SEA SURFACE TEMPERATURES IN WATERS SURROUNDING SWEDEN

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SMHI Rapporter

METEOROLOGI OCH KLIMATOLOGI

Nr RMK 1 (1974)

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T A B L E   O F   C O N T E N T S

SUMMARY

One of the sub-projects within the sea ice research programme carried out at SMHI deals with the thermodynamics of the sea and the ice. In these studies the sea surface temperature plays a fundamental role. During the latest years considerable efforts have been made in order to obtain more temperature observations, in particular from the open sea. Various vessels have been equipped with new instruments, the collection of observations improved, the sea surface temperature distribution analysed every second day and all information stored in digital form.

The instruments are discribed and their specifications given in the report. Various observational methods are compared and examples of sea surface temperature analyses for the period July 1973 - July 1974 illustrating yearly variations, tendency to circulation patterns, coastal effects, up-welling etc. are given.

SAMMANFATTNING

Ett av delprojekten i den havsisforskning som på uppdrag av Sjöfartsverket bedrivs vid SMHI, rör havets och isens termodynamik. Vid dessa studier spelar ytvattentemperaturen en fundamental roll. Under de senaste åren har därför mätverksamheten intensiverats, speciellt ute till havs, båtar har utrustats med nya fjärrinstrument, insamlingsförfarandet har rationaliserats, ytvattentemperaturens fördelning har analyserats varannan dag och informationen har lagrats i digital form.

Instrumenten och deras noggrannhet har beskrivits och mätmetoderna jämförts. Dessutom har ytvattentemperaturkartor för perioden juli 1973 - juli 1974, som visar variationerna under året, tendenser till cirkulationsmönster, kusteffekter och "up-welling", diskuterats.

1 INTRODUCTION

The Maritime Section of the Swedish Meteorological and Hydrological Institute (SMHI) has since many years collected sea surface temperatures from waters surrounding Sweden. The main objective was to follow the cooling in the sea from early autumn to the time of ice formation in order to be able to forecast the ice formation. The observations were mainly made at fixed locations along the coast, e.g. from lightships and lighthouses.

In connection with a winter navigation research programme, coordinated by the Swedish Administration of Shipping and Navigation, SMHI carries out an extensive sea ice research programme, including thermodynamic studies of the sea and the ice. During the last few years the number of sea surface temperature observations has therefore increased rapidly, in particular from the open sea through the participation of vessels of various kinds. In order to facilitate the observation of sea surface temperatures the Maritime Section has initiated the development and production of remote reading electrical thermometers. These are particularly intended for vessels with unmanned machine rooms, where the use of the conventional condenser intake method is inconvenient. The frequency of observations has been increased to three times per week for the fixed stations and more or less daily for the mobile stations.

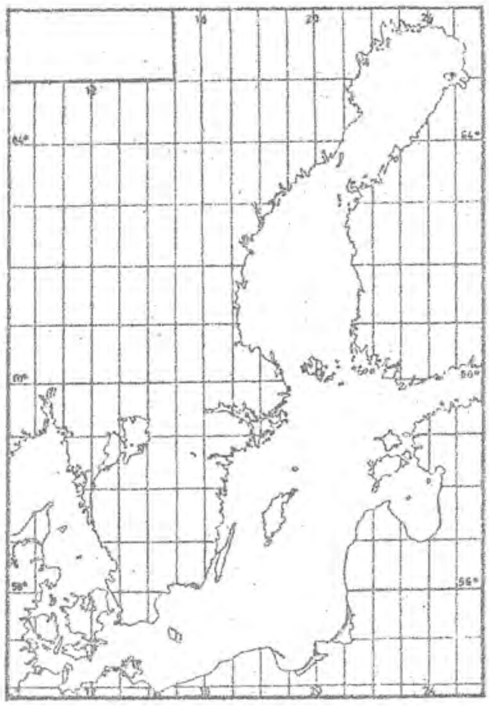

Fig 1. Sea areas for which sea surface temperature analyses are made.

From November 1972 the sea surface temperature distribution has been regularly analysed within the area shown in figure 1. From the beginning the analyses were mainly intended as input data for the sea ice investigation programme that is carried out within the Maritime Section but lately a growing interest for the sea surface temperature analyses has been expressed from other fields of application, e.g. ship companies, yachting clubs, oil companies, the navy, the air force and various other sections of the weather service.

2 OBJECTIVES

Reliable information about the water temperature, in particular the sea surface temperature, is fundamental when studying the thermal energy exchange between the atmosphere and the ocean and for forecasting ice formation. Figure 2 shows a schematic picture of the flow of energy, affecting the sea surface temperature.

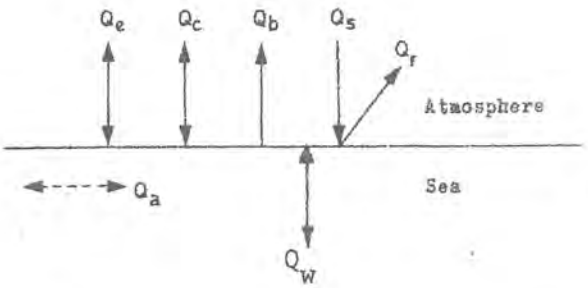

Fig 2. Thermal energy flow at the boundary between sea and atmosphere.

From figure 2 we can see that in the atmosphere we have a flow of energy to or from the sea through latent heat (Q_e) and sensible heat (Q_c). Further the atmosphere receives energy from the ocean through the outgoing long wave radiation (Q_b) and the ocean is receiving energy from the atmosphere through the short wave radiation (Q_s), part of which is reflected at the sea surface back to the atmosphere (Q_r). These transports of energy between the ocean and the atmosphere affect the sea surface temperature, which in turn also affects the flow of sensible heat and outgoing long wave radiation. Below the surface we have a vertical flow of energy (Q_W) as well as a horizontal advection (Q_a). The flux Q_a is caused by the energy transport to and from surrounding areas and consequently, when studying the temperature variation with time, it is also necessary to know the horizontal temperature distribution. For the sea ice investigation programme mentioned above it was not sufficient with information about sea surface temperature at fixed stations but a complete analysis of the temperature distribution over the whole investigation area was necessary. It has been possible to analyse sea surface temperature in this area since 1972, thanks to an increased number of observation points, better spacial distribution, increased frequency of observation, better instruments, improved data collection etc.

Apart from the sea ice investigation programme the sea surface temperature analyses have proved to be of interest for many other activities such as:

- Weather forecasting. In particular for cloud, precipitation and visibility forecasts the sea surface temperature analyses are of great importance.

- Marine and air force activities. The survivel time for a person in the water is to a high degree dependent on the surface temperature. Knowing the sea surface temperature distribution it is easier to deside on overflying certain areas and rescue programme in cases of accidents.

- Yachting activities, sporting etc. For the arrangements of races along the coast as well as off shore it is possible to take the necessary precautions in planning as well as during the events themselves.

- Certain other marin activities, transportation etc. For certain type of cargoes it is important to know the sea surface temperature. The same is the case for various types of coastal activities.

3 DEFINITIONS

The sea surface temperature may be measured by various types of instruments and from various types of platforms. A bucket thermometer can be used from a pier or bridge, from at caisson lighthouse, from the deck of a vessel. The temperature can be measured in the intake water on a ship. One can use remote reading with hull contact or through-the-hull thermometers. One can fly with infra-red instruments registering the temperature of the upper skin of the sea surface etc. These various methods will not measure the temperature at the same depth and the definition "sea surface temperature" is therefore not always well defined. With the infra-red radiation thermometer one measures the so-called skin temperature, which is the temperature of the upper millimetre of the surface. With the bucket method one measures the temperature in the nearest one metre, while the intake and the hull contact thermometers may measure the temperatures from one to ten metres below the sea surface.

Normally the upper part of the sea can be divided into 3 different layers:

(a) The skin layer, which is only a few tenths of a millimetre and is strongly influenced by the atmospheric conditions.

(b) The mixed surface layer, where the vertical temperature variations are very small. The mixing is due to mechanical turbulence and thermal convection and the depth varies with the season from less than one metre to tens of metres.

(c) The thermocline layer in which considerable vertical temperature variations occur.

In this report the term sea surface temperature will be considered as a temperature representative for the mixed layer. In those cases, where the infra-red radiation thermometer has been used, corrections have been applied in order to obtain comparable values. In the same way we have tried to introduce compensations for low placed sensors.

The observations are taken at positions representative for the open coast and the sea outside the coast. The temperature in narrow inlets, harbours, shallow beaches etc. may therefore in many cases differ from the temperatures reported and shown in the analysis.

4 INSTRUMENTS AND METHODS

4.1 Bucket thermometers

With the bucket method one may in the simplest case only fill a bucket with water and measure the temperature with a separate thermometer, making sure that it is as far as possible sheltered from sunshine or strong winds to avoid changes in the temperature because of radiation or evaporation. A better method is to use a small bucket with a built-in thermometer, which can be lowered into the water, where it is held for about 3 minutes in order to completely fill the bucket with water and allow the bucket to adjust completely to the water temperature. When the bucket is lifted out of the water the temperature can be quickly read thus minimizing the atmospheric effects. The accuracy of such a temperature reading is $\pm$ 0.1° C. At SMHI only the method with built-in thermometers is used. In this case the bucket is made in steel and connected to a cylinder, in which a mercury thermometer is placed. Two types of buckets are in use, one with a bucket containing 60 ml water weighing about 320 gram and filling immediately when lowered into the water, see figure 3a. The other has a bucket containing 435 ml water with total weight of 1190 gram, see figure 3b. The latter bucket has a smaller intake, dimensioned for a filling period of about 3-4 minutes, thus allowing time for the bucket to adjust to the water temperature before taken up. Air bubbels are let out during the filling period and thus indicating when the bucket is completely filled with water.

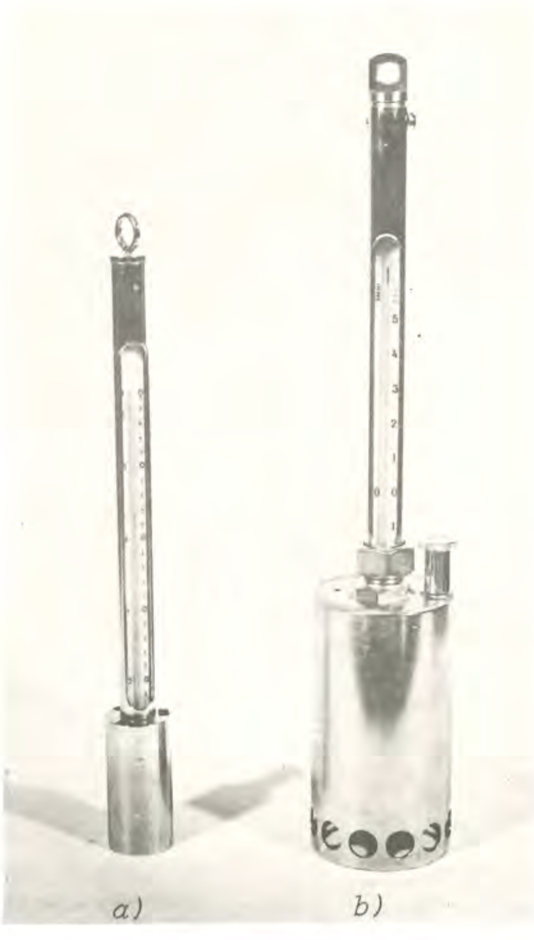

Fig 3. Bucket thermometers
a) Small type
b) Big type

4.2 Condenser intake thermometer

This method implies that the temperature of the condenser intake water is measured when circulating past a mercury thermometer, placed in a steel cylinder, screwed into the intake pipe, see figure 4. The thermometer is placed as close to the hull as possible and between the hull and the water pump. If this thermometer is conveniently situated and the reading carefully performed, the accuracy of the measurements is comparable with the bucket method. It is, however, not always possible to get the true surface temperature as the condenser intake normally is placed well below the water line at a depth that will vary with the loading of the ship. In stratified water the measurements may show significant variations and this is in particular observable during the summer season.

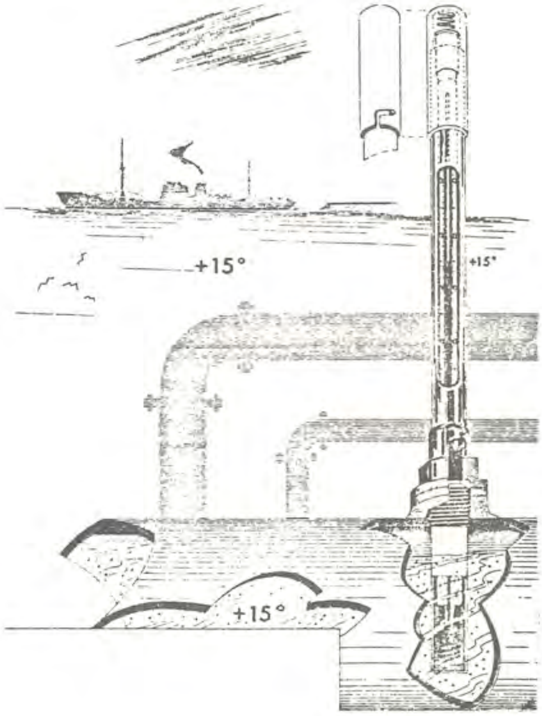

Fig 4. Condenser intake thermometer.

4.3 Electrical, remote-reading thermometers

The electrical, remote-reading thermometers are based on the fact that the resistance in a thin wire will vary with the temperature. A sensor is placed in direct contact with water or attached to the inside or the outside of the ship hull, which quickly adjusts to the temperature of the water. By cable the sensor is connected to a reader unit placed either on the bridge of the ship or in the machine control center for convenient reading. Several sensors may be connected to the reader instrument. It is thus possible, by placing sensors at different levels, to read the temperature at a constant depth independent of the loading of the ship. Two different types of electrical remote-reading thermometers are used by SMHI for installation onboard ships:

(a) Digital temperature meter for Pt 100 transducers.

With this instrument the temperature may be read directly on a digital display and a switch permit six individual sensors to be attached. The instrument is produced by the firm System-

teknik AB, Sweden, and carries the number S 1062. It corrects for the nonlinearity of a 100 ohm platinum resistance transducer. The instrument is shown on figure 5 and technical specifications are given in Attachment A.

Fig 5. Digital temperature meter

Two types of sensors are at present used together with the reading instrument. One is a through-the-hull, immersion type sensor with fitting in stainless steel, see figure 6.

Fig 6. Through-the-hull immersion sensor (Pt 100)

The other is a contact sensor that is glued directly to the inside of the hull and insulate from inside with 5 cm frigolit, see figure 7. Both sensors are Pt 100 transducers, produced by the firm SWEMA, Sweden.

Fig 7. Hull contact sensor (Pt 100)

(b) Remote temperature meter for linear transducers, type LL 1.

The reading instrument is in principal a Wheatstone bridge, which is set to zero by a precision potentiometer connected to a digital scale. The zero-setting is sensed by two light emitting diods. The sensor, CUPROSWEM produced by SWEMA, Sweden, is of contact type and the resistance is linearily dependent on the temperature. No conversion table is thus necessary and it is possible to read the temperature directly from the instrument. The instrument and the sensor is shown on figure 8 and specifications are given in Attachment B.

Fig 8. Remote temperature meter, type LL 1, with the Cuproswem sensor

4.4 Infra-red radiometer, type BARNES IT2-S

This instrument measures the radiation energy that is emitted from the earth surface within the wave length interval 8 to 13 µm, an interval within which the water can be regarded as an ideal black body. The instrument consists of a detector head, an indication instrument and a curve plotter, see figure 9. The detector senses the radiation from the water surface as well as a carefully calibrated reference body. The radiation difference between the two bodies is converted into an electrical impulse which is transferred to the curve plotter. The instrument is mounted in a small aeroplane. When flown below 300 metres in clear weather it measures the temperature with an accuracy of about ± 0.5° C and a resolution of 0.2° C.

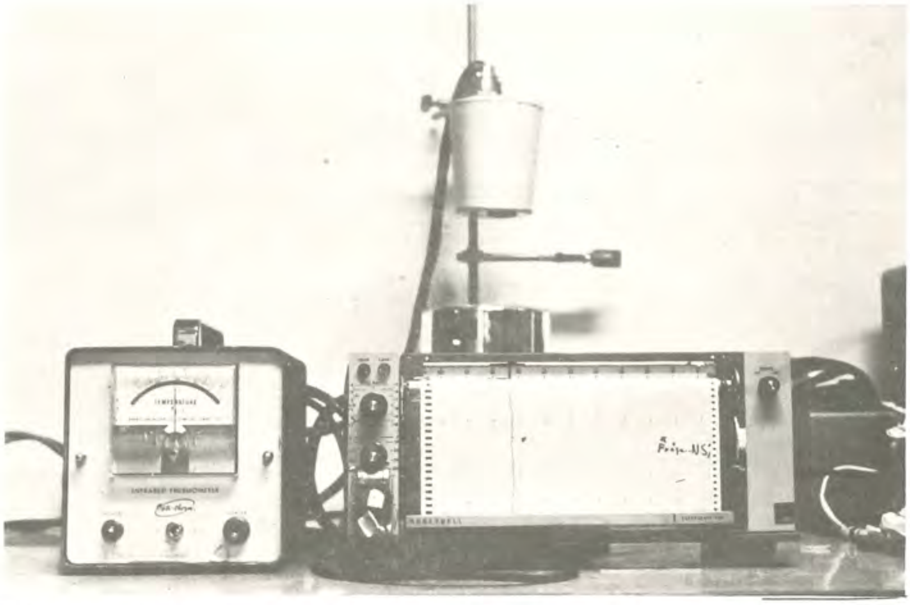

Fig 9. Infra-red radiometer, type BARNES ITS-2

4.5 Comparison between the different types of instruments

Table 1 shows the type of instrument used on various platforms.

TABLE 1:

Instruments used on various platforms		
Instrument	Number	Platform
Bucket (small)	37	Fixed stations Pilot vessels
Bucket (big)	21	Fixed stations Coast guard Pilot vessels
Condenser intake thermometer	4 4	Ferries Merchant vessels
Remote-reading electrical thermometer, type LL 1	4 5	Ferries Merchant vessels
Remote-reading electrical thermometer, type S-1062:		
with through-the-hull sensor	5	Icebreakers
with contact sensor	5	Icebreakers

The bucket thermometer, which is a simple and cheap instrument, is suitable for use on fixed stations or nonmobile platforms. Onboard ships the instrument is less suited as it requires the vessel to stop or considerable slow down the speed during measurements of the sea surface temperature. This in particular as accurate measurements requires the bucket to remain in water for at least 3 minutes before reading. Condensor intake thermometers are therefore better suited for use onboard mobile stations. One drawback is, however, that the depth on which the reading is made will depend on the type of the vessel and its loading. In addition it is not always easy to obtain an accurate reading of a mercury thermometer in a machine room with a lot of other installations.

In order to facilitate the measurements of the sea surface temperature from moving vessels and in particular from vessels with unmanned machine rooms, the above described electrical remote-reading thermometers were developed. Comparisons between the electrical thermometer and the bucket thermometer have shown very good correlations. An increased number of ships will therefore be equipped with these types of instruments. The digital instrument discribed under 4.3 (a) is, however, fairly expensive, why the Maritime Section took the initiative to the development of the LL 1 remote temperature meter. The LL 1 is a simple and a relatively cheap instrument (about 800 Sw.Cr.), it is easy to install and easy to read. The contact type sensor may also be placed in the scientifically best position with respect to depth and outlets of hot water from the ship. This in contrast to the fixed position of the intake thermometer.

The airborne infra-red radiation thermometer has a number of advantages. It is fairly easy to use and can cover vast areas in fairly short time. A disadvantage is, however, that it can not meet the accuracy requirements of 0.1° C but it may still give horizontal gradients to an acceptable degree of accuracy. Another disadvantage is the relatively high cost of the platform and that it is dependent on environmental conditions such as the weather, which limitates its usefulness.

5 NETWORK AND COLLECTION

Sea surface temperature observations are made from a number of fixed stations e.g. lighthouse personel, militaries and fishermen living in the outer archipelagoes, from moving stations by the crew on ferries, merchant vessels, coastguard vessels, pilot vessels and icebreakers. The positions of the fixed stations as well as the main ship routes are given on figure 10 and on Attachment C.

By July 1974 the number of fixed stations were 43. They are all using the above described bucket thermometers. The sea surface temperature is measured every Monday, Wednesday and Friday between 9 and 10 o'clock. The pilots measure the sea surface temperature at various times of the day depending on their work and normally at least one observation is received per day. The observations are telephoned to the nearest meteorological collecting center and from there transmitted to SMHI by teleprinter. Some observations are transmitted directly to the Institute by telephone or telex.

Of the moving stations the ferries are an important source of information as they are playing regular routes and thus observations can be made regularily at the same time and at fixed positions. The ferries use partly the condensor intake thermometers, partly the electrical remote-reading thermometer of the type LL 1. Immediately after arrival to port the observations are telephoned to the nearest collecting center or directly to SMHI.

The number of merchant vessels that regularily report the sea surface temperature are at the moment 9. They are mainly recruited from the ship companies Cementa, SCA and Gorthon, which all regularily traffic the Baltic region as well as the Gulf of Bothnia. Observations are made every three hours in open sea. Special logs are completed and mailed to SMHI immediately the vessel arrives in port. During the winter season, but even to some extent during the summer, the observations are sent via coastal radio stations to SMHI. Observations are also received from the so-called "selected ships", which make regular weather observations including sea surface temperature measurements every three or six hours. As can be seen from figure 10b the western part of the Baltic and Gulf of Bothnia is fairly well covered, while the eastern part contains less information. This because the Swedish ships normally traffic the western part of the Baltic.

The coast guard measures the sea surface temperature when on mission in the outer archipelagoes or the regions outside the coast. The coast guard vessels are all equipped with the version (b) of the bucket thermometer (see figure 3b) and the number of vessels measuring the sea surface temperature is at present 21. The coast guard measures also the deep water temperatures at special points and is for this reason equipped with bathytermographs. The observations are transmitted to SMHI in code form via the coast guard communication centers.

During the winter season 5 icebreakers make sea surface temperature observations, when in open sea. They are equipped with the digital temperature meter discribed under 4.3 (a) and have a through-the-hull as well as a hull contact sensor. The observed

temperatures are transmitted to SMHI via coastal radio stations or by telecopier. The water temperature logbooks are sent to SMHI by mail. Most of the icebreakers also make full weather observations.

In addition to the Swedish observations, reports are received from surrounding countries. Denmark and Norway have a number of coastal stations observing the sea surface temperature. These temperatures are reported daily in the regular weather messages SYNOP. During autumn and winter observations are also received from Finland, who has 8 fixed stations, 4 ferries and one research vessel, Aranda, that normally makes extensive cruises in the Gulf of Bothnia in the beginning of the winter. During the winter season Poland reports the sea surface temperature from 5 fixed stations along the coast.

During the last two years trials have been made to supplement the ordinary sea surface measurements with an airborne infra-red radiation thermometer. The measurement has normally been carried out the first few weeks before expected ice formation and the purpose has been to more accurately follow the cooling of the surface water during these periods.

As can be seen from figure 10, the network has still a number of gaps, mainly in the eastern part of the Baltics but during the summer period also in the eastern part of the Gulf of Bothnia. Efforts are being made in order to improve the network.

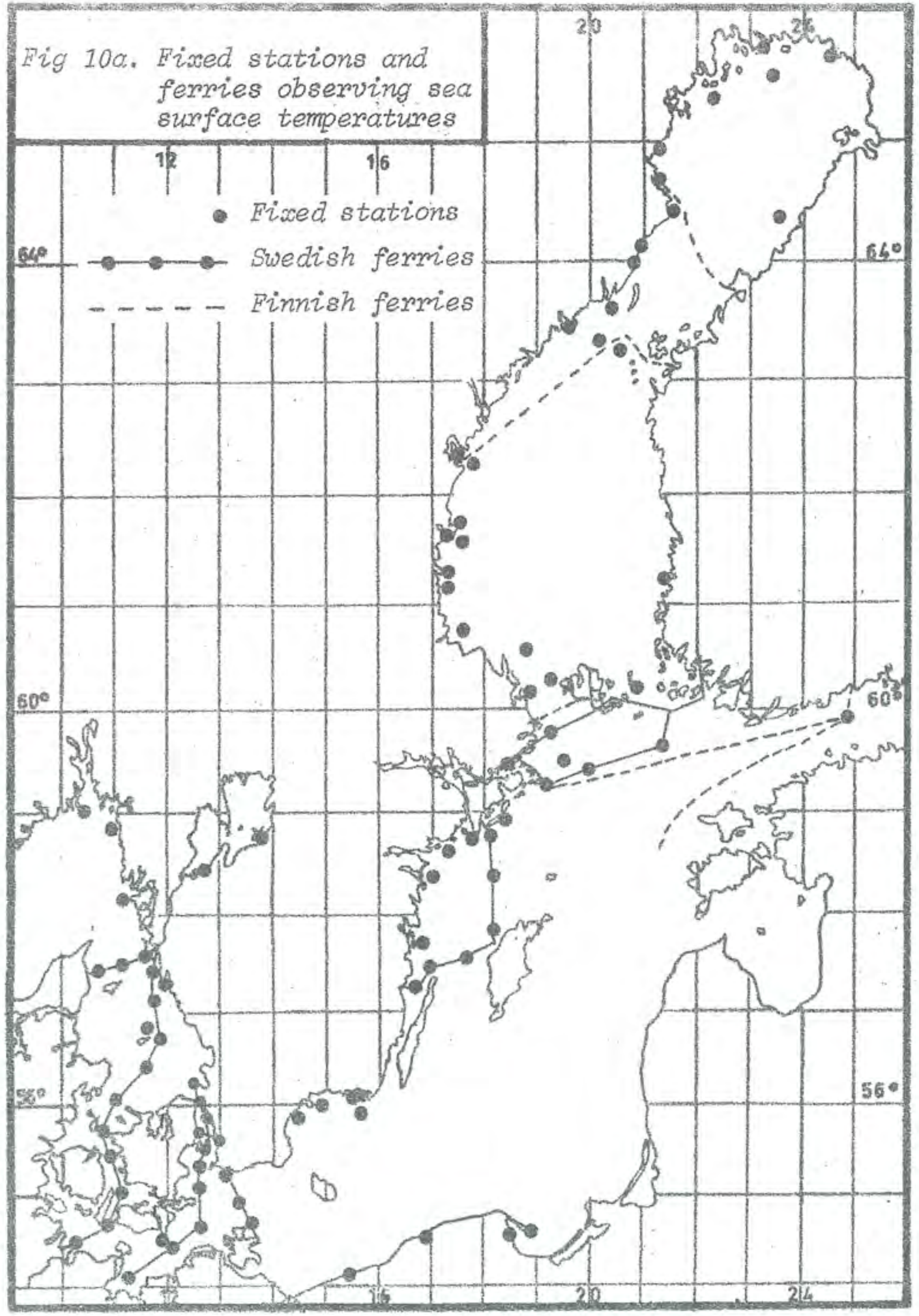

Fig 10a. Fixed stations and ferries observing sea surface temperatures

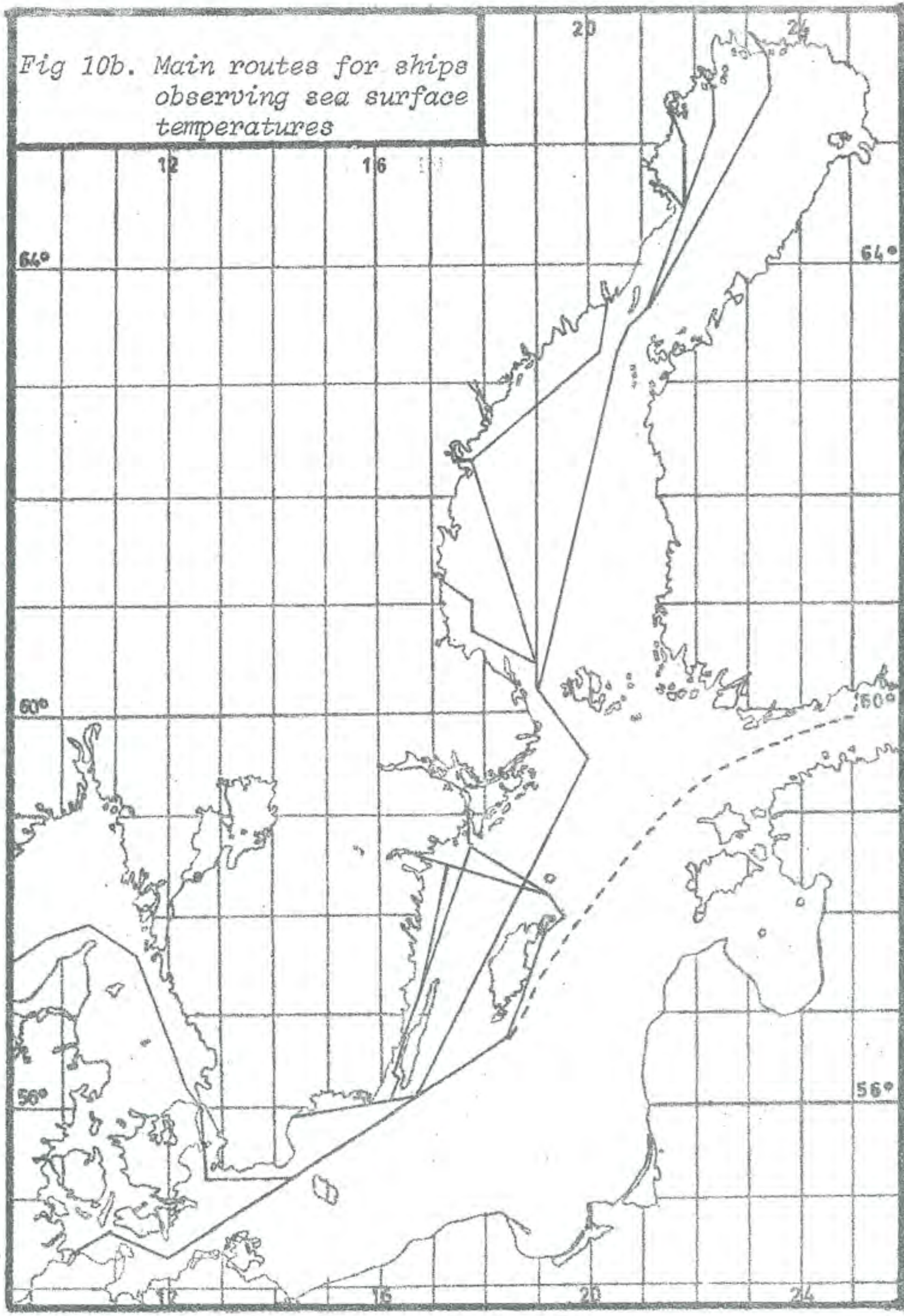

Fig 10b. Main routes for ships observing sea surface temperatures

6 ANALYSES

6.1 Plotting and analysis procedures

When received at SMHI, the sea surface temperatures are plotted on a map. In order to have sufficient data for a reliable analysis observations from two successive days are plotted on each map but with different colours. The number of observations per map is normally around 150. The sea surface temperatures are analysed every second day. Although the observations are from two successive days and different times of the day, depending on whether they are made at fixed or mobile stations, the analyses will represent the mean conditions for the last day. This means that if observations are available from the same point for both of the two days greater emphasis is placed on the latest observation. Isotherms are drawn for every whole degree Celsius with occasional half degree isotherms drawn in areas with weak gradients. Warmer and colder areas are marked with a "W" respectively "C" (see Attachment D).

6.2 Error sources

The sea surface temperature analyses may not always depict the exact temperature distribution for several reasons. Apart from the instrumental errors, discussed in chapter 2, there are some other sources of error that will be discussed below.

(a) Daily variation

The sea surface temperature has a certain daily variation. The amplitude between maximum and minimum is greatest when the incoming radiation is greatest and when the turbulent mixing is small, that means at clear sky conditions, weak winds and relatively sheltered waters. The daily variations will normally not create any significant errors in the analyses but under certain conditions the fact that the measurements are not made at the same time of the day may give an error in the analysis estimated to maximum 1° C.

(b) Thin mixing layer

The mixed surface layer will,as mentioned earlier, vary considerably in thickness and may under certain conditions during the summer not even exist. In these cases the vertical temperature gradient below the surface may be considerable. Table 2 gives the water temperatures at various depth during certain days the year 1973. From the table it can bee seen that the upper 10 metres may be well stratified during July but even during May, June and August. The temperature gradient is greatest during calm days with a minimum of turbulent exchange in the upper layer of the water. Due to this relatively strong temperature gradient that may occur frequently during the summer period the reported temperatures will depend on the methods used for measurements, e.g. bucket or condenser intake. The error may amount to several degrees Celsius.

Also when the thermocline is shallow considerable horizontal temperature variations may occur. These differences are often very local. They are difficult to distinguish from

measurement errors and therefore difficult to correct in the analyses. The maximum error is estimated to some degrees Celsius.

(c) Other sources of error

Occasionally the temperature observations from a certain region will be missing, either because the observer has not been able to observe at that particular day or that no ships have passed the area during the period in question. In these cases the temperatures are estimated through the use of earlier maps, knowledge about the passed weather or, when possible, interpolation from surrounding measurements.

From a, b and c above it becomes clear that the sea surface temperature maps are difficult to analyse during the summer period, when significant local variations in the temperature may occur for various reasons. Already during August, when the thermocline normally is found at a greater depth, the temperature variations become smaller, the maps easier to analyse and therefore also more accurate.

TABLE 2:
The sea water temperature in °C, measured at three positions during 1973

LANDSORTSDJUPET (Position: N 58°35,1´ E 18°13,2´)

Depth (m)	Date: 7/1	26/2	12/3	15/4	9/5	6/6	22/7	31/8	30/9	22/10	26/11
0.5	4.5	2.5	2.4	3.5	6.1	11.9	17.8	13.7	9.5	8.0	4.7
10	4.5	2.3	2.4	3.5	4.9	7.6	9.9	12.3	9.5	8.1	4.7
20	4.5	2.4	2.5	3.3	3.4	5.8	8.9	7.7	10.1	8.1	4.7
t(0.5)-t(10)	0	0.2	0	0	1.1	4.3	7.9	1.4	0	-0.1	0

SEA OF ÅLAND (Position: N 60°12,1´ E 19°06,6´)

Depth (m)	Date: 4/3	15/4	22/5	23/6	22/7	27/8	30/9	25/10	21/12
0.5	1.1	2.4	5.8	11.1	18.2	13.0	9.0	6.9	1.1
10	1.1	2.3	4.1	9.8	12.3	12.8	8.9	6.9	1.1
20	1.7	2.2	4.2	7.0	5.9	12.7	8.6	6.9	2.0
t(0.5)-t(10)	0	0.1	1.7	1.3	5.9	0.2	0.1	0	0

HÖGBONDEN (Position: N 62°55,0´ E 18°57,0´)

Depth (m)	Date: 12/1	5/5	7/6	5/7	2/8	8/9	6/10	18/11
0.5	2.0	2.1	9.2	18.1	18.3	10.6	7.8	3.3
10	2.3	2.2	6.6	7.2	17.9	10.6	7.8	3.3
20	2.4	2.0	4.2	3.5	5.8	7.9	7.9	3.4
t(0.5)-t(10)	-0.3	-0.1	2.6	10.9	0.4	0	0	0

7 EXAMPLES OF ANALYSES

The selected maps from the period July 1973 to June 1974, shown on figures 12 to 23, illustrate how the sea surface temperatures may vary during the year. They also show the existence of upwelling regions along the coast during the summer period and the tendency to certain circulation patterns in the Gulf of Bothnia.

7.1 Seasonal variations

The maps from July 1973, figures 12 and 13, show generally high temperatures. The Westcoast and the Baltic proper had temperatures around 20-23° C, which was the maximum for that year. As a comparison it can be mentioned that the temperature during the same period in 1974 was only 14-16° C. The highest temperature in the Gulf of Bothnia occurred in the middle of July and was 20-22° C. Corresponding value during 1974 was 13-14° C. Figures 12 and 13 further show that the temperature difference from north to south is small during the summer period.

The maps in figures 14 to 20 show the cooling during the autumn and winter. Already 1 September the temperature at the northern coast of the Bay of Bothnia had decreased from 20 to 9° C, while in the southern part of the Baltic the temperature had only decreased a few degrees Celsius. One can further observe that the cooling starts at the coast and continues out towards the open sea. Pronounced temperature gradients occur along the coast as can be seen in the Bay of Bothnia on figure 15. Distinct temperature gradients can later be seen in the Baltic and at the Westcoast. The maps show that during the cooling period the warmest water can be found at sea, which is natural as one there has the greatest heat capacity. Further, the temperature difference between the northern and the southern part increases during autumn. From figure 17 it can be seen that the Baltic proper is nearly 10° warmer then the northern part of the Bay of Bothnia. Later during the winter this temperature contrast decreases again, when the ice period starts. In figure 20 the Baltic proper is only 3° warmer than the Sea of Bothnia where the temperature is close to 0° C.

From the end of March the water starts warming from the south. The warming begins from the coast and continues out towards deeper water. From figure 22 and figure 23 it can be seen that great temperature gradients are again developed along the coast but these are opposite to those seen on the autumn maps. The lowest temperatures are found out at sea, and again one can observe the considerable temperature contrast, about 10° C, between the Baltic and the Bay of Bothnia.

7.2 Local variations

During the summer period local and rapid temperature variations are often observed on the maps. One striking effect is the upwelling, which occurs when the warm and the strongly stratified surface water is transported out from the coast by wind and current and replaced by colder bottom water. Examples of upwelling along the Swedish coast of the Bay and Sea of Bothnia, along the eastcoast of Gotland, outside Landsort and along the Skåne eastcoast can be seen from figures 11 to 14. The rapid temperature changes have a considerable importance for visibility and fog forecasting for the navigation.

7.3 Tendency to circulation patterns

During the autumn and first part of the winter the horizontal temperature gradients are often greater on the Finnish side of the Gulf of Bothnia than on the Swedish side. Also somewhat higher temperatures can be observed on the Finnish side. This may indicate a water transport from south with a counter-clockwise circulation in the Sea of Bothnia (see figures 18 and 19) and to a certain extent also in the Bay of Bothnia (see figure 15). However, the temperature pattern may just reflect the bottom topography.

It should be observed that the map series are only an example of water temperature analyses and should not be judged as normal maps for the period, in particular as the winter 1973/74 was extremly mild and the extent of ice was exceedingly small.

8 DATA STORAGE

The sea surface temperature information is available in various forms and stages of processing.

8.1 Observations

All observations from fixed stations, including ferries, are tabulated in station order day by day.

Observations from stations with long records have been placed on magnetic tape. Observations from mobile stations (ships, coast-guard etc.) are stored on the log sheets.

8.2 Analyses

The analyses are available in chart form as well as grid point values. The charts are available for every second day starting from 1 November 1972. They all include plotted data.

The grid used for digitizing is geographical with a grid distance of 15´ latitude and 30´ longitude which, at the actual latitude, gives a close to square grid with a distance of 27.8 km. The grid is shown on figure 11. The grid values are stored on magnetic tape.

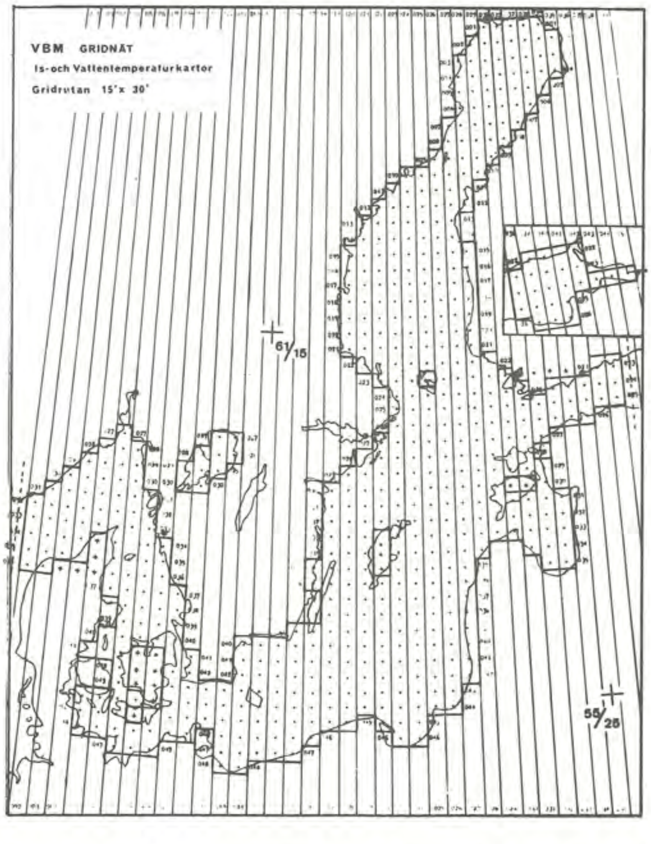

Fig 11. Geographical grid used for digitizing sea surface temperature analyses.

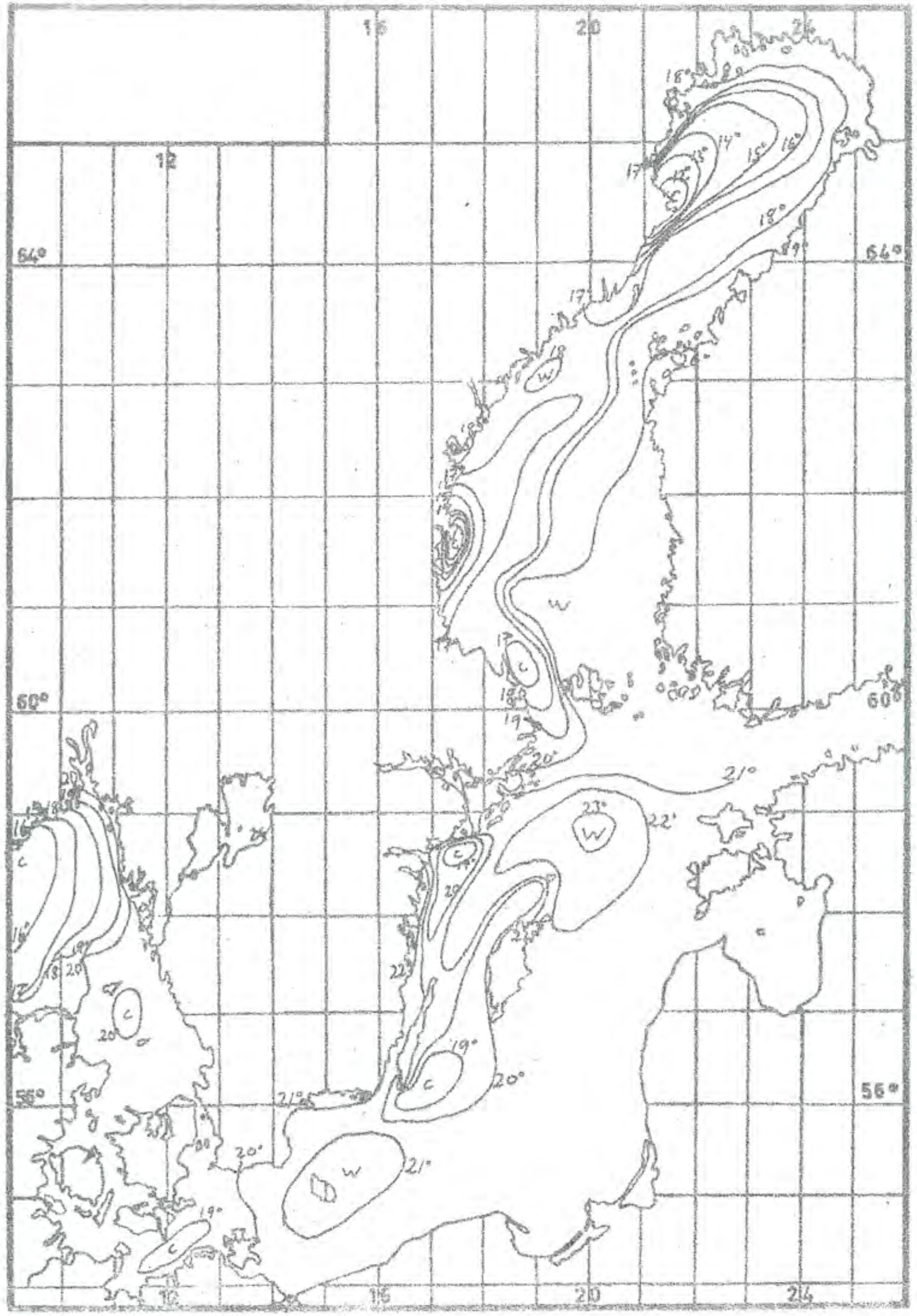

Fig 12. Sea surface temperature analysis 7 July 1973

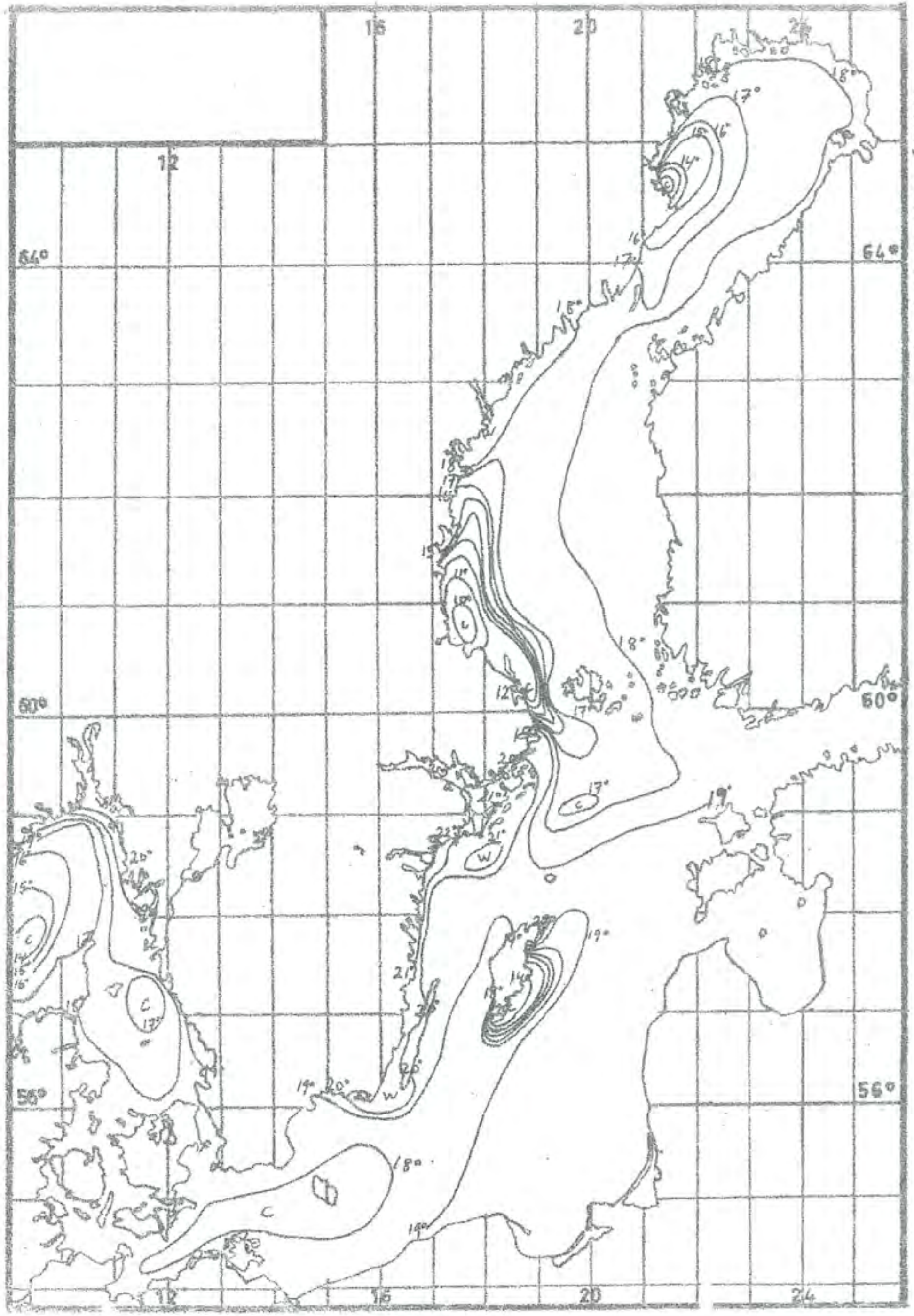

Fig 13. Sea surface temperature analysis 11 July 1973

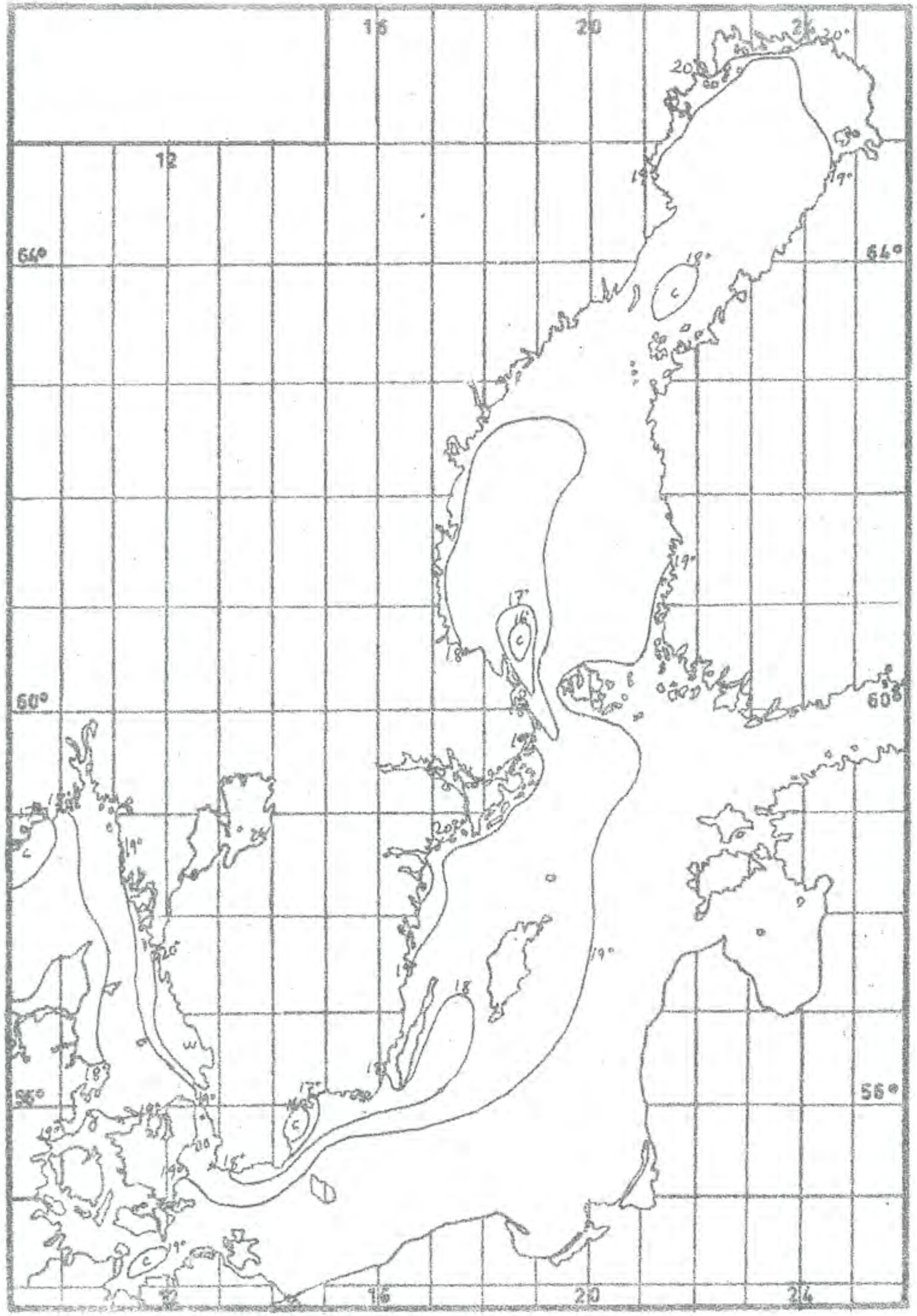

Fig 14. Sea surface temperature analysis 1 August 1973

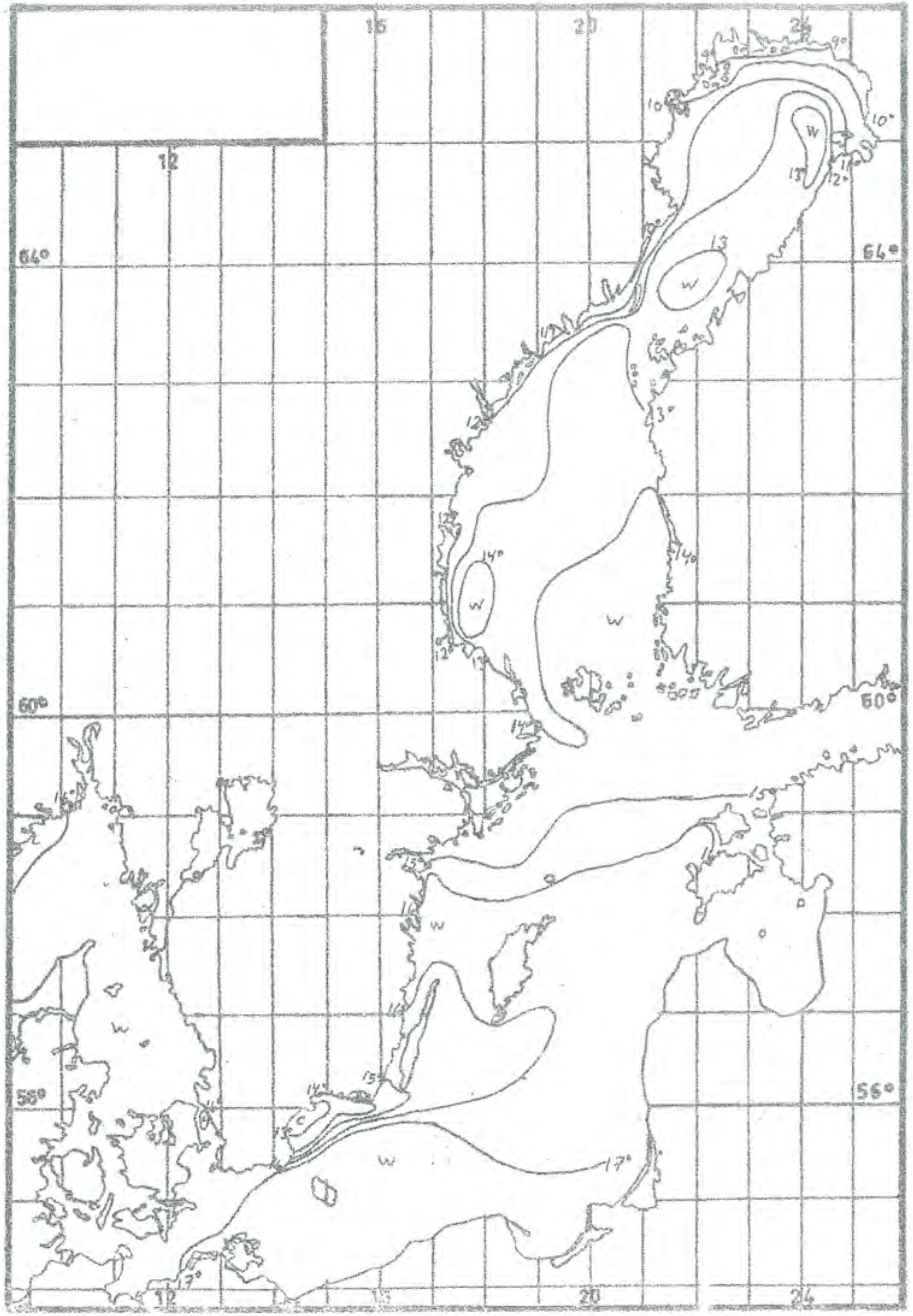

Fig 15. Sea surface temperature analysis 1 September 1973

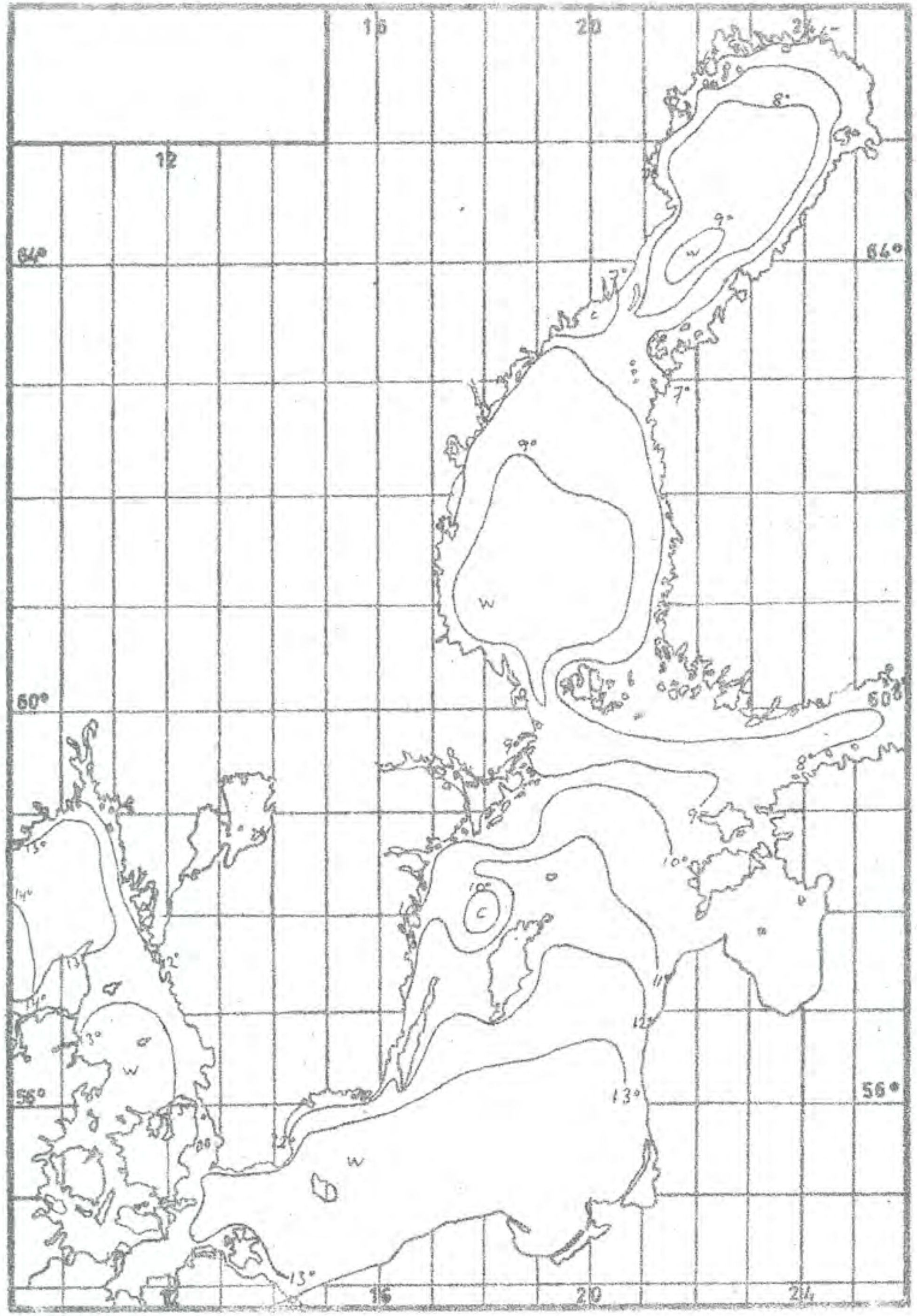

Fig 16. Sea surface temperature analysis 1 October 1973

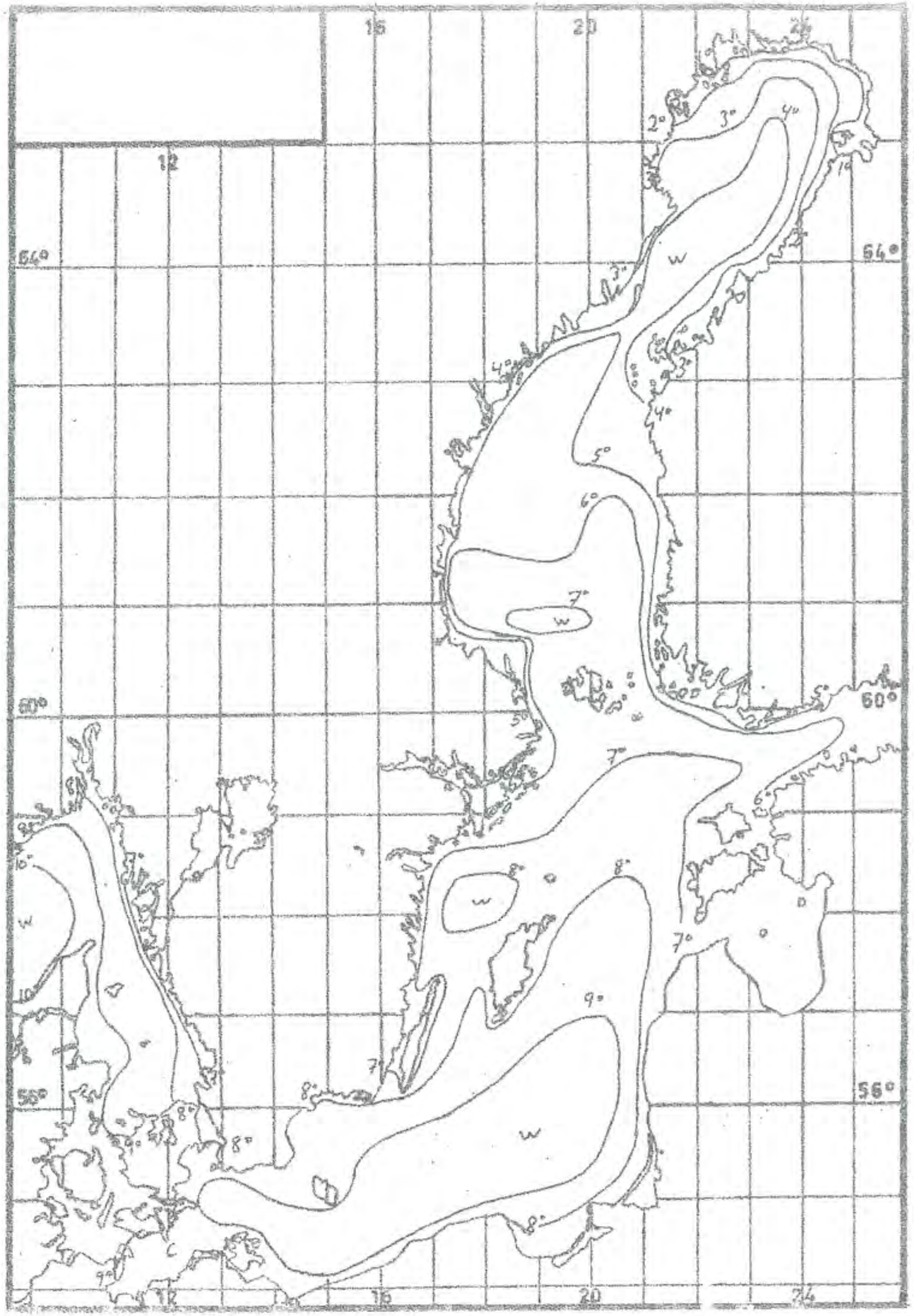

Fig 17. Sea surface temperature analysis 1 November 1973

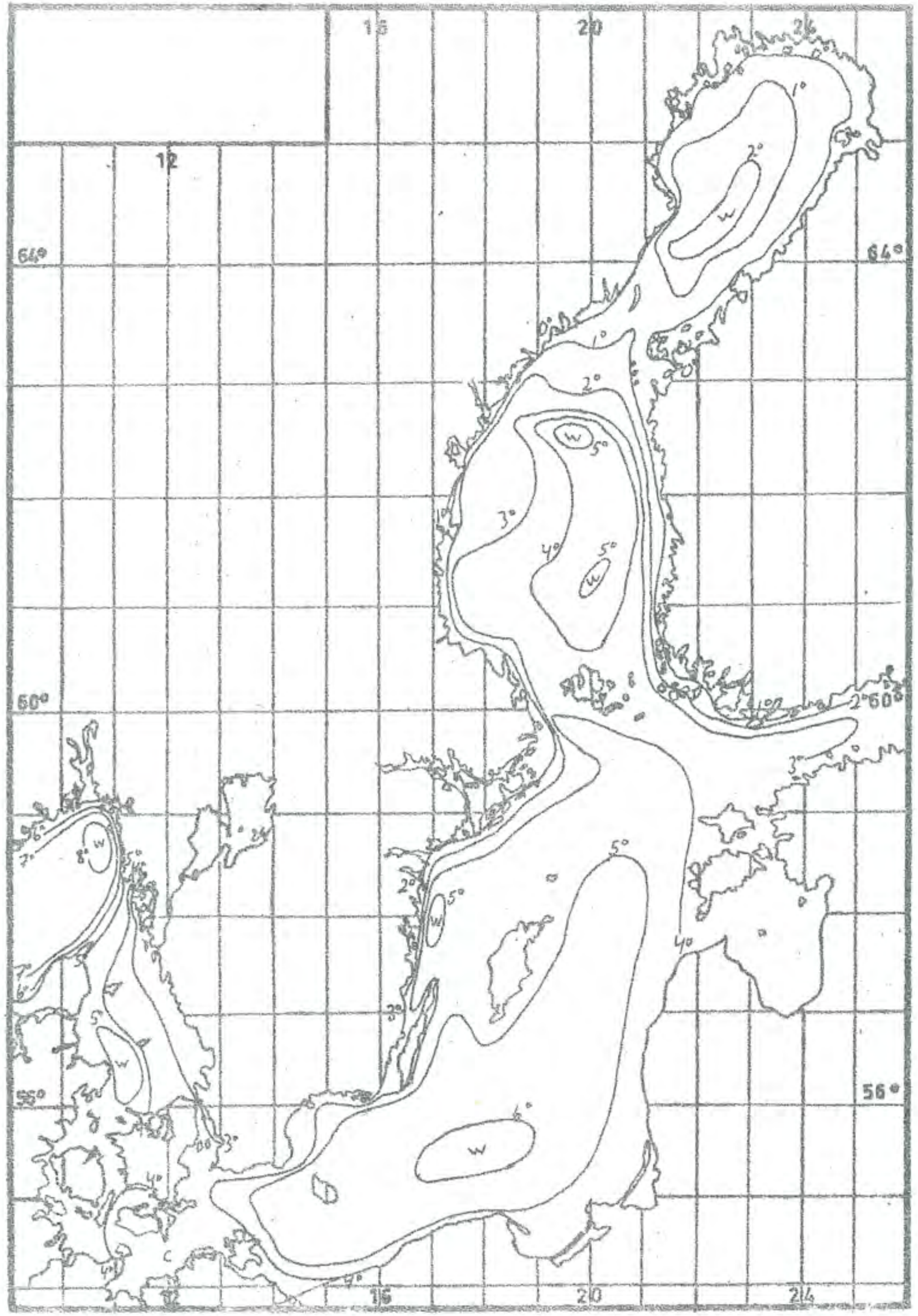

Fig 18. Sea surface temperature analysis 1 December 1973

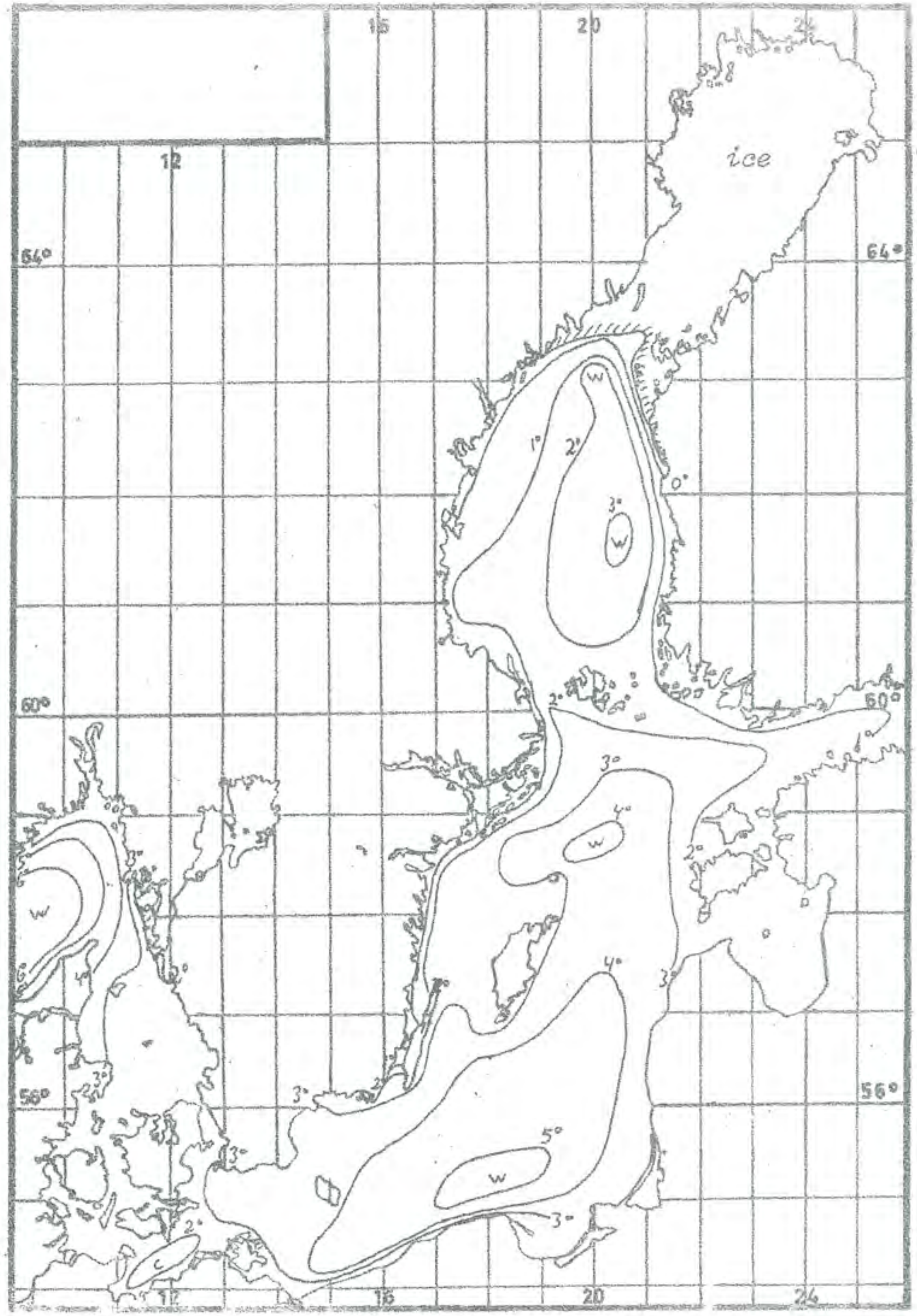

Fig 19. Sea surface temperature analysis 1 January 1974

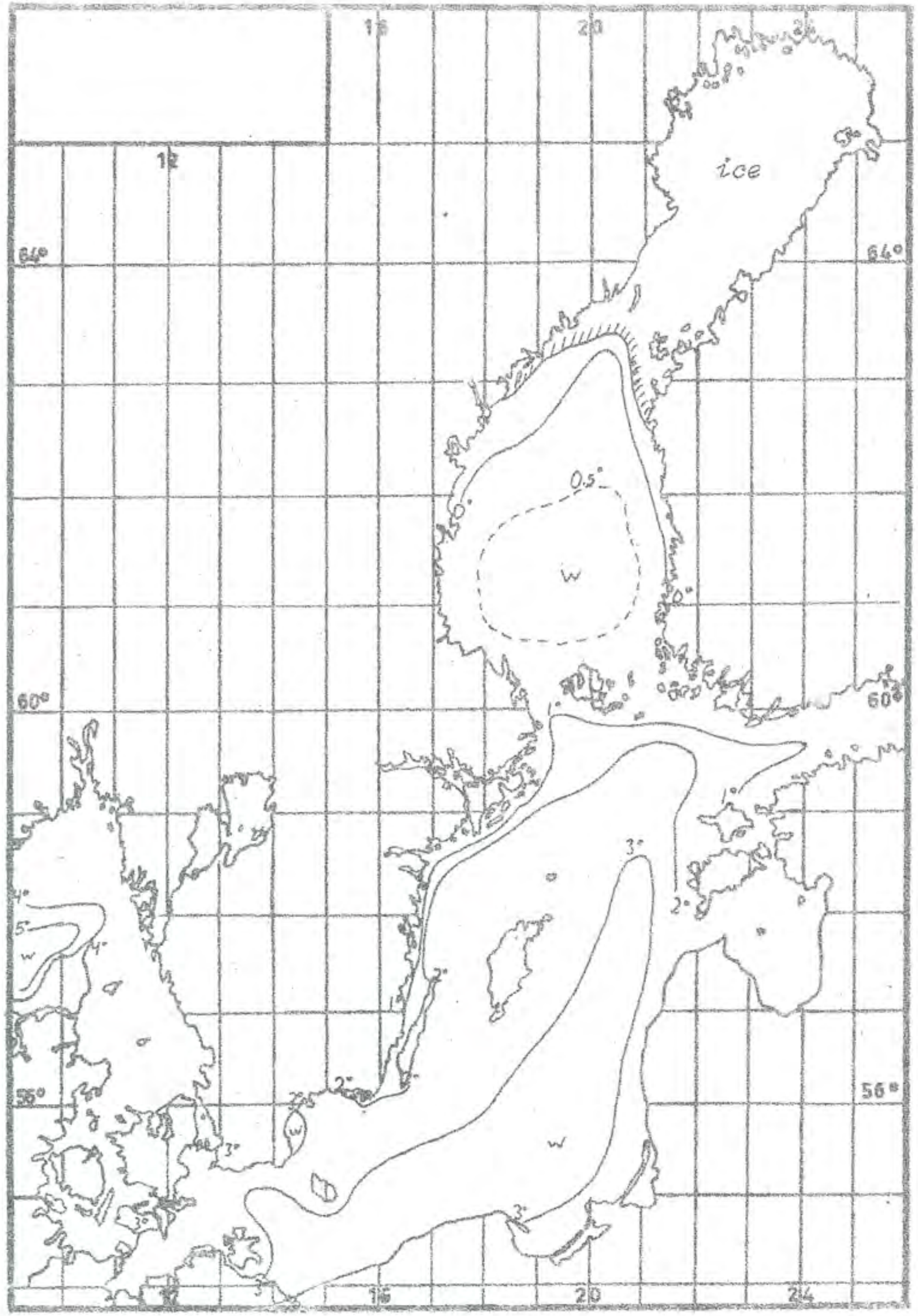

Fig 20. Sea surface temperature analysis 15 February 1974

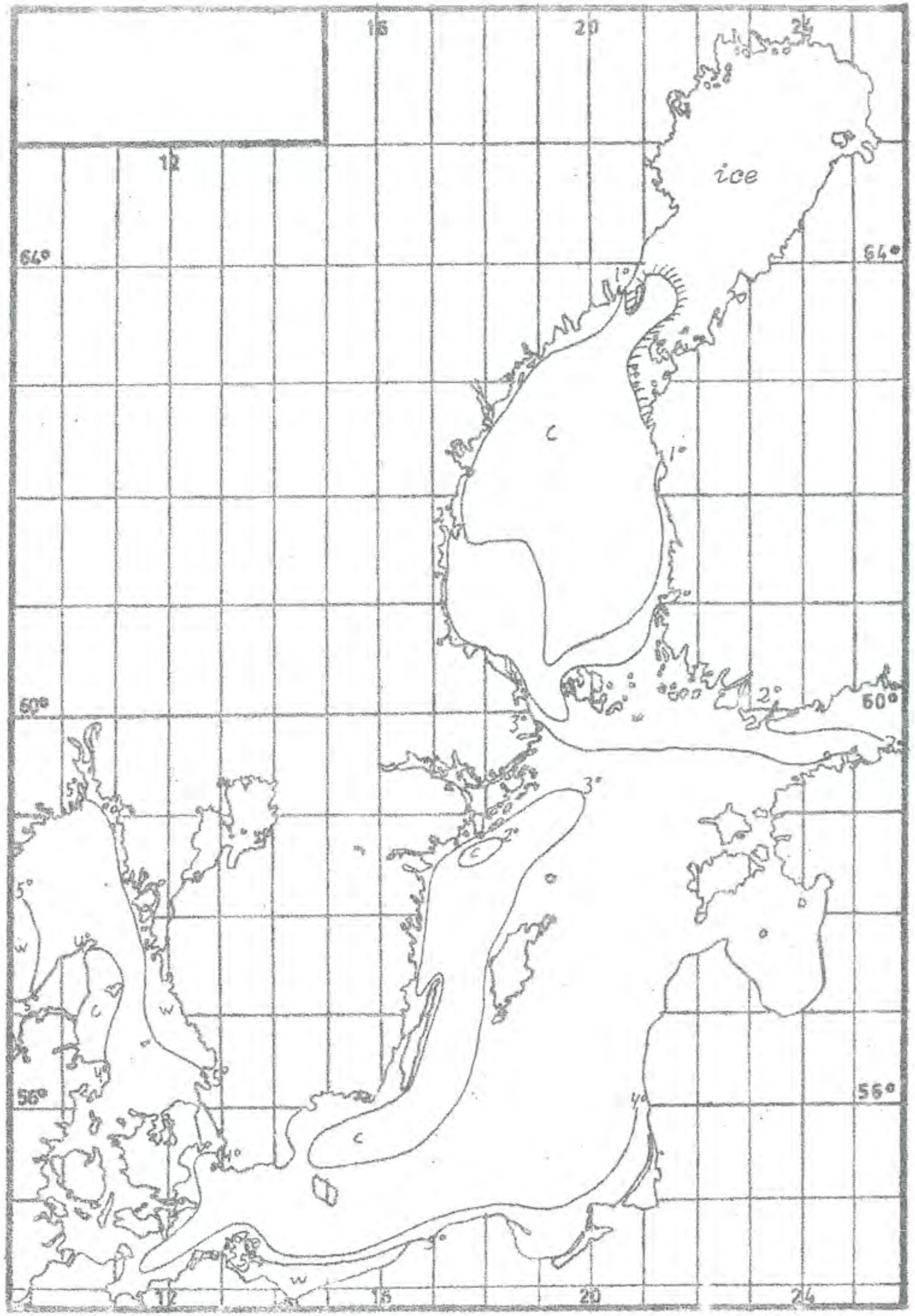

Fig 21. Sea surface temperature analysis 1 April 1974

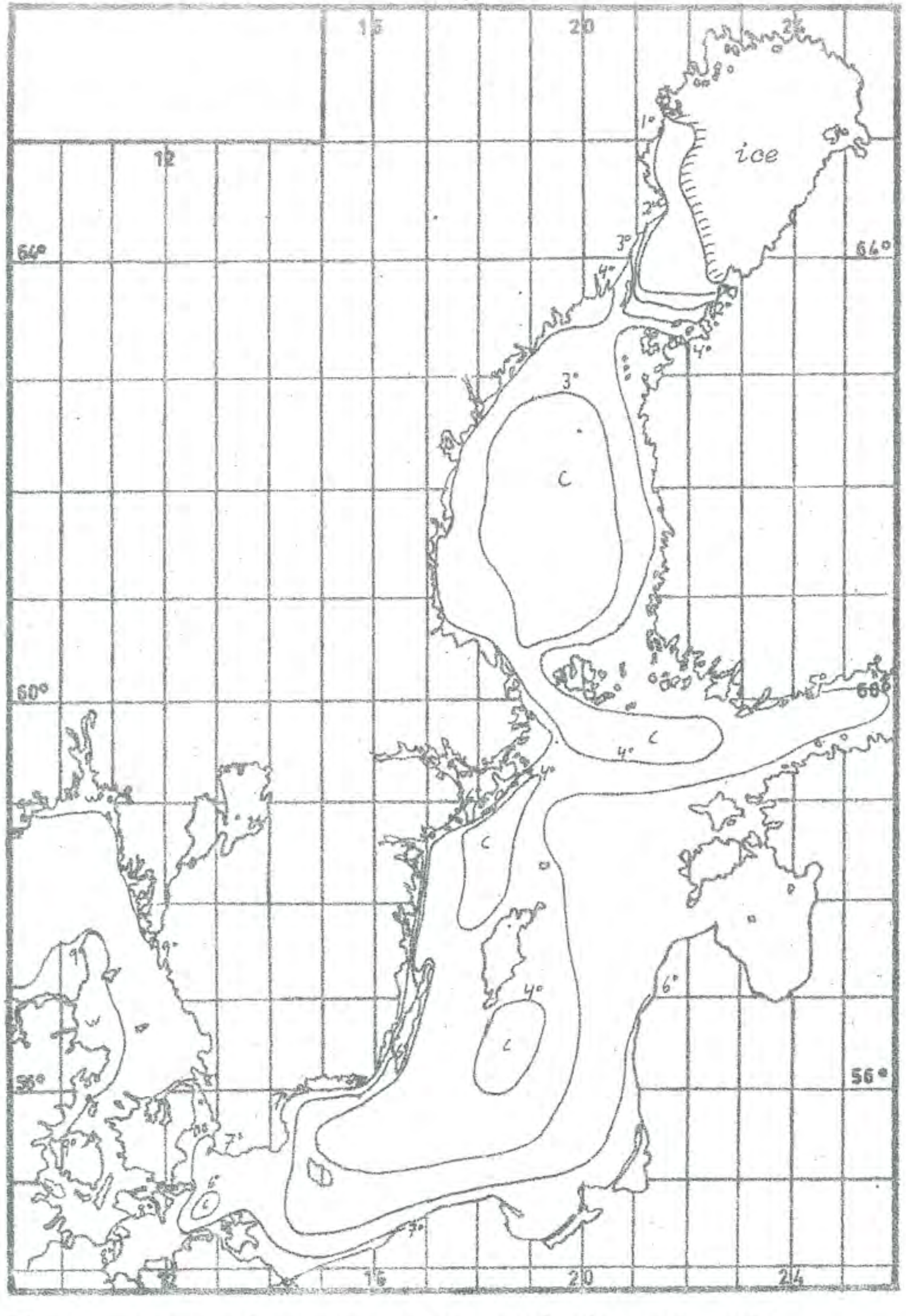

Fig 22. Sea surface temperature analysis 1 May 1974

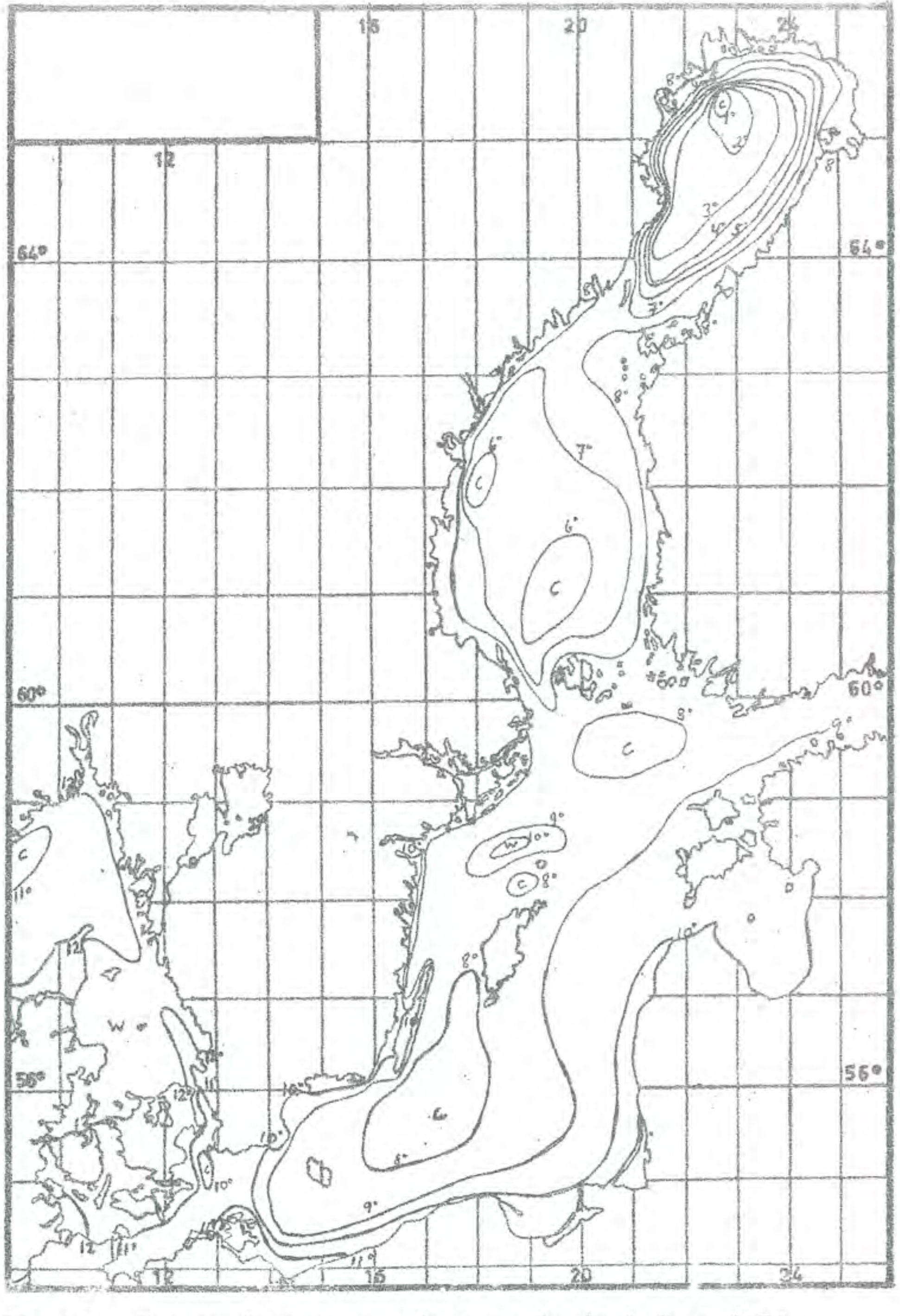

Fig 23. Sea surface temperature analysis 1 June 1974

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World Meteorological Organization, 1969: Sea-surface temperature. Technical note no 103 (WMO-247, TP 135)

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PM Nr 202.
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U Ehlin, B Juhlin, 1974: Oceanografiska observationer i Östersjön 1973 med kustbevakningens båtar samt från isbrytare.
HB Rapport nr 3.
Sveriges meteorologiska och hydrologiska institut

ATTACHMENT A

SYSTEMTEKNIK AB

TORSVIKSSVÄNGEN 26
S-181 34 LIDINGÖ - Sweden
PHONE: 08-765 25 50,

DIGITAL TEMPERATURE METERS FOR Pt 100 TRANSDUCERS

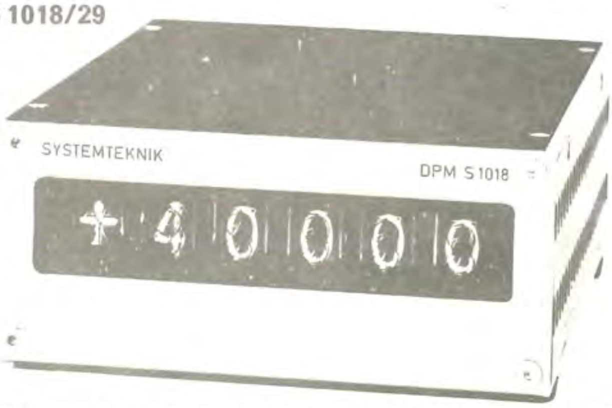
S 1062 · S 1030/29 · S 1016/29 · S 1018/29 · S 1118/29

S 1062

S 1030/29

S 1016/29

S 1018/29



S1062, S1030/29, S1016/29, S1018/29 and **S1118/29** are digital temperature meters to be used with 100 ohm platinum resistance transducers. The instruments perform a four wire resistance measurement, linearization, analog to digital conversion and digital presentation.

The voltage, generating the measuring current through the transducer and the voltage reference at the A-D conversion are the same. Thus, the stability of the instrument is only dependent on resistors and amplifiers.

The dependence between resistance R_T and temperature T in °C for a platinum resistor can be written:

$$R_T / R_O = 1 + AT + BT^2 + CT^3 (1 - T/100)$$

The constants A, B and C are dependent on purity of the platinum and strain of the material. The value of A according to DIN 43760 is 0.0039078, which is rather a low value. For high purity strain-free material A can approach. 0.0039855.

B according to DIN 43760 is $-0.5784 \cdot 10^{-6}$.
C is 0 when $T > 0$ and about $0.43 \cdot 10^{-9}$ when $T < 0$.

The values of resistance for a negative temperature according to DIN 43760 are similar but cannot exactly be met by the equation.

The linearization of the instruments is normally adjusted to meet DIN 43760 concerning A and B, but any values can be set later.

The instruments can be delivered with or without digital output in BCD 8421 TTL level. S1118/29 has as standard digital output in BCD TRISTATE.

SPECIFICATIONS

TYPE	S1062	S1030-29	S1016-29	S1018-29 and S1118-29
RANGE:	± 190.0°C	± 190.0°C	± 99.99°C	± 220.00°C
ACCURACY: 1 year 23°C 65 % RH				
± 60°	± 0.1°C	± 0.1°C	± 0.02°C	± 0.03°C
< 150°	± 0.1°C	± 0.1°C	± 0.03°C	± 0.04°C
< 220°	—	—	—	± 0.05°C
JITTER: Better than	1 digit	1 digit	1 digit	1 digit
LINEARITY: Typically better than	1 digit	1 digit	1 digit	1 digit
TEMPERATURE COEFFICIENT	Better than ± 8 % of accuracy ± 0.1 digit per °C. Ambient operating temperature between 0° and 50°C			
MEASURING CURRENT:	2,5 mA ± 5 %	2,5 mA ± 5 %	2,5 mA ± 5 %	2,5 mA ± 5 %
WIRE RESISTANCE: Max. incl. transd.	200 ohm	200 ohm	146 ohm	200 ohm
POWER:	115/220V ± 10 % 50 or 400 c/s 12 VA (60 c/s as option)			
SIZE:	65×220×213	65×130×213	65×130×213	65×153×213
CASE:	Blue and grey anode oxidized aluminium			
WEIGHT:	1,8 kg	1,4 kg	1,4 kg	1,5 kg
ANALOG OUTPUT	0—10V ± 5 % max. load 50 kohm			
DIGITAL OUTPUT: (BCD 8421 TTL Level)	Option	Option	Option	Option S1118 BCD 8421 TRISTATE as standard
	6 channels manually selected			

S 1118: Similar to S1018 but has SPERRY display, BCD TRISTATE output and the display can be mounted separately from the A-D converter. S1118 gives more possibilties for special options.

THE SWEDISH METEOROLOGICAL
AND HYDROLOGICAL INSTITUTE
Box 12108
S-102 23 STOCKHOLM 12

REMOTE TEMPERATURE METER
FOR LINEAR TRANSDUCERS
Type LL 1

CONSTRUCTOR: Lars Löfgren

LL 1

DESCRIPTION:
The instrument consists of three main parts, the resistance temperature sensor, the digital scale and two light emitting diods. The temperature sensor is one link in a Wheatstone bridge, which is set to zero by a ten turn precision potentiometer connected to the digital scale on which the temperature is read. The zero-setting is sensed by integrated amplifiers and indicated by the two light emitting diods, one lit when above and the other lit when below the right temperature. The exact temperature is read on the scale at light shift. Temperatures above zero are read directly from the scale. Temperatures below zero are read from the scale as indicated value minus 100. E.g. 99,6 - 100 = -0,4° C. The cable resistance between the instrument and the temperature sensor can be compensated by turning a trimpotentiometer with a small screw driver through a hole in the cover. Cable resistance up to 3 ohms can be compensated for. Normally no shielded cable is required but may be recommended under unnormally noisy conditions. The instrument can be delivered for desk and wall mounting.

SPECIFICATION:

Temperature measuring range:	-5 to +40° C (-5 to +90° C)
Accuracy after calibration:	±0,1° C in range -5 to +40° C (±0,4 % in range +30 to +90° C)
Accuracy of setting:	±0,02° C
Reading accuracy of scale:	0,02° C
Ambient temperature:	0 to +30° C
Supply voltage:	115 to 220 volts ±10 %, 50 or 60 Hz
Power consumption:	Approximately 10w
Size:	16 x 13 x 7 cm

OBSERVING PLATFORMS

Fixed stations	Latitude	Longitude
Repskärsgrund	N6544	E2322
Malören	N6532	E2334
Rödkallen	N6519	E2222
Furuögrund	N6455	E2115
Gåsören	N6440	E2125
Bjuröklubb	N6429	E2134
Gumbodafjärden	N6412	E2103
Sikeå	N6410	E2059
Ratan	N6400	E2054
Väktaren	N6337	E2026
Sydostbrotten	N6320	E2011
Järnäs	N6326	E1941
Skagsudde	N6310	E1858
Spikarna	N6222	E1732
Gubben	N6221	E1737
Kuggören	N6143	E1731
Hölick	N6137	E1726
Myran	N6136	E1728
Hällgrund	N6116	E1724
Blomman	N6112	E1717
Eggegrund	N6044	E1734
Grundkallen	N6030	E1851
Svartklubben	N6011	E1850
Svenska Högarna	N5926	E1930
Hårsfjärden	N5905	E1810
Stabbo	N5859	E1826
Landsort	N5844	E1752
Hävringe	N5837	E1718
Aspöja	N5825	E1700
Kungsgrundet	N5742	E1655
Ölands norra udde	N5722	E1706
Kalmar	N5639	E1623
Karlskrona	N5603	E1534
Styrsvik	N5608	E1522
Hanö	N5600	E1450

Fixed stations	Latitude	Longitude
Åhus	N5555	E1425
Kullen	N5618	E1227
Nidingen	N5718	E1154
Trubaduren	N5736	E1138
Måseskär	N5806	E1120
Strömstad	N5854	E1105
Såtenäs	N5827	E1242
Karlsborg	N5830	E1430

Totally 43 observing points

Ferries

Route	Latitude	Longitude	Ferry
Stockholm - Nådendal	N5926	E2000	Trelleborg
" "	N5915	E1901	
" "	Trälhavet		
" "	N5938	E2000	
" "	N5947	E1924	
" "	Lillharu		
Nynäshamn - Visby	N5844	E1809	Visby
" "	N5824	E1810	
" "	N5750	E1815	
Oskarshamn - Visby	N5718	E1647	Gotland
" "	N5725	E1708	
" "	N5732	E1740	
Trelleborg - Sassnitz	N5517	E1310	Skåne
" "	N5500	E1322	
" "	N5446	E1332	
Malmö - Köpenhamn	N5540	E1255	Malmöhus
" "	N5544	E1241	
Helsingborg - Travemünde	N5413	E1123	Sveaborg
" "	N5427	E1211	
" "	N5444	E1241	
" "	N5506	E1249	
" "	N5523	E1241	
" "	N5532	E1243	
" "	N5551	E1244	
" "	N5600	E1240	

Route		Latitude	Longitude	Ferry
Göteborg - Kiel		N5430	E1016	Stena Olympica
"	"	N5441	E1045	
"	"	N5500	E1102	
"	"	N5531	E1052	
"	"	N5545	E1051	
"	"	N5606	E1137	
"	"	N5631	E1137	
"	"	N5645	E1151	
"	"	N5709	E1139	
"	"	N5721	E1135	
Göteborg - Fredrikshamn		N5736	E1138	Desiree or
"	"	N5732	E1120	Christina
"	"	N5728	E1052	

Totally 38 observation points from 9 ferries

Coast-guard

Tv 249	Tv 241
Tv 104	Tv 101
Tv 220	Tv 246
Tv 245	Tv 243
Tv 260	Tv 116
Tv 13	Tv 236
Tv 244	Tv 252
Tv 253	Tv 102
Tv 103	Tv 254
Tv 256	Tv 255
Tv 250	

Totally 21 vessels

Merchant vessel	Owner
Västanvik	Cementa
Mälarvik	"
Sunnanvik	"
Nordanvik	"
Östanvik	"
Holmsund	SCA
Munksund	"
Tunadal	"
Ada Gorthon	Gorthon

Icebreakers and Research vessel	
Njord	Icebreaker
Tor	"
Oden	"
Thule	"
Ale	"
Argos	Fishery Board

Totally 15 vessels


SVERIGES METEOROLOGISKA OCH HYDROLOGISKA INSTITUT
SEA SURFACE TEMPERATURES
~~ISKARTA nr~~ den 27.5.1974
TECKENFÖRKLARING
EXPLANATION OF SYMBOLS
Nyis eller mycket tunn is (<5 cm)
New ice or nilas
Jämn, fast is (>5 cm)
Level, fast ice
Spridd drivis (1—6/10), stora resp. små flak
Open pack ice, big or small floes
Tät drivis (7—8/10), stora resp. små flak
Close pack ice, big or small floes
Mycket tät drivis (9—10/10)
Very close or compact pack ice
Sammanfrusen drivis
Consolidated pack ice
Sammanpackad issörja eller krossis
Compacting shuga or brash ice
Hopskjuten is
Rafted ice
Is med vallar eller upptornad is
Ridged or hummocked ice
Isgräns
Ice edge or ice boundary
Uppskattad isgräns
Estimated ice edge or ice boundary
30—50 Uppskattad istjocklek i cm
Estimated thickness in cm
38 Uppmätt istjocklek
Observed thickness in cm
+1.8 Ytvattentemperatur i °C
Sea surface temperature in °C
W= WARM C= COLD
Skala 1: 4000 000
200 km
100 naut. mil
SMHI 3014 ALLF 177 73 044
Nov 1973 30 000
AB SVENSK KARTTJÄNST/SRA
Stockholm 1973 35589
Attachment D

NOTISER OCH PRELIMINÄRA RAPPORTER. Serie METEOROLOGI

Nr 1 K a r l s s o n, K.E., Instrumentella och visuella åskobservationer. (1960)

Nr 2 T h o m p s o n, T., Den naturliga radioaktivitetens variation med vädret. (1961)

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Nr 7 W a l l é n, C.C., Sannolikheten för olika mängder av dygnsnederbörd i Sverige. (1963)

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Nr 24 L ö n n q v i s t, O., MASKINELL PROGNOSTEXT: Ett experiment med i datamaskin formulerade väderrapporter. (1971)

Nr 25 N y b e r g, A. och H å r s m a r, P-O., Mätningar av avdunstning - kondensation samt snösmältning från en snöyta. (1971)

Nr 26 P e r s s o n, Anders O., En enkel metod att beräkna rådande vertikalvind och nederbördsintensitet ur aerologiska vind- och fuktighetsdata. (1971)

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