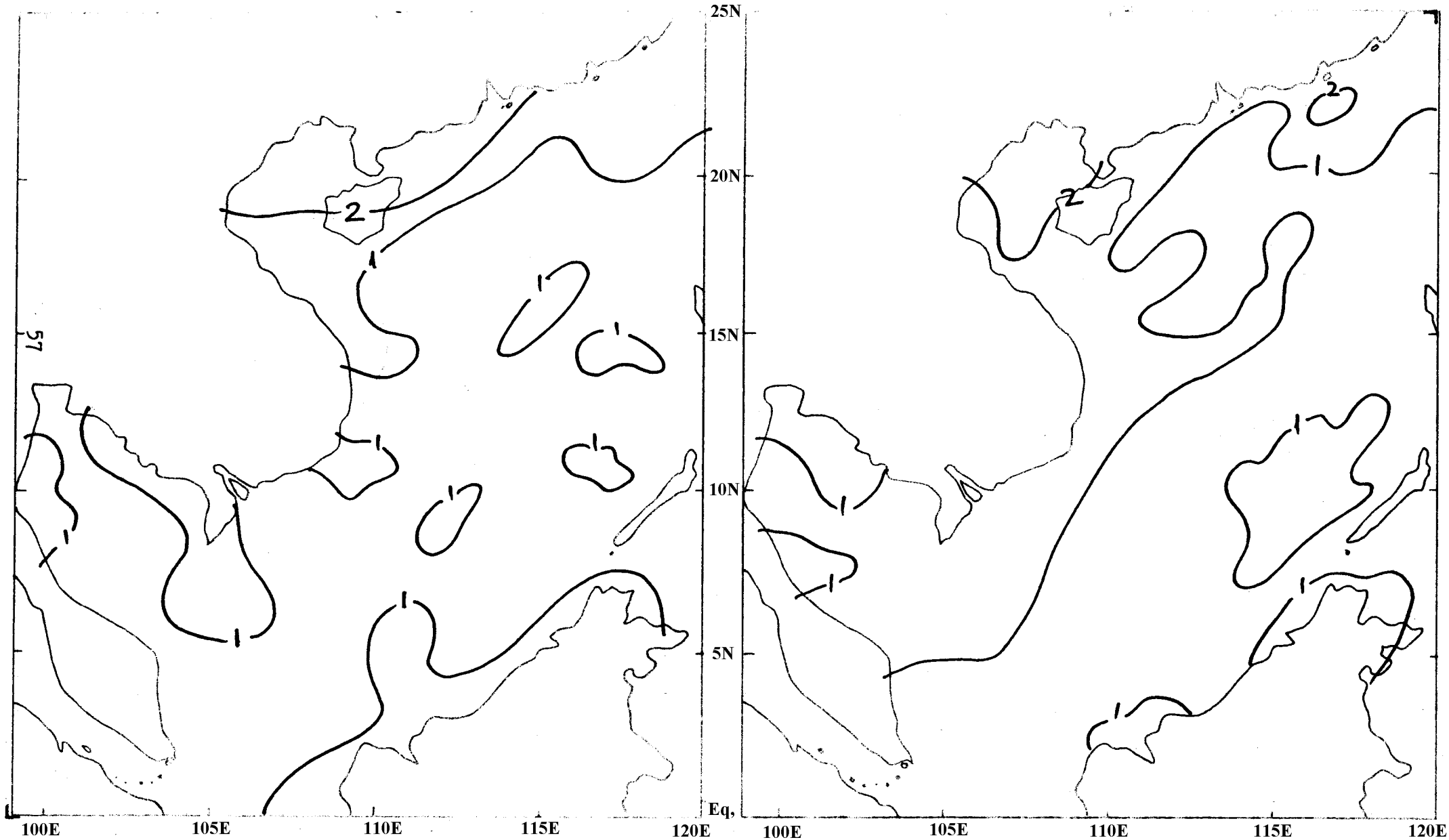


Figure 51. Interannual variation of the monthly mean sea surface temperature for March.

Figure 52. Interannual variation of the monthly mean sea surface temperature for April.

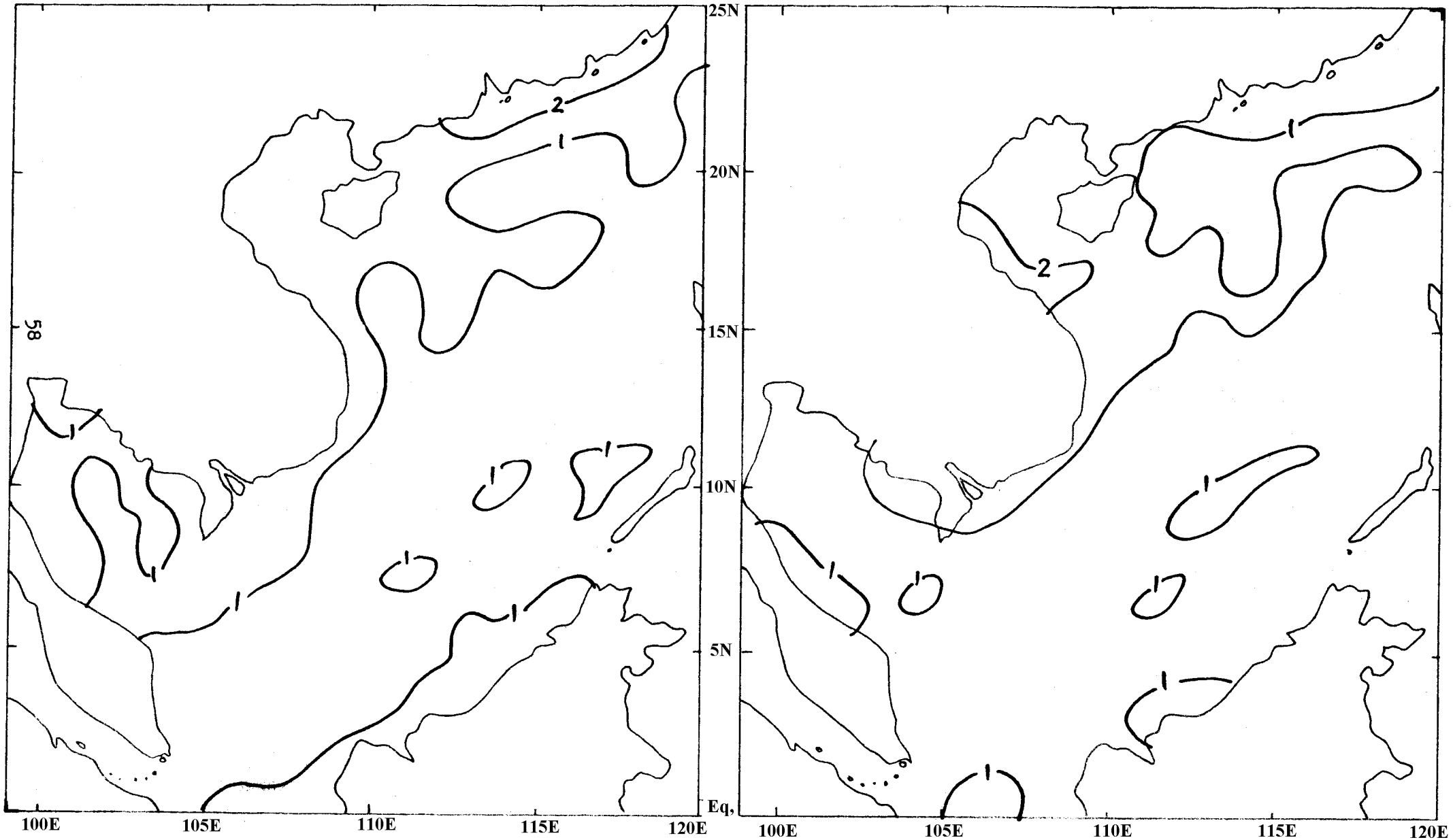


Figure 53. Interannual variation of the monthly mean sea surface temperature for May.

Figure 54. Interannual variation of the monthly mean sea surface temperature for June.

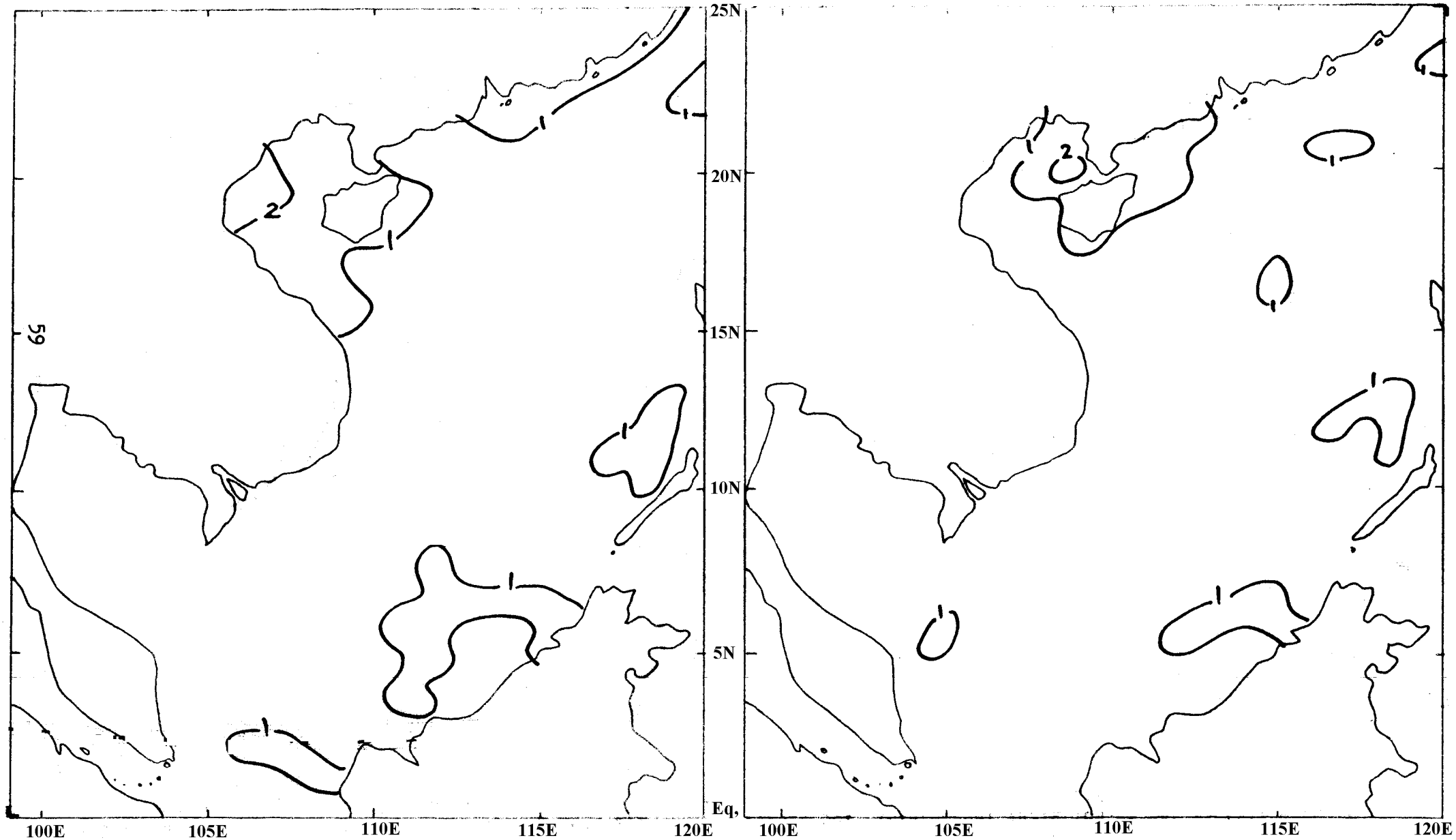


Figure 55. Interannual variation of the monthly mean sea surface temperature for July.

Figure 56. Interannual variation of the monthly mean sea surface temperature for August.

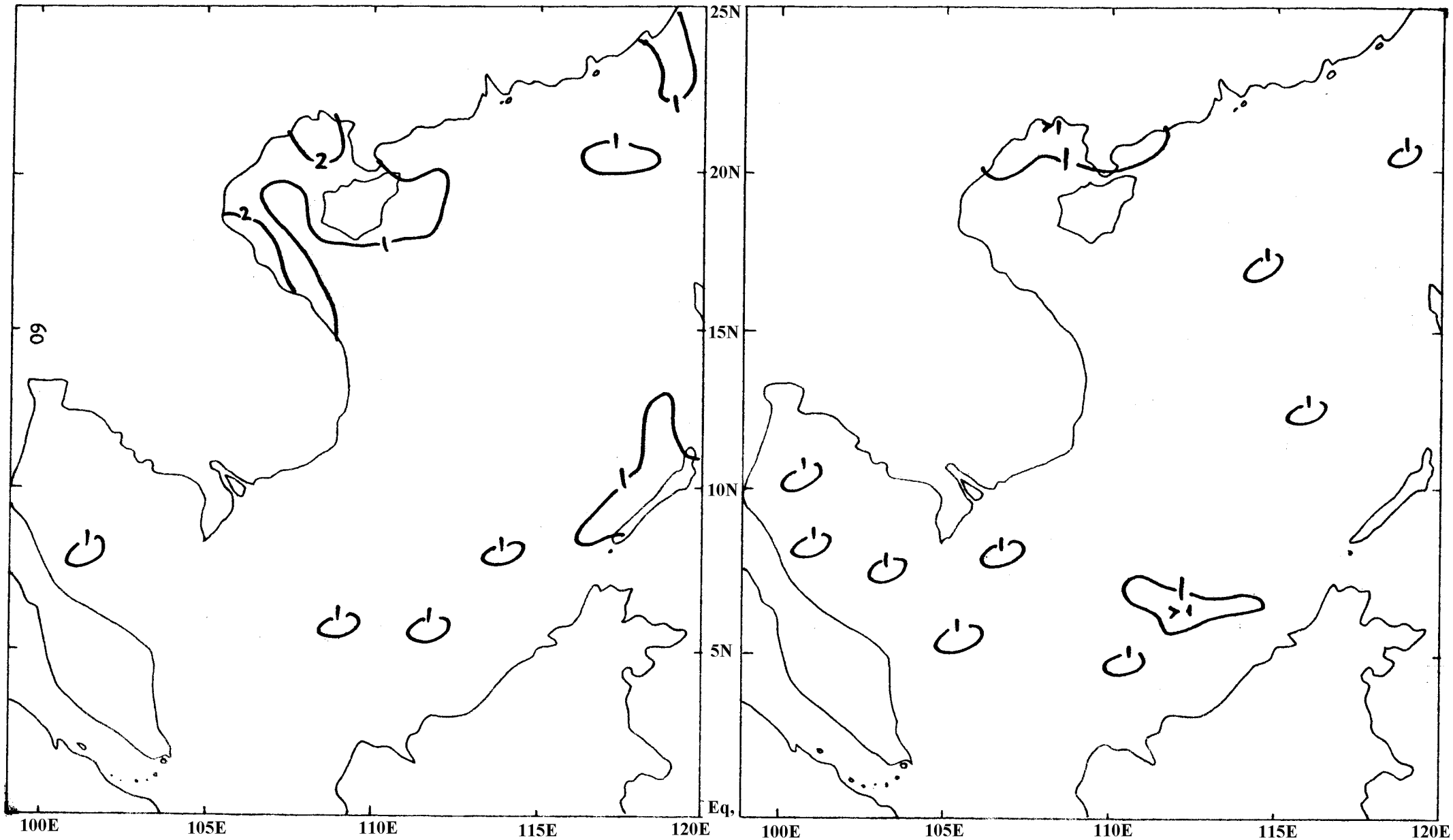


Figure 57. Interannual variation of the monthly mean sea surface temperature for September.

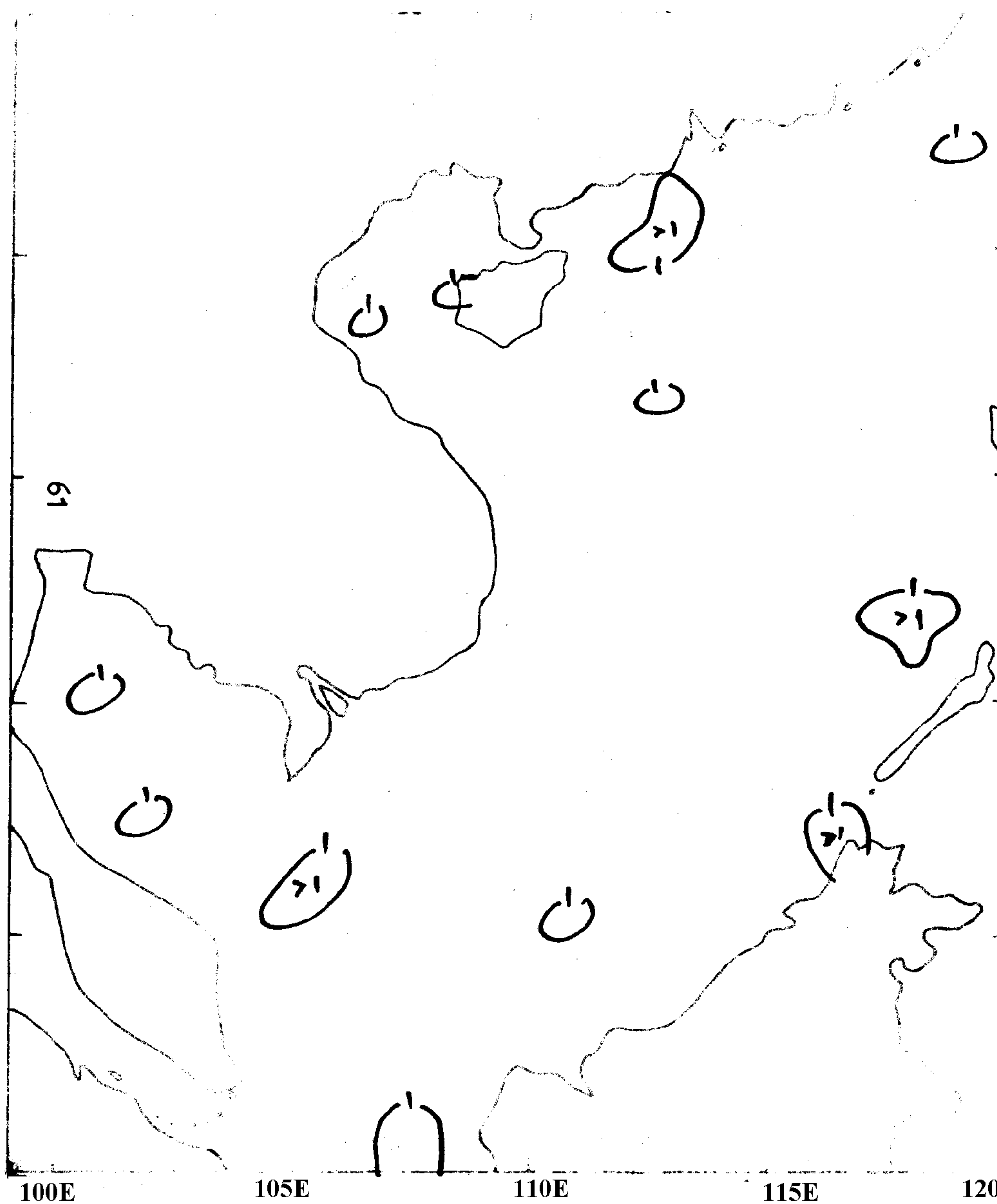


Figure 58. Interannual variation of the monthly mean sea surface temperature for October.

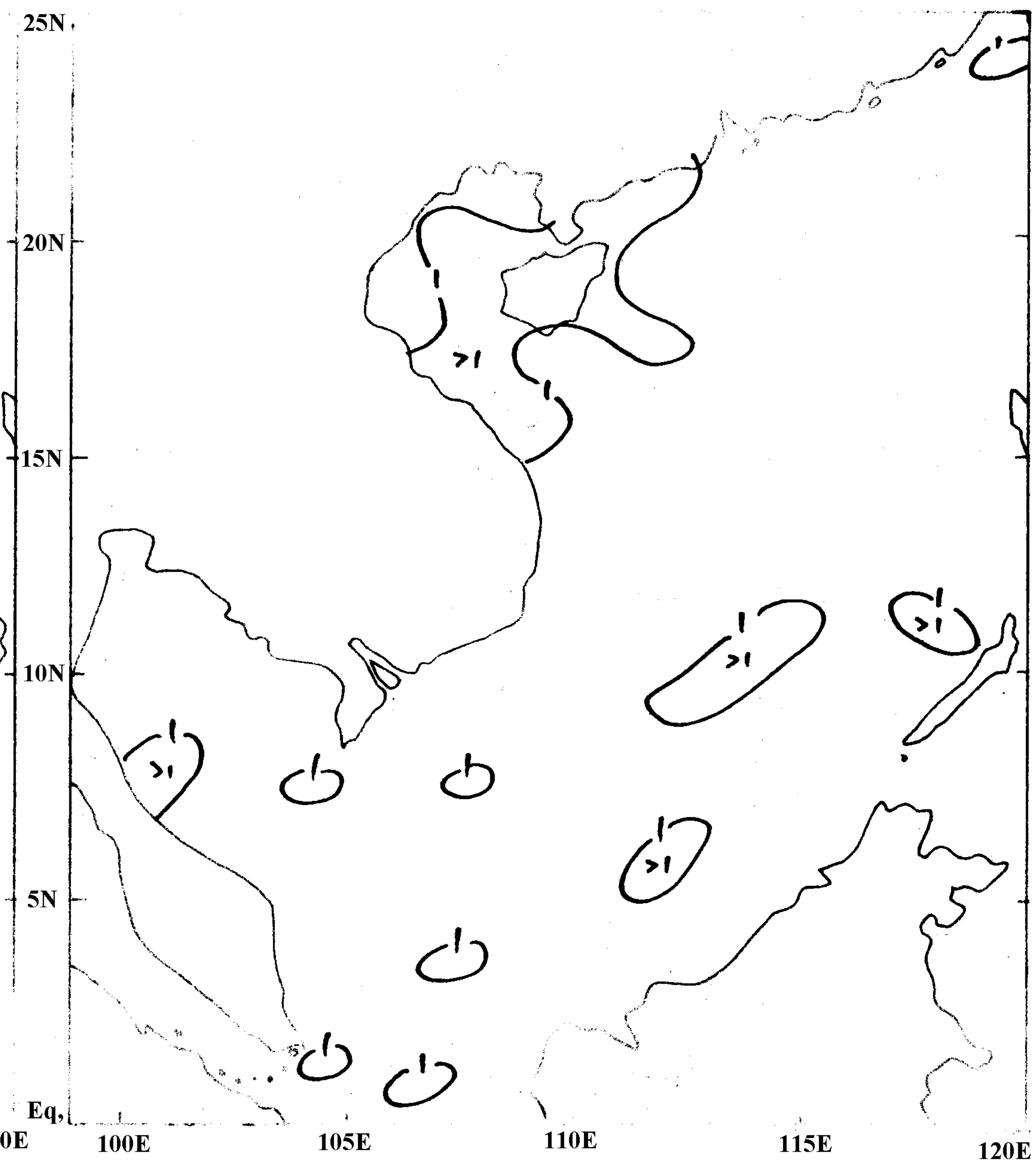
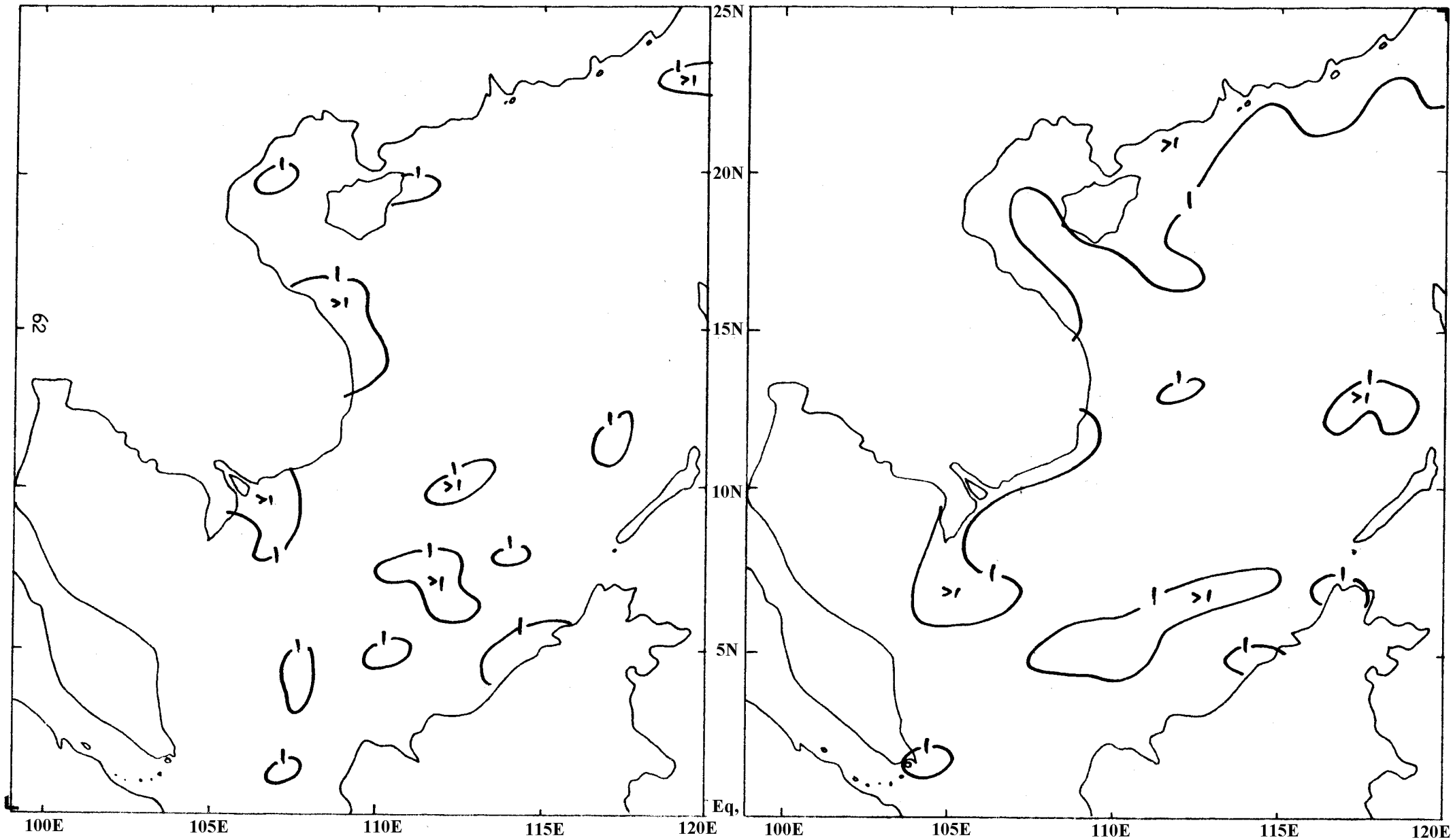


Figure 59. Interannual variation of the monthly mean sea surface temperature for November.

Figure 60. Interannual variation of the monthly mean sea surface temperature for December.



APPENDIX

RELIABILITY OF MEAN SEA SURFACE TEMPERATURE CALCULATIONS

1. Introduction

An important part of a study of this nature is to analyse the accuracy of the computed results. Two aspects are covered in this appendix :

(i) To what extent are the interannual variations shown in figure 49 - 60 real?

(ii) What is the accuracy of the computed ten-year monthly means?

2. The interannual variation of monthly means

In order to assess the significance of the interannual variations of the monthly mean they were compared with the uncertainty of the individual 1-year monthly means. The standard deviations of individual reports about each 1-year monthly mean were calculated and denoted by S_i (i stands for the i-th year). The standard error of each 1-year monthly mean was obtained according to : $S_{mi} = S_i/\sqrt{n_i}$, where n_i was the number of observations. For each square, there would be ten such S_{mi}'s corresponding to the ten 1-year monthly means. (If data were absent in certain years, there would be less than ten). The largest of these, S_{max}, was then taken as the uncertainty in the 1-year monthly means. If $S_{i.v.} \gg S_{max}$, it could be concluded that the accuracy of the data was adequate to resolve the interannual variation in sea surface temperature at a high level of confidence. This is illustrated in Figures A1 and A2. The ratio $S_{i.v.}/S_{max}$ was calculated for each square and for each month of the year. Results were analysed manually and are presented in isopleth charts (Figure A3 to A14). It was found that these ratios are generally greater than 1. During the six months from October to March these ratios are greater than 3 along the main commercial sea routes.

3. Standard error of the ten-year monthly mean

The standard error S_M was obtained from :

$$S_M = \frac{\sqrt{\sum S_{mi}^2}}{N}$$

where N is the number of years with data and S_{mi} is the standard error of the monthly mean of the i-th year of the decade. As defined in paragraph 2 above,

$$S_{mi} = \frac{S_i}{\sqrt{n_i}}$$

where S_i is the standard deviation of the n_i numbers of reports in that particular month in the specified one-degree square. The results of calculation were analysed manually and it was found that the standard errors were generally of the order of about 0.1°C to 0.2°C.

Figure A-1. Interannual variation adequately resolved.
($S_{i.v.} \gg S_{max}$)

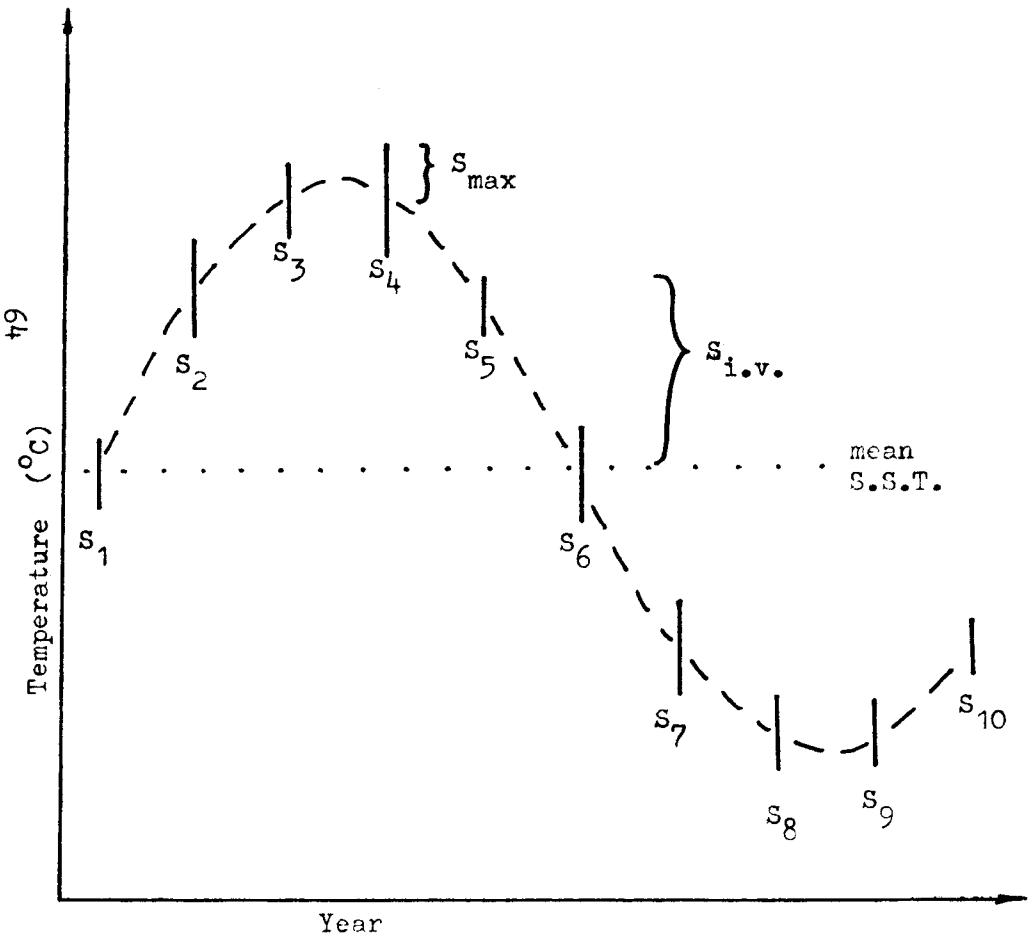


Figure A-2. Interannual variation not properly resolved.
($S_{i.v.} \ll S_{max}$)

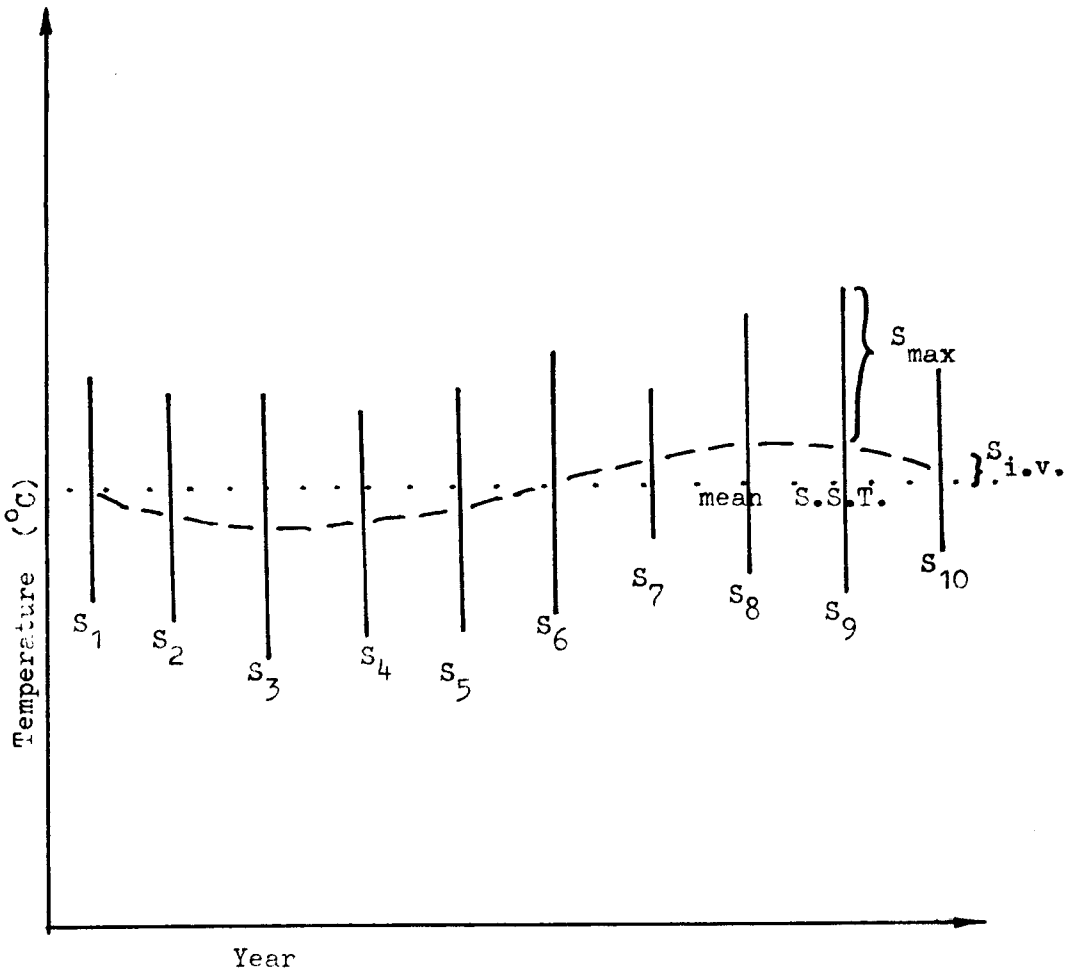


Figure A-3. Interannual variation of monthly mean for January (refer to text for details).

Figure A-4. Interannual variation of monthly mean for February (refer to text for details).

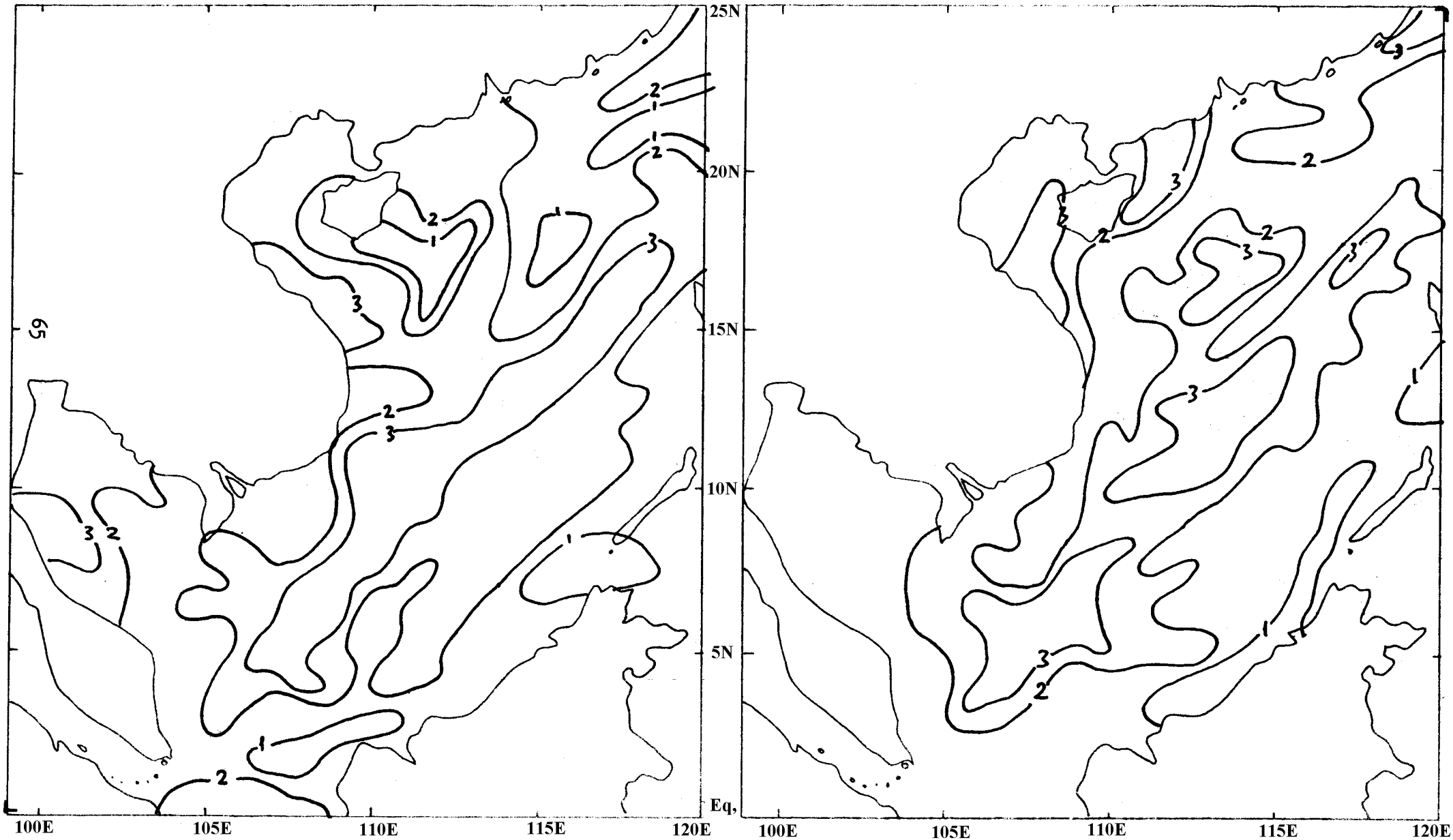


Figure A-5. Interannual variation of monthly mean for March (refer to text for details).

Figure A-6. Interannual variation of monthly mean for April (refer to text for details).

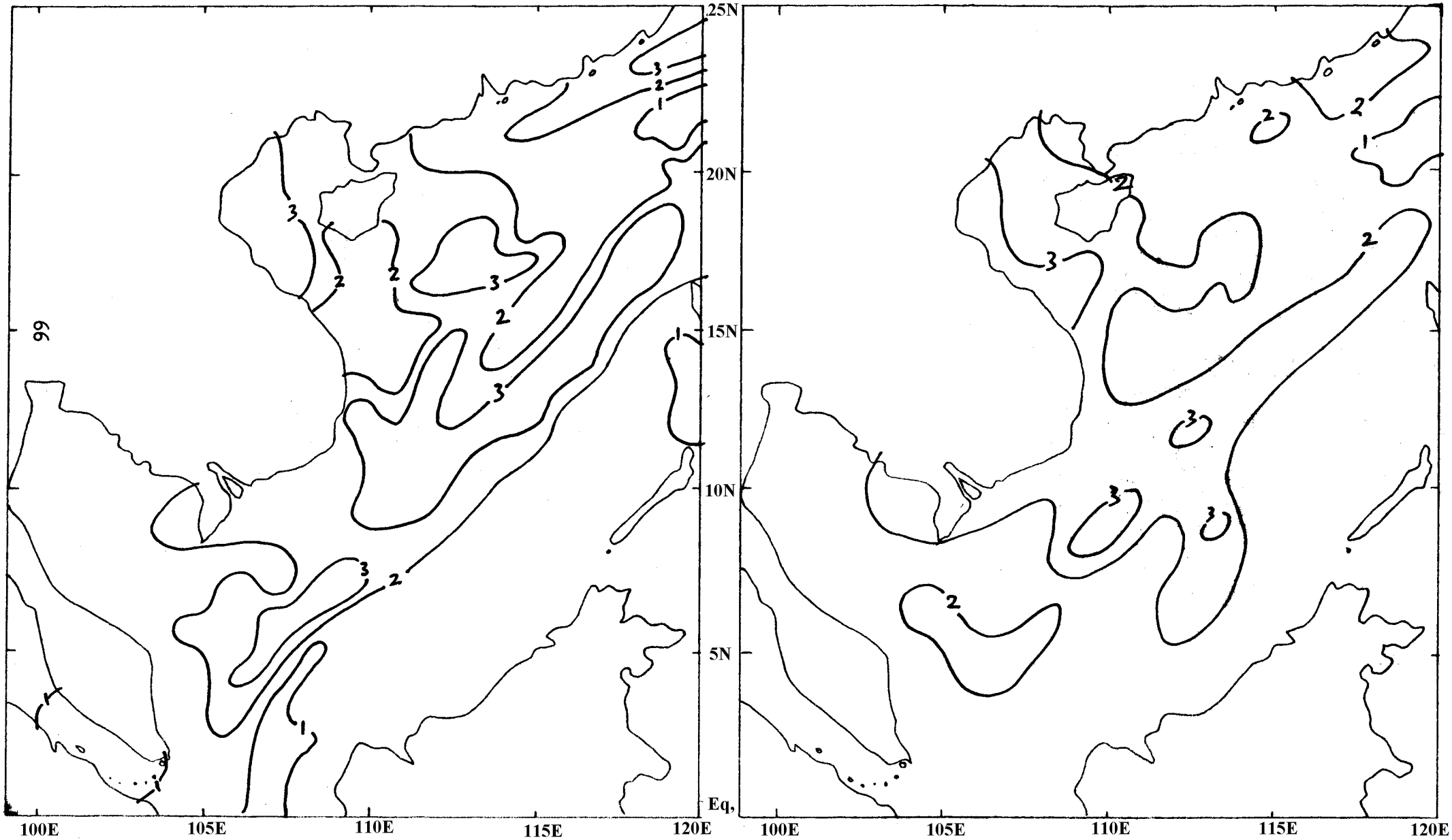


Figure A-7. Interannual variation of monthly mean for May (refer to text for details).

Figure A-8. Interannual variation of monthly mean for June (refer to text for details).

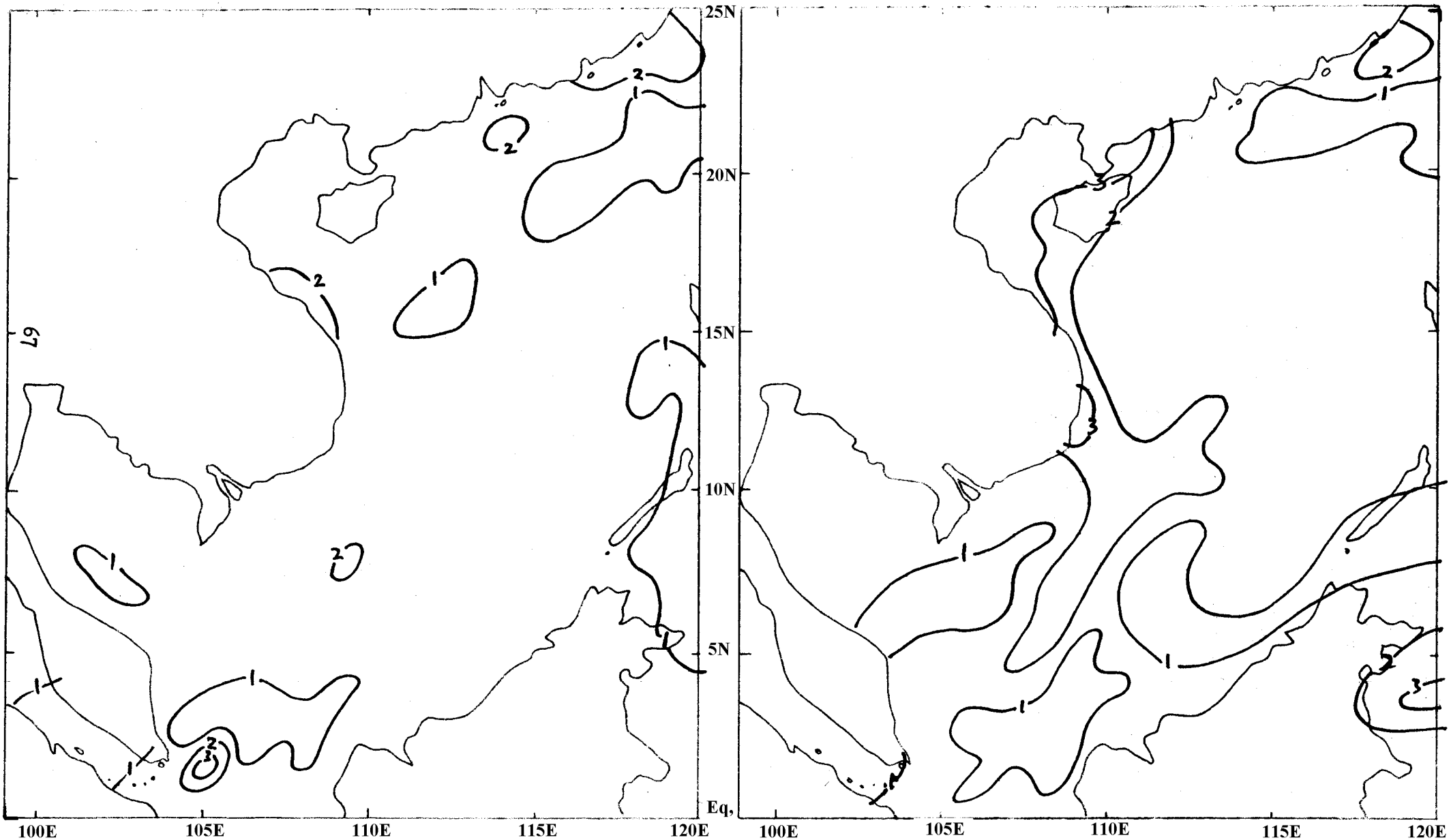


Figure A-9. Interannual variation of monthly mean for July (refer to text for details).

Figure A-10. Interannual variation of monthly mean for August (refer to text for details).

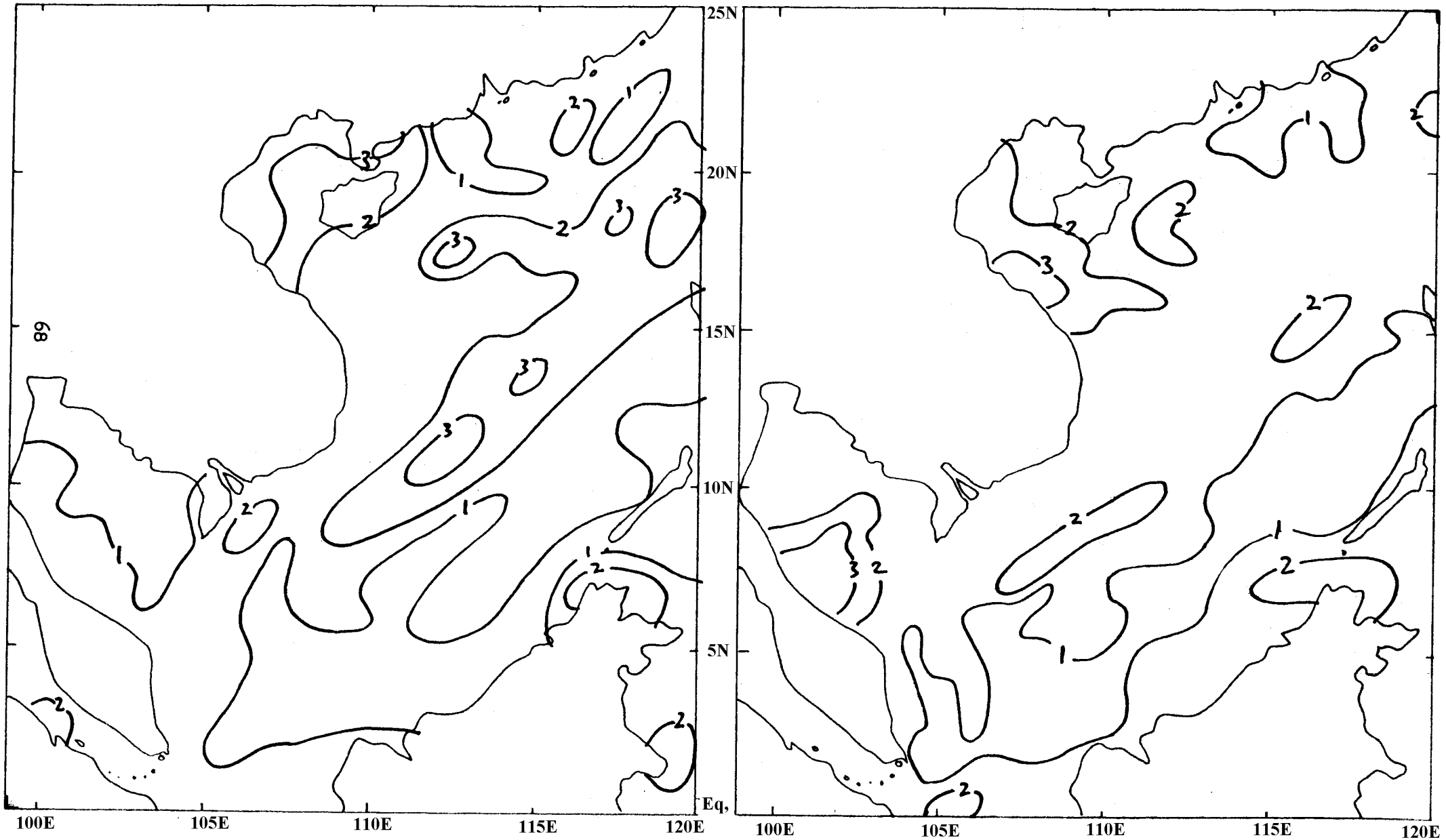


Figure A-11. Interannual variation of monthly mean for September (refer to text for details).

Figure A-12. Interannual variation of monthly mean for October (refer to text for details).

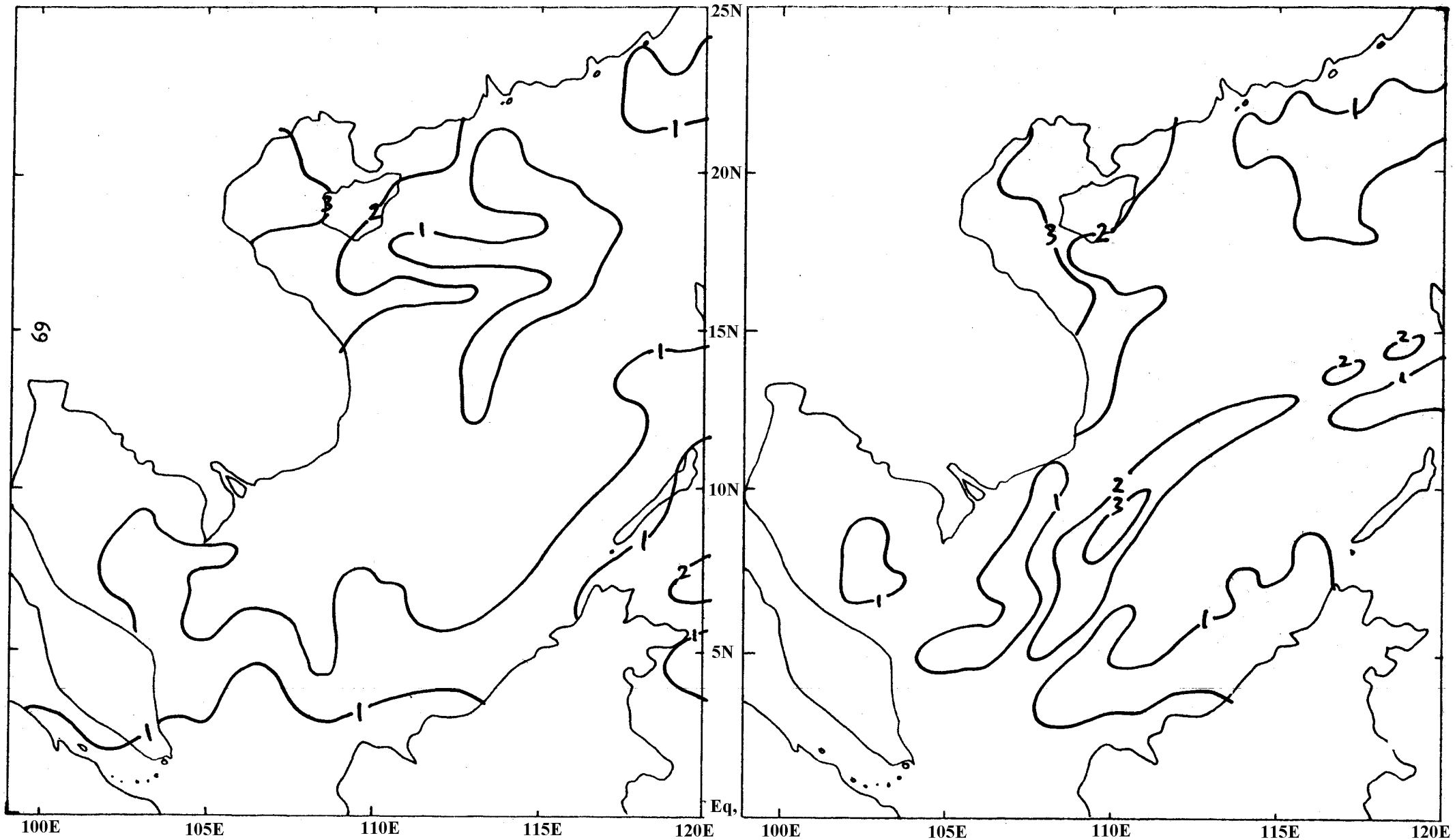


Figure A-13. Interannual variation of monthly mean for November (refer to text for details).

Figure A-14. Interannual variation of monthly mean for December (refer to text for details).