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Synoptic Sea-Surface Temperature Charts

by

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Introduction

Sverdrup (1951), in commenting on the place of hydrography in fisheries research, noted that the most important goal of fisheries research is to prepare predictions of value in fisheries problems. In general, the contribution of hydrography may be placed in two groups, the prediction of availability and the prediction of the size of the stock. In considering the former, the first step is to ascertain if a given species of fish may be caught commercially within specific hydrographic conditions. If such is the case, the second step is to predict when and where appropriate hydrographic conditions occur. The prediction of the size of the stock may be materially assisted if the hydrographic conditions are of particular importance in the formation of concentations of the species.

Sverdrup (1951) did not imply that hydrography would or could solve all of the problems of fishery prediction. He did say that it "must take its place as an integral and indispensible part of the combined effort". To meet the requirements for the prediction of the time and location of specific hydrographic conditions, it is first necessary to know what the base conditions are and how they change with time.

Attempts to achieve the basic knowledge were made by repeated observations along specific hydrographic sections. This method is unsatisfactory because of the difficulties associated with repeated monitoring, which means that standard sections are generally monitored irregularly and not sufficiently frequent to be of the greatest value. The subject of forecasting environmental conditions was one of the topics discussed at the ICNAF Environmental Symposium in 1964 (ICNAF, 1965).

Hydrography is an international endeavor, simply because of the size of the oceans if for no other reason. Some years ago, the author noted that there was indeed a lot of international activity and attempted to combine the results of individual endeavors to present a realistic description of hydrographic conditions. The results were presented by Bailey (1956) and Hachey *et al.* (1954), and an example is shown in Fig. 1. Although the exercise was an interesting one, the approach did not provide monitoring techniques essential to hydrographic forecasting. However, it did show, given the data, that even over relatively short periods of time reasonable descriptions of the surface temperature distribution could be made.

In the late 1950's, work at the U.S. Navy Hydrographic Office pointed the way to the synoptic monitoring of hydrographic conditions. The data source was the synoptic weather reports from ships at sea, which contained sea-surface temperature observations. Shown in Fig. 2 is one of the U.S. Navy Hydrographic sea-surface temperature charts for September 1960, drawn from data extracted from weather messages. Examples of early Canadian products are shown in Fig. 3 and 4 for winter and summer respectively. During the past 20 years, the sea-surface temperature chart has evolved as the user requirements became better known, and significant changes in data sources have taken place.

Data Sources

Synoptic weather reports

Synoptic weather reports from ships, as part of the International Programme of Safety of Life at Sea, have played a major role in the development of the synoptic sea-surface temperature chart. However, as Weiler *et al.* (1966) pointed out, the reports received from ships can be of doubtful accuracy and are by no means uniformly distributed but rather tend to cluster in certain regions. An example of the distribution of sea-surface temperature data is shown in Fig. 5.

As a measure of the amount of synoptic sea-surface temperature data being used, it was first determined that, during the year, the data receipts for July would be close to the monthly mean number of observations for the year. The data receipts in July by 5° of latitude for the Northwest Atlantic during 1967-81 are given in Table 1. These observations include reports from oil-drilling rigs, moored buoys, ferries, coastguard stations and fishing vessels as well as from ocean-going vessels.

Bathythermograph reports

Included in the sea-surface temperature counts are the IGOSS Bathy Project reports. The collection of these data for the 1972-81 period are given in Table 2. The bathythermograph data represent on the average about 4% of the total data but in 1977 the quantity represented 12%.

Airborne radiation thermometer (ART) measurements

The infrared radiation thermometer data have been used from time to time to supplement data gathered by ships. However, because of the cost and other factors, this technique could not make a significant contribution to the production of synoptic sea-surface temperature charts. The use of an ART as a special investigative tool was invaluable when used in conjunction with special ship observations (Weiler *et al.*, 1967).

Satellite imagery

Satellite imagery in the infrared band, used in conjunction with that in the visual band, has been heralded as a major triumph in oceanography. Most certainly, good imagery has been extremely helpful in defining the shape and nature of various oceanographic patterns. However, as seen in Fig. 6, the opportunities for good imagery of Northwest Atlantic waters are less than desirable.

Comparison of satellite imagery and synoptic weather reports

A comparison was made between sea-surface temperatures derived from satellite imagery and those given in synoptic weather charts based on weather reports from merchant ships for the same general locations. During the period from April 1980 to December 1981, there were 40 experimental sea-surface temperature charts produced from digitized satellite data covering Canadian waters between Georges Bank and the Grand Bank. These charts were experimental computer products of the Hydrometeorological Division of the Canadian Atmospheric Environment Service. For the same period, 682 sea-surface temperature observations from merchant ships were used in the comparison.

On a given date, observations at specific locations may have varied from -7.0 C° to +5.0 C°. On particular charts, mean differences were between -2.2 C° and +2.6 C°. Over the entire 21-month period, the mean difference between the two sets of data was -0.02 C°. Statistically, there was no significant difference between the two sets of data.

Synoptic Sea-Surface Temperature Charts

For the purposes of this paper, only the four types of sea-surface temperature charts which are regular products will be discussed. In the strictest sense, two of the charts are not sea-surface temperature charts but ocean frontal analysis charts. In the latter case, less emphasis is placed on the actual temperature and more is placed on water-mass locations. The charts range from a completely computer-generated product to manual analysis of data. They also vary as to the amount of satellite imagery that may be injected either as data points or contours.

Sea-surface temperature (U.S. National Weather Service)

Figure 7 shows a sea-surface temperature analysis by the U.S. National Weather Service. Utilizing information collected from marine weather messages and digitized satellite imagery, the data are averaged by grid spacing over a period of 6 days and analyzed by a computer program. The main objective of the analyst is to ensure that a sufficient volume of data is injected into the analysis. The analysis is displayed on a polar sterographic projection to a scale of 1:15,000,000.

Oceanographic analysis (U.S. National Weather Service and National Earth Satellite Service)

The interpretation of infrared imagery from the GOES and NOAA-7 satellites, coupled with spot sea-surface temperature data extracted from marine weather observations, permits the development of a complex chart as shown in Fig. 8. These unique charts are possible through the utilization of an interactive digital satellite-image processing system (Pressman and Holyer, 1978). The half-hourly observation by the GOES satellite is very useful because of the high frequency of data collection, albeit oblique. On clear days, the best imagery is provided by the NIMBUS-7 satellite. The results of the oceanographic analysis are presented on Mercator projection maps to a scale of about 1:10,000,000.

Ocean frontal analysis (U.S. Naval Eastern Oceanographic Center)

The ocean frontal analysis maps (Fig. 9) are developed in much the same way as the oceanographic analysis maps noted in the preceding paragraph. However, the major differences are that the degree of computer assistance is considerably less and the imagery is not as recent in the ocean frontal analysis maps. As before, spot sea-surface temperatures from weather observations are utilized. The maps are produced every 7 days.

Sea-surface temperature (Canadian Meteorology and Oceanographic Centre)

The product of the Meteorology and Oceanographic Centre, Halifax, Nova Scotia, is illustrated in Fig. 10. This map is developed primarily from sea-surface temperature data extracted from marine weather messages and such satellite infrared imagery data that may be available from NIMBUS-7. These charts are produced at 3-4 day intervals, and are designed as the framework of an experimental Ocean Frontal Analysis in the same vein as those produced by U.S. Navy Eastern Oceanographic Center (Fig. 9). The chart is presented on a polar stereographic projection to a scale of 1:5,000,000. However, with limited satellite imagery and without facilities for digital analysis, the analyst must rely heavily on (a) marine meteorological observations, (b) a seasonal model, and (c) guidance from other sources. As noted earlier, the relationships between data gathered by different methods may lead to some considerable differences. Coupled with differences in data are those of interpretation which may lead to considerably different results.

General observations on charts

The value of a sea-surface temperature chart is its capability to meet the realistic demands placed upon it, and that can only be answered by the enquirer. Because of the differing scales and projections of the charts and even the time frames, a comparison of the different charts in any more than a superficial manner is not feasible.

Since eddies are a dominant feature of all of the charts, a brief comparison might be in order. The U.S. National Weather Service chart (Fig. 7) does not show any warm-core eddies north of 40°N latitude. However, the U.S. Eastern Oceanographic chart (Fig. 9) shows four eddies, the Canadian chart (Fig. 10) shows five, and the U.S. National Earth Satellite chart (Fig. 8) shows five. Because of time frame differences, it becomes a matter of conjecture whether there is a missing eddy on one chart or additional eddies on the other two. That there should be a difference of interpretation is understandable, when one is dealing with differences in water masses of only a few degrees and the satellite imagery may differ by that amount from day to day.

One area where difficulties occur is in the vicinity of 38°N, 67°W, where none of the data are in particular agreement and where, in the Fig. 8 and 9, the analysts have left areas undertermined. The Canadian chart (Fig. 10), in the vicinity of the tail of the Grand Bank, encountered an unresolved contour-labelling problem.

Conclusions

It is obvious that one may combine data from two entirely different observing techniques. Also, it is obvious that difficulties arise in determining the nature of a particular water mass. As invariably happens, when one measures a particular parameter with two different instruments, there is a difference in value. So with satellite imagery and the values extracted from various weather messages, there are definite differences in the values obtained. As noted earlier, although the differences between the two sets of data may be as great as ±7.0°C, they are not statistically significant.

From the author's experience in using satellite imagery, observed temperature difference in the cool coastal waters may be of the order of ±1°C, while in warmer offshore waters the observable difference is at least ±2°C. The major difficulty is the determination of the actual value within a range of 5-10°C. With digitized data the actual value is reduced to ±2.5°C. Thus data for the same or adjacent areas at different times may have fairly large observational errors that make water mass identification awkward.

Every technique applied to the study of the oceans has its strengths and weaknesses, and so there are problems in the application of satellite observations. It is the author's opinion that satellite imagery of sea-surface temperature requires a large measure of "ground truth", which would greatly enhance its use in the identification of water masses.

As noted at the begining of this paper, the principal values of these charts lies in their use for meteorological forecasting, oceanographic research, fisheries research, and the fisheries. Thus, a better chart may lead to a better understanding of the three questions: why, where and when. Not only must attention be given to researching the relationships between the environmental and biological aspects of the fisheries but also to the differing techniques of observation.

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Table 1. Numbers of sea-surface temperature observations available in July from the ship synoptic meteorological program 1967-1981 by 5° of latitude in the western North Atlantic Ocean based on the area of Figure 3.

	Latitude							
Year	30°-35°N	35°-40°N	40°-45°N	45°-50°N	50°-55°N	55°-60°N	Total	Observ. Per Day
1967	844	1068	1200	984	444	112	4652	150
1968	776	1220	1284	744	372	76	4472	144
1969	792	1064	1376	688	360	104	4384	141
1970	700	972	1120	660	388	200	4240	137
1971	772	1057	1112	785	389	133	4298	139
1972	740	888	1572	768	352	84	4404	142
1973	736	920	1448	668	476	128	3376	109
1974	780	1004	1728	688	164	28	4492	145
1975	796	1161	1103	482	284	61	3887	109
1976	552	832	1082	360	260	61	3147	102
1977	387	567	750	403	215	55	2377	77
1978	750	1027	1090	596	604	132	4199	150
1979	635	900	1010	649	426	133	3753	134
1980	765	1106	1100	670	356	114	4111	147
1981	640	828	1116	728	377	195	3834	137

Table 2. IGOSS BATHY PROJECT: Atlantic summary of data receipts, 1972-81.

AVERAGES PER DAY

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1. GTS	17.6*	44.7	39.8	66.9	60.3	49.9	43.5	37.1	50.67	48.9
2. ATL	-	-	-	-	25.4*	19.3	17.6	15.7	16.61	19.5
3. PLOT	5.2	7.5	2.4	3.8	3.7	8.2	6.3	5.8	3.3	14.3

* For 9 months

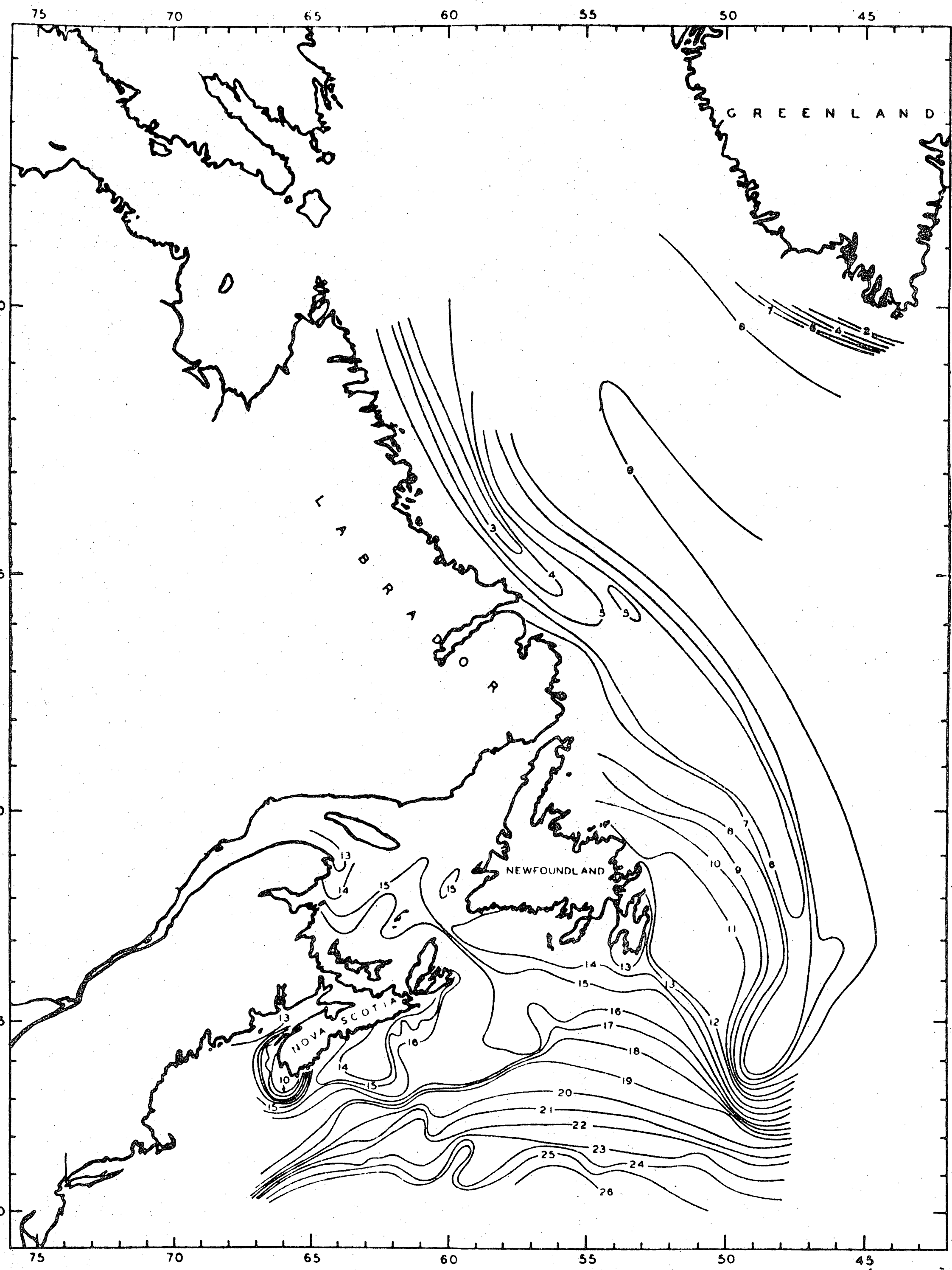

Fig. 1. Surface temperature distribution, August 1950. (After Bailey, 1956).

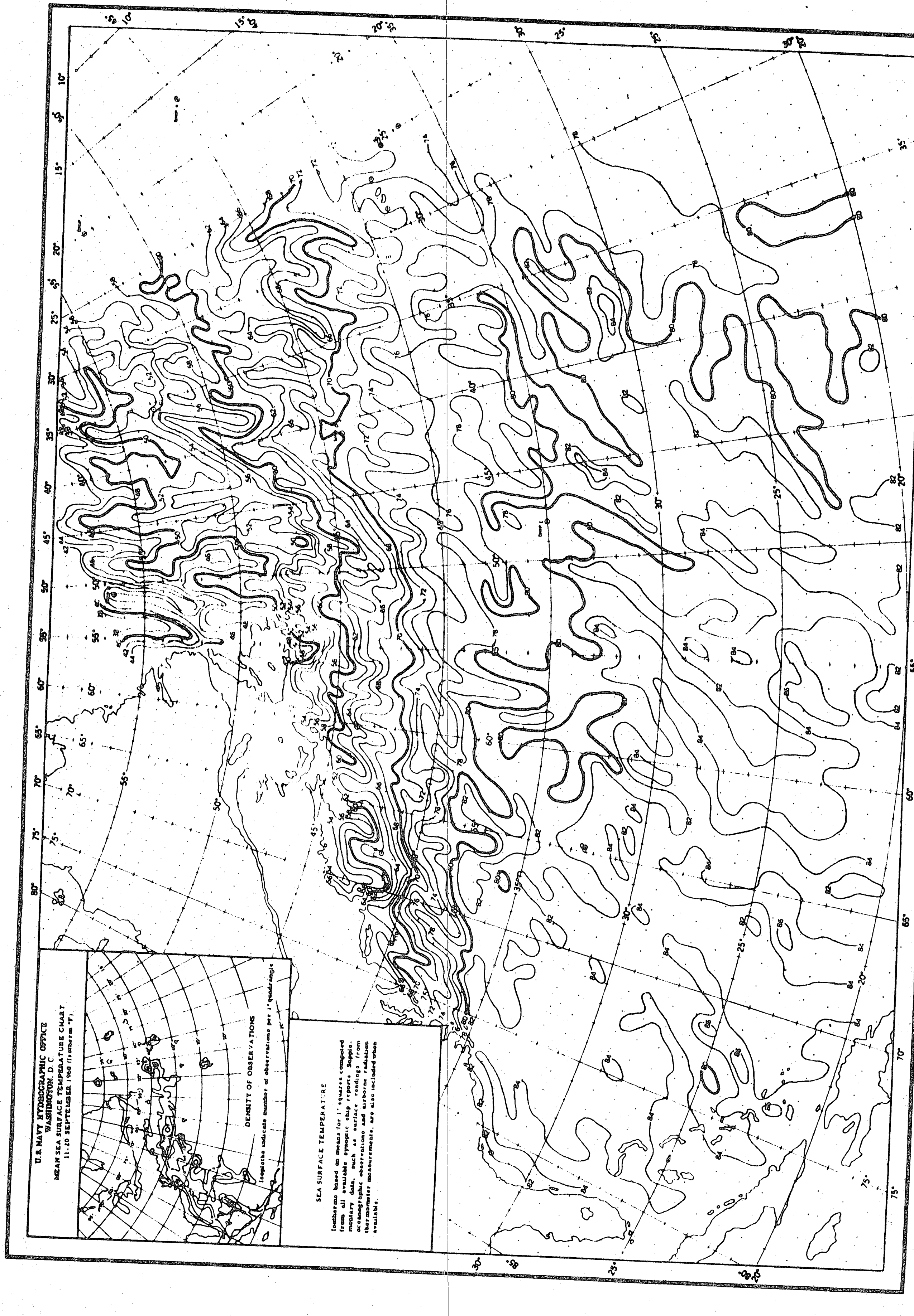

Fig. 2. A synoptic sea-surface temperature chart for 11-20 September 1960 (U.S. Navy Hydrographic Office).

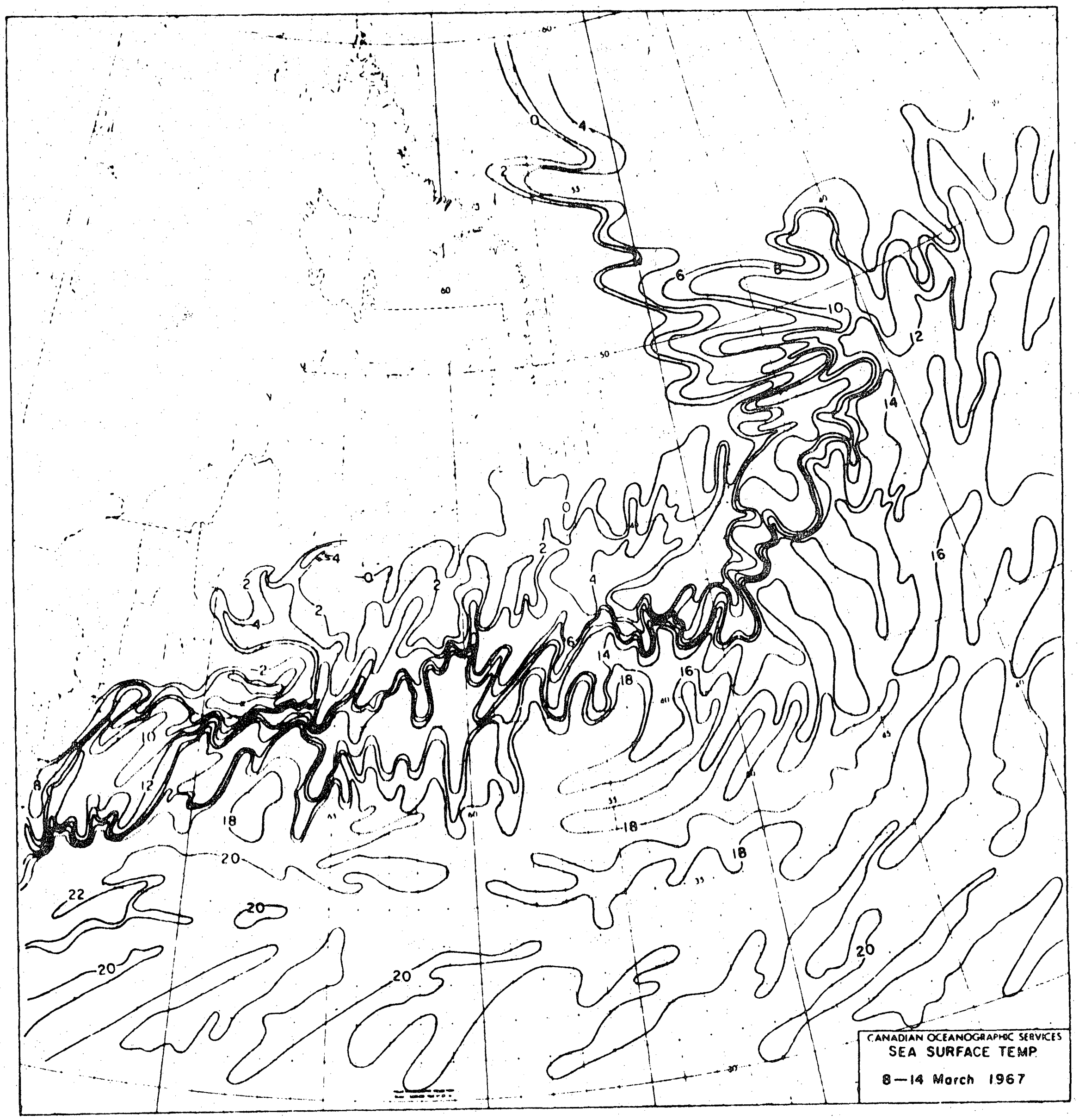

Fig. 3. A synoptic sea-surface temperature chart for 8-14 March 1967 (Canadian Oceanographic Services).

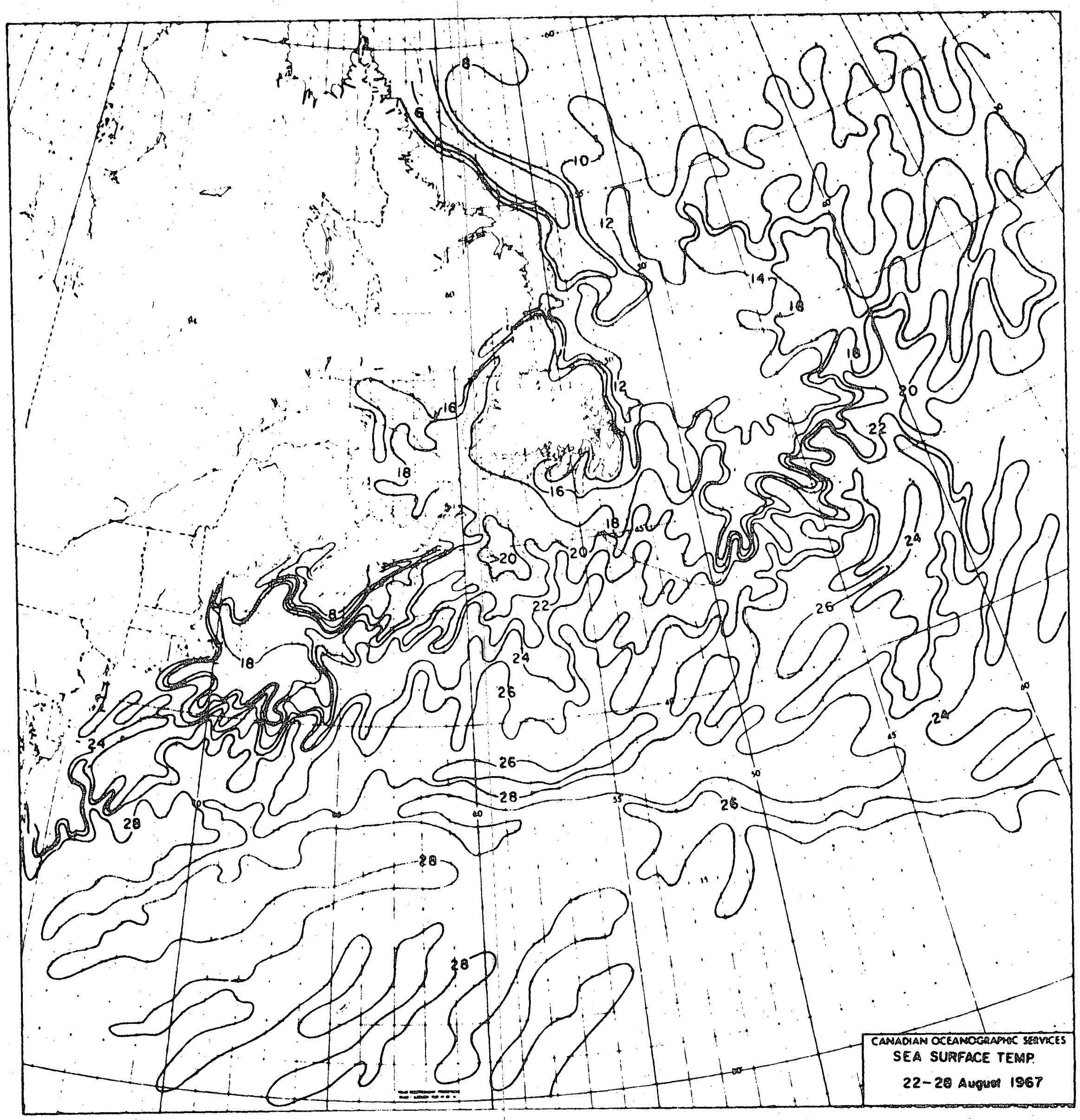

Fig. 4. A synoptic sea-surface temperature chart for 22-28 August 1967 (Canadian Oceanographic Services).

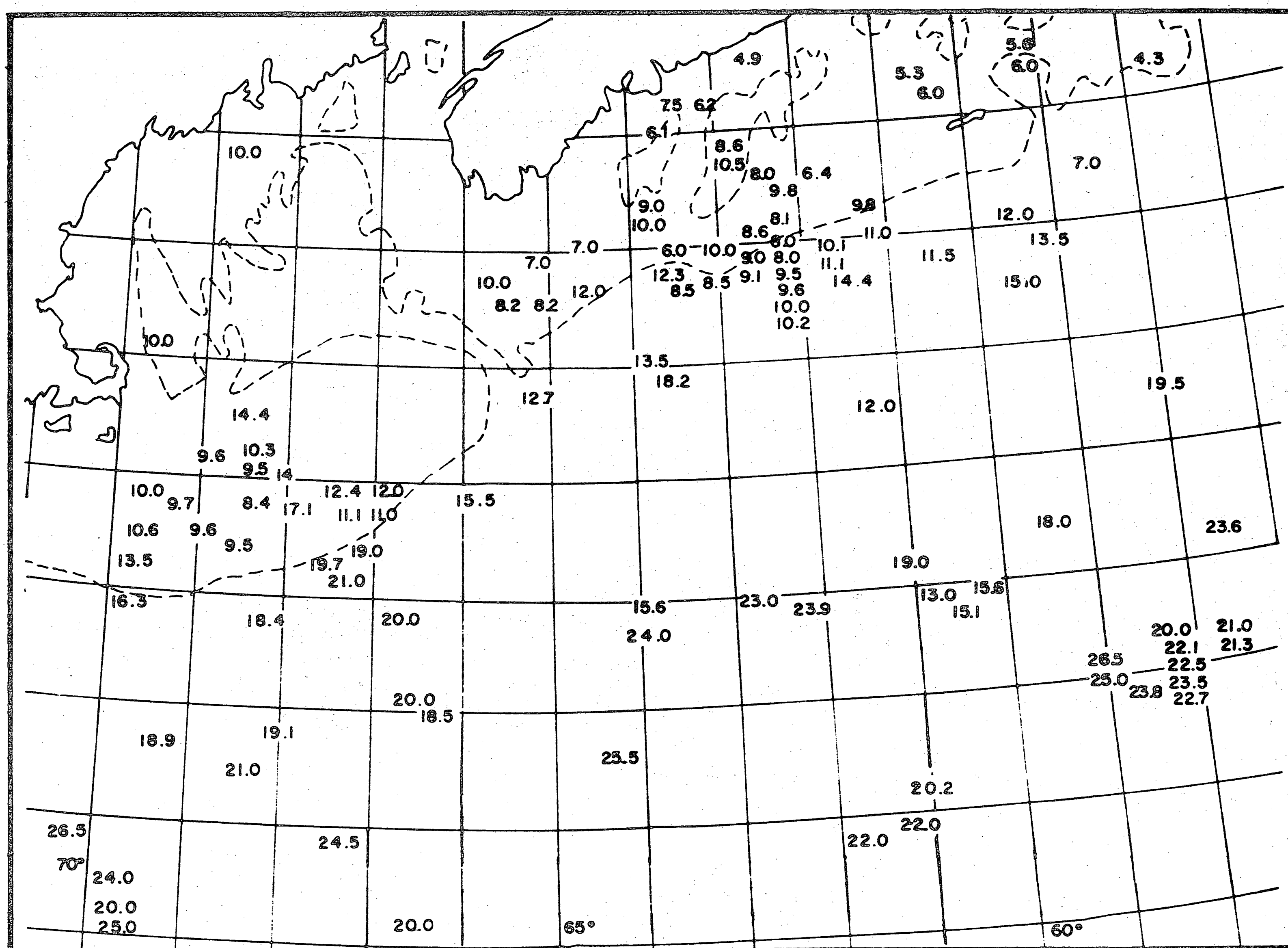

Fig. 5. Sea-surface temperature observations from marine weather reports from ships at sea, 30 May-5 June 1977.

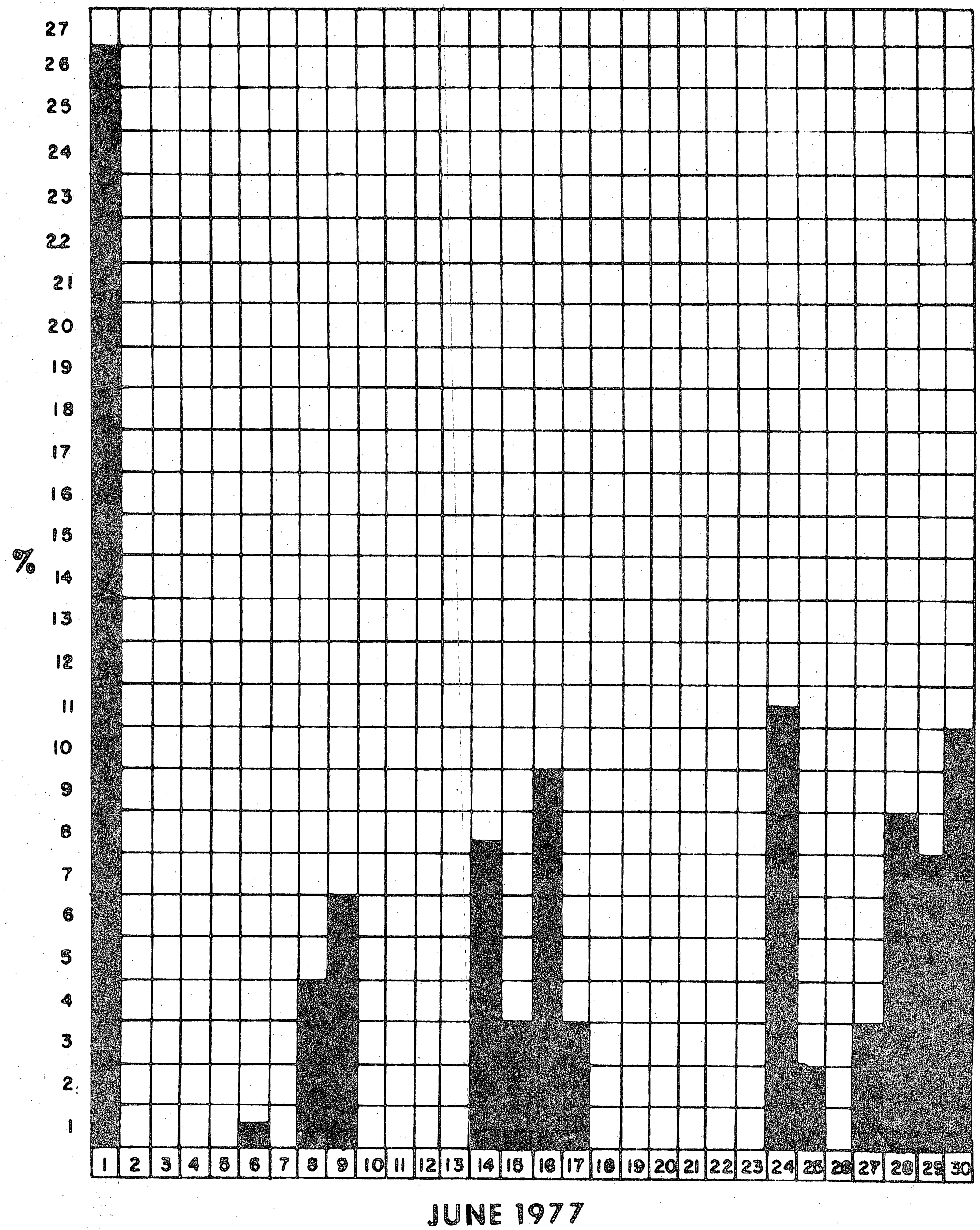

Fig. 6. Percentages of satellite imagery usable for each day in June 1977.

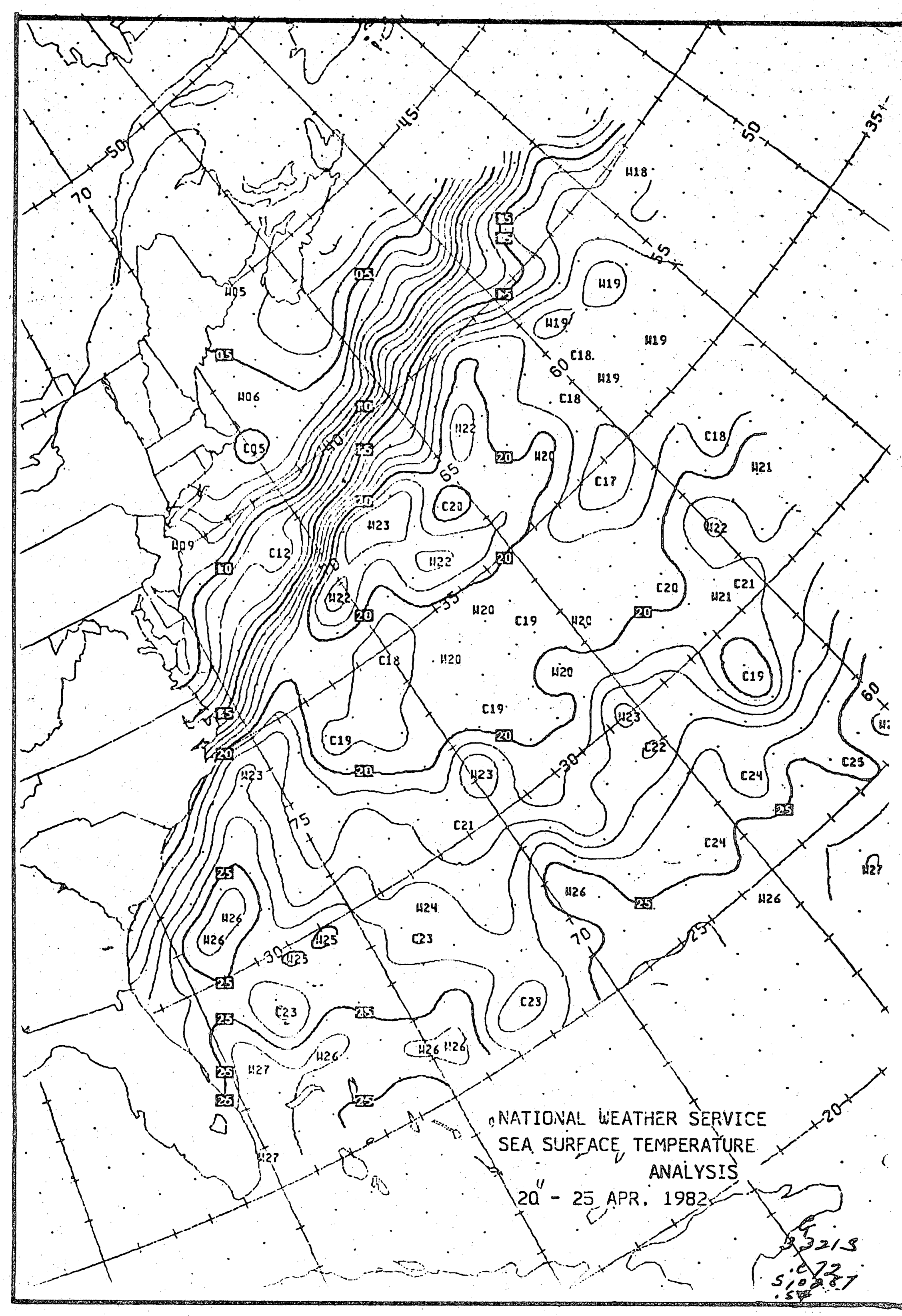

Fig. 7. A computer-generated sea-surface temperature analysis for 20-25 April 1982 (U.S. National Weather Service).

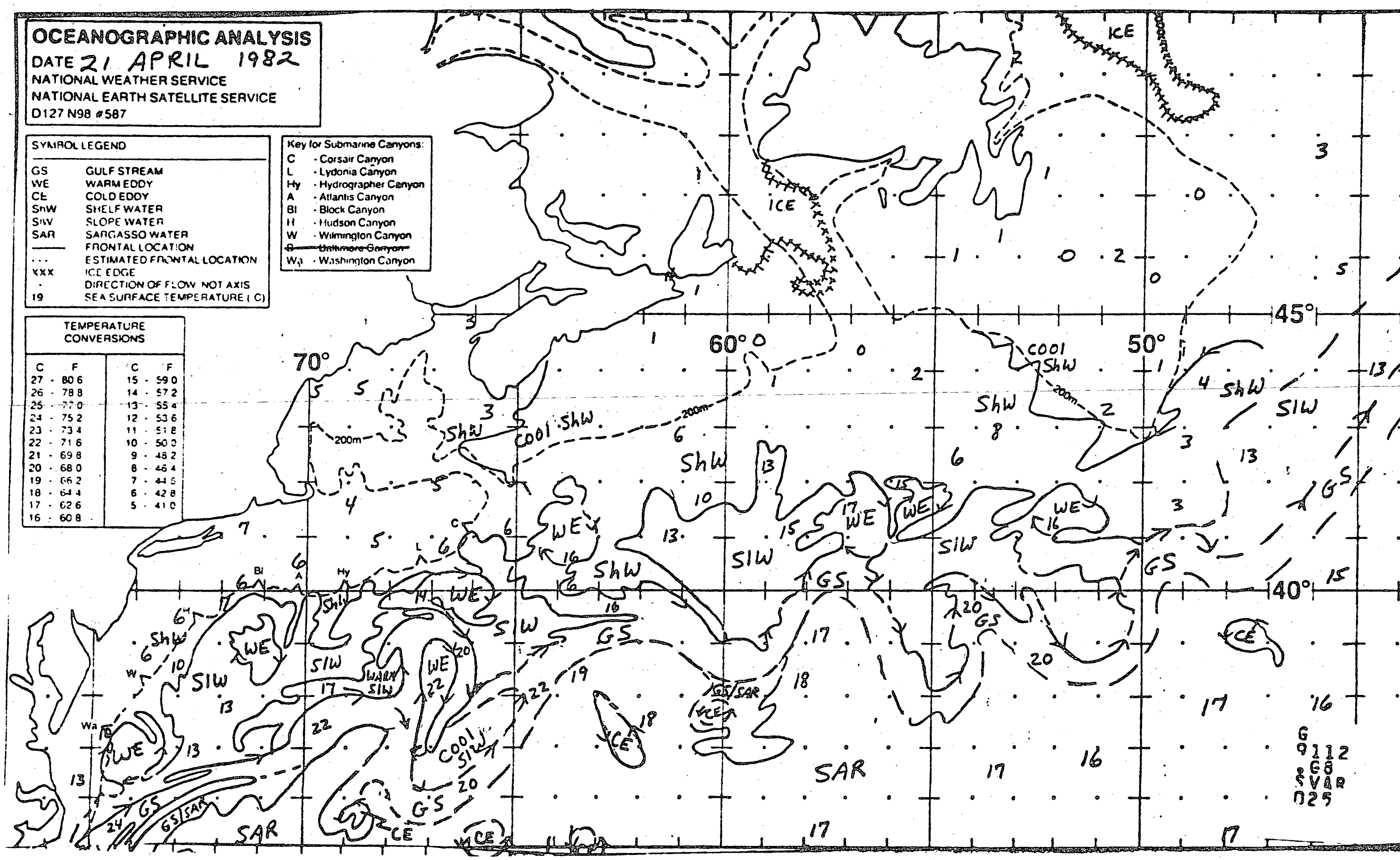

Fig. 8. A portion of the oceanographic analysis for 21 April 1982 (U.S. National Weather Service and National Earth Satellite Service).

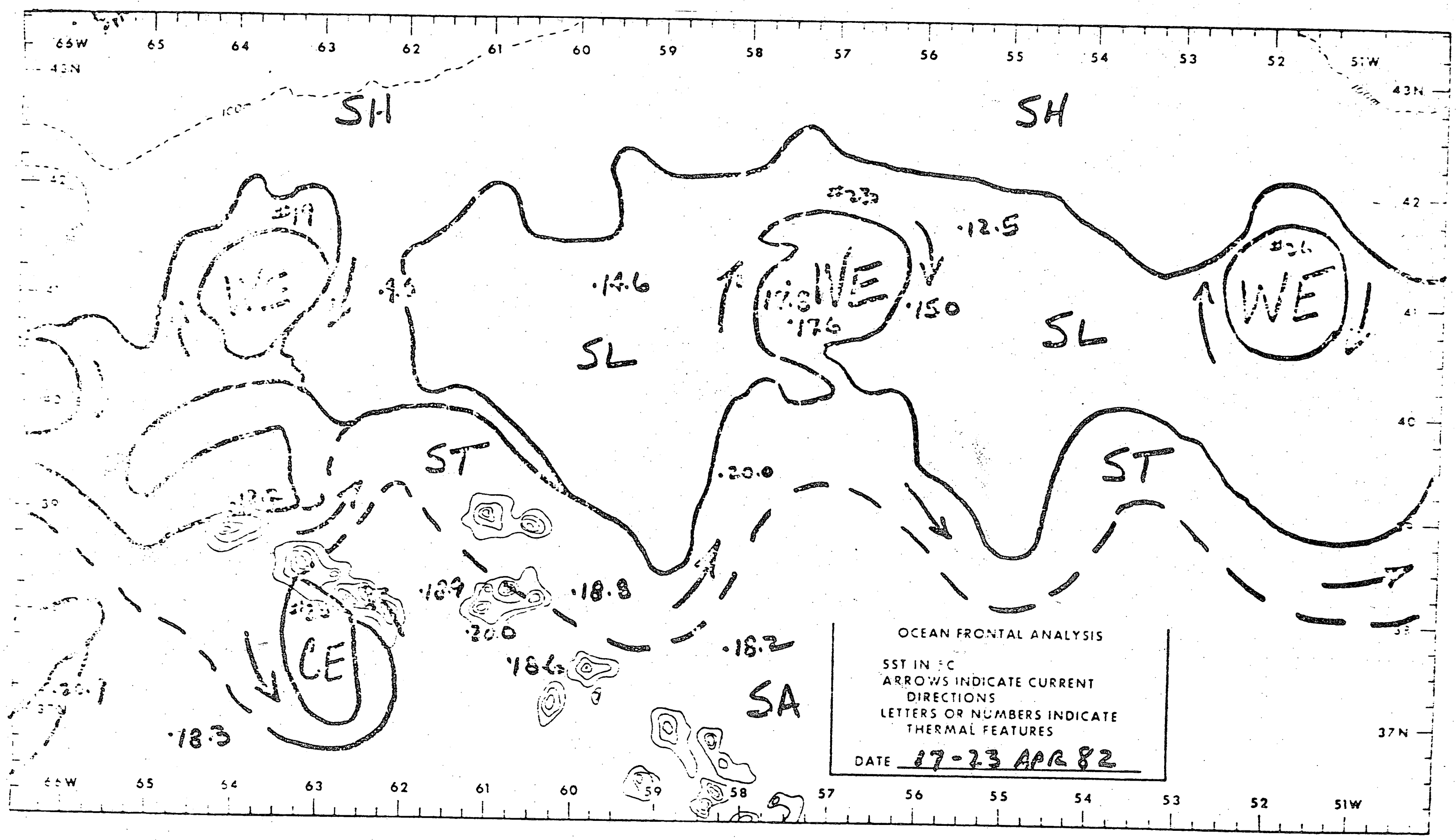

Fig. 9. A portion of the ocean frontal analysis for 17-23 April 1982 (U.S. Naval Eastern Oceanographic Center).

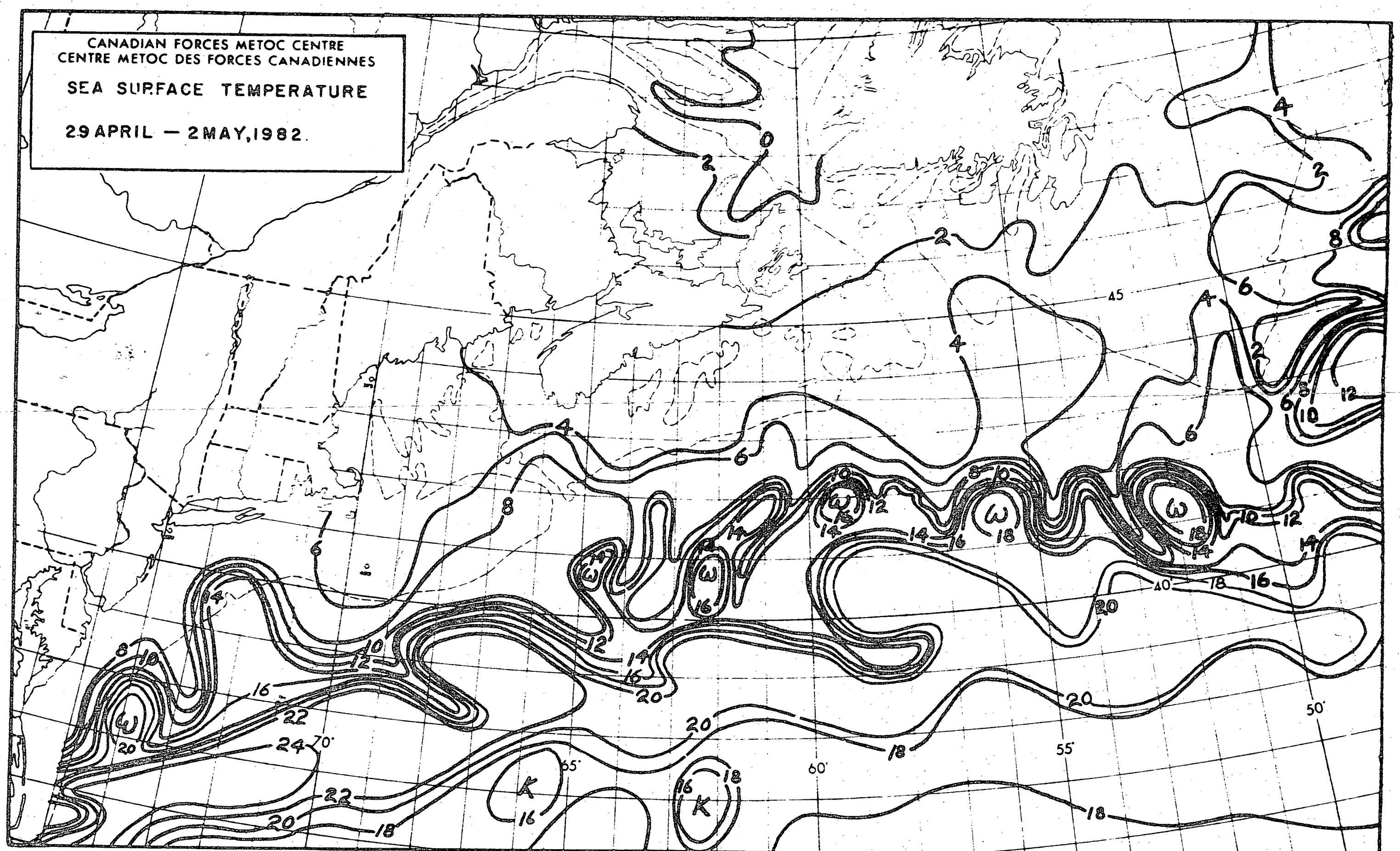

Fig. 10. A sea-surface temperature chart for 29 April-2 May 1982 (Canadian Forces METOC Centre).