

# Dynamical report

by Ingemar Udin and Anders Omstedt

Norrköping 1976

*Cover picture:  
The icebreaker TOR in the middle  
of the test area for SEA ICE —75  
and an example of the forces acting  
upon the ice on March 17, 1975.*

SMHI  
Fack  
S-601 01 Norrköping

# SEA ICE 75

## Dynamical report

by Ingemar Udin  
and Anders Omstedt  
Norrköping 1976



# Table of Contents

<b>Foreword</b> .....	4
<b>Summary</b> .....	5
<b>Sammanfattning</b> .....	5
<b>1. Introduction</b> .....	6
<b>2. Background</b> .....	8
2.1 Weather and Ice .....	8
2.2 Hydrography .....	10
<b>3. The Ice Mass</b> .....	12
<b>4. The Wind</b> .....	15
<b>5. The Ice Motion</b> .....	16
<b>6. The Current</b> .....	20
<b>7. The Sea Surface Tilting</b> .....	23
<b>8. The Force Balance</b> .....	25
<b>9. Temperature and Salinity</b> .....	27
<b>10. Conclusions and Discussion</b> .....	28
<b>Acknowledgements</b> .....	30
<b>References</b> .....	31
<b>Attachments 1—32</b> .....	33
<b>Appendix A</b> .....	56

# Foreword

The Winter Navigation Research Board presents report no. 16:8. The experiment SEA ICE-75, carried out in the Bay of Bothnia in March 1975, was basically aimed at the testing of various remote sensing techniques for sea ice mapping. It provided, however, also an excellent opportunity to carry out a number of measurements related to the dynamics of the ice in conjunction with the ground truth work. Ingemar Udin, Anders Omstedt and Anders Berg from the Swedish Meteorological and Hydrological Institute (SMHI) were responsible for the work in which the captain and the crew on icebreaker TOR took an active part. The helicopter stationed onboard TOR was of great assistance.

The ice dynamics measurements will provide necessary test data for the numerical ice model that is being developed at SMHI. It is hoped that this model will soon provide ice forecasts to assist in an efficient planning of navigation in ice.

The Winter Navigation Research Board wish to express its sincere thanks to the authors as well as all others having contributed to this report.

Norrköping and Helsingfors, July 1976

**Lennart Johansson**

**Helge Jääsalo**

## Summary

Field measurements on sea ice was carried out in the Bay of Bothnia during March 10—20, 1975. The forces and parameters in the equation of motion for sea ice have been studied on the mesoscale. Winds and currents were measured to calculate the wind and water stress, the ice mass distribution was studied, the tilting of the sea surface computed, vertical temperature and salinity soundings in the water made and surface temperatures at different ice types measured. From the data obtained and with classical boundary layer theory the forces in the equation of motion have been calculated and their balance studied. The results support the assumptions made in a numerical ice forecasting model under development at the SMHI and the data obtained will be used for further development and improvements.

## Sammanfattning

Fältmätning på havsis genomfördes i Bottenviken under perioden 10—20 mars, 1975. Krafter och parametrar som ingår i rörelseekvationen för havsis har studerats på mesoskalan. Vind och ström mättes för att möjliggöra vind- och vattenstressberäkningar, ismassans fördelning i havet studerades, havsytans lutning beräknades från vattenståndsregistreringar, vertikala temperatur- och salthaltssonderingar gjordes under isen och ytvattentemperaturen på olika isslag mättes. Från erhållna data och med en klassisk gränsskiktsbehandling har krafterna i rörelseekvationen beräknats och balansen dem emellan studerats. Resultaten stödjer de antaganden som gjorts i en numerisk isprognosmodell under utveckling vid SMHI och de erhållna data kommer att användas för förbättringar och en vidare utveckling av modellen.

# 1. Introduction

Under the joint Swedish-Finnish winter navigation research programme the Swedish Meteorological and Hydrological Institute is participating with a programme in which the interaction between atmosphere, ice and sea is studied. One main project within this programme treats the ice drift in the Bay and Sea of Bothnia and the numerical modelling of the ice motion and redistribution (ref.1).

The general equation for ice motion can be written (ref.2)

$$m \frac{dv}{dt} = \tau_a + \tau_w + C + G + R \quad (1)$$

It can be seen that the ice motion,  $v$ , depends on the wind stress,  $\tau_a$ , the water stress,  $\tau_w$ , the coriolis force,  $C$ , the gravitational force due to tilting sea surface,  $G$ , and the stress transmitted through the ice (internal ice stress),  $R$ .

From the equation, it can be seen, that parameters of interest when modelling the sea ice are,

- the ice motion itself at different times and places;
- the ice mass and its distribution over the sea area;
- the winds;
- the currents below the floating ice;
- the seat level and its changes at different places.

In order to collect the necessary information on the above mentioned parameters of which most are not available from the routine observations with a sufficient degree of accuracy some field experiments have been carried out. During the winter 1974, two field projects were carried out in the Bay of Bothnia (ref.3). They were followed by one project the winter 1975 called SEA ICE-75.

SEA ICE-75 was carried out during March 10—20, 1975 in the northern part of the Bay of Bothnia. Initially the project was planned to cover areas in both the Bay and Sea of Bothnia but due to an extremely mild winter (the third in succession) no ice was present in the Sea of Bothnia and the experiment was therefore limited to the Bay of Bothnia. The measurements, registrations and observations were made from and around the icebreaker TOR, which was frozen into the ice during the period (fig.2).

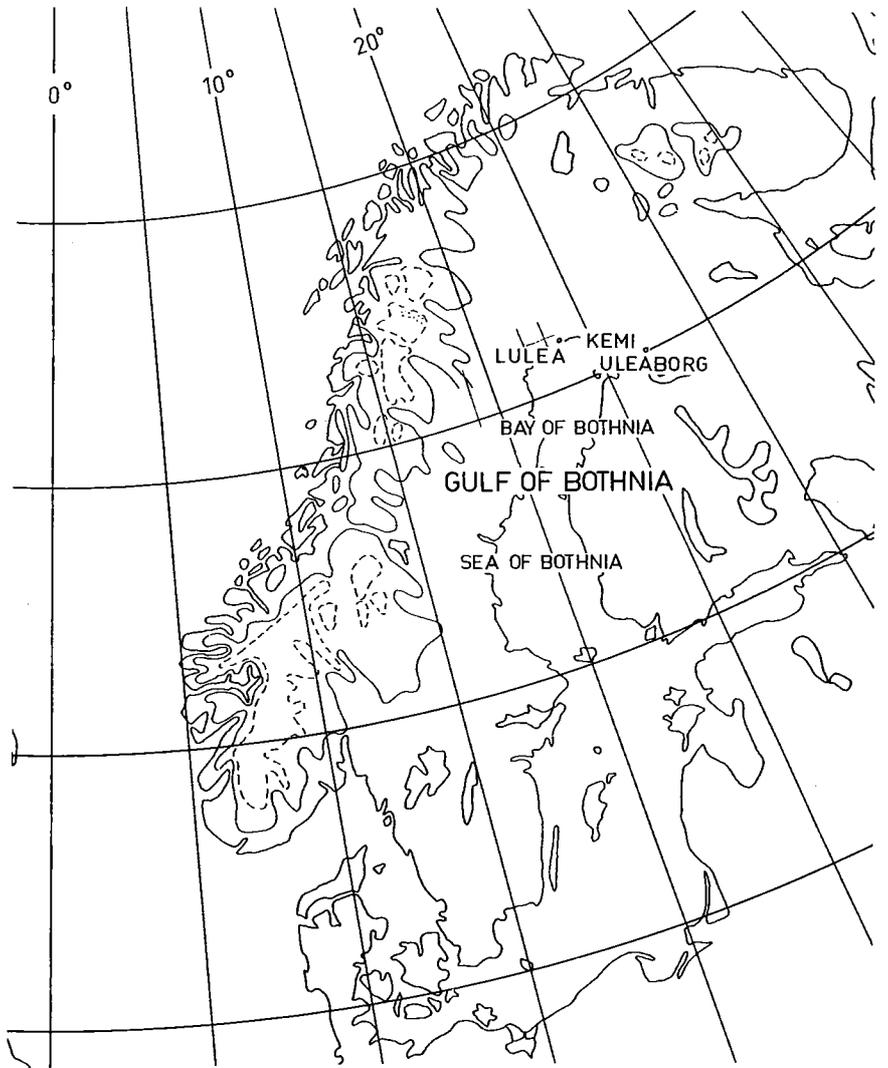
The project covered in reality two different objectives,

- one studying remote sensing of sea ice (ref.4);
- one studying dynamical and physical parameters relevant for ice drift.

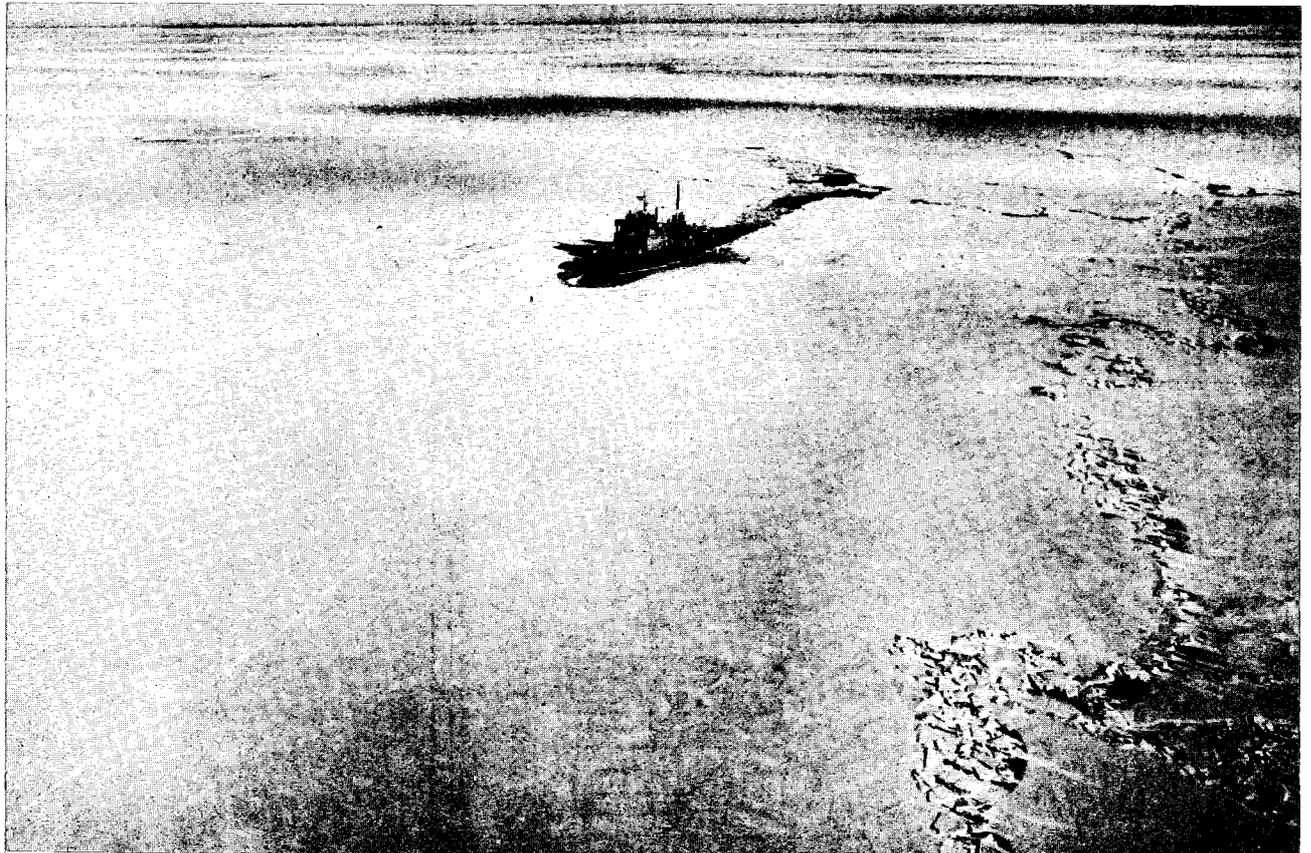
Results from the remote sensing part of the project, will be presented in separate reports.

The aim of this report is to present the data collected during the dynamical and physical part of SEA ICE-75 and to discuss some of the results obtained. Part of the field work was made in cooperation with the Finnish Institute for Marine Research.

**Figure 1.** Map over Scandinavia with surrounding waters.



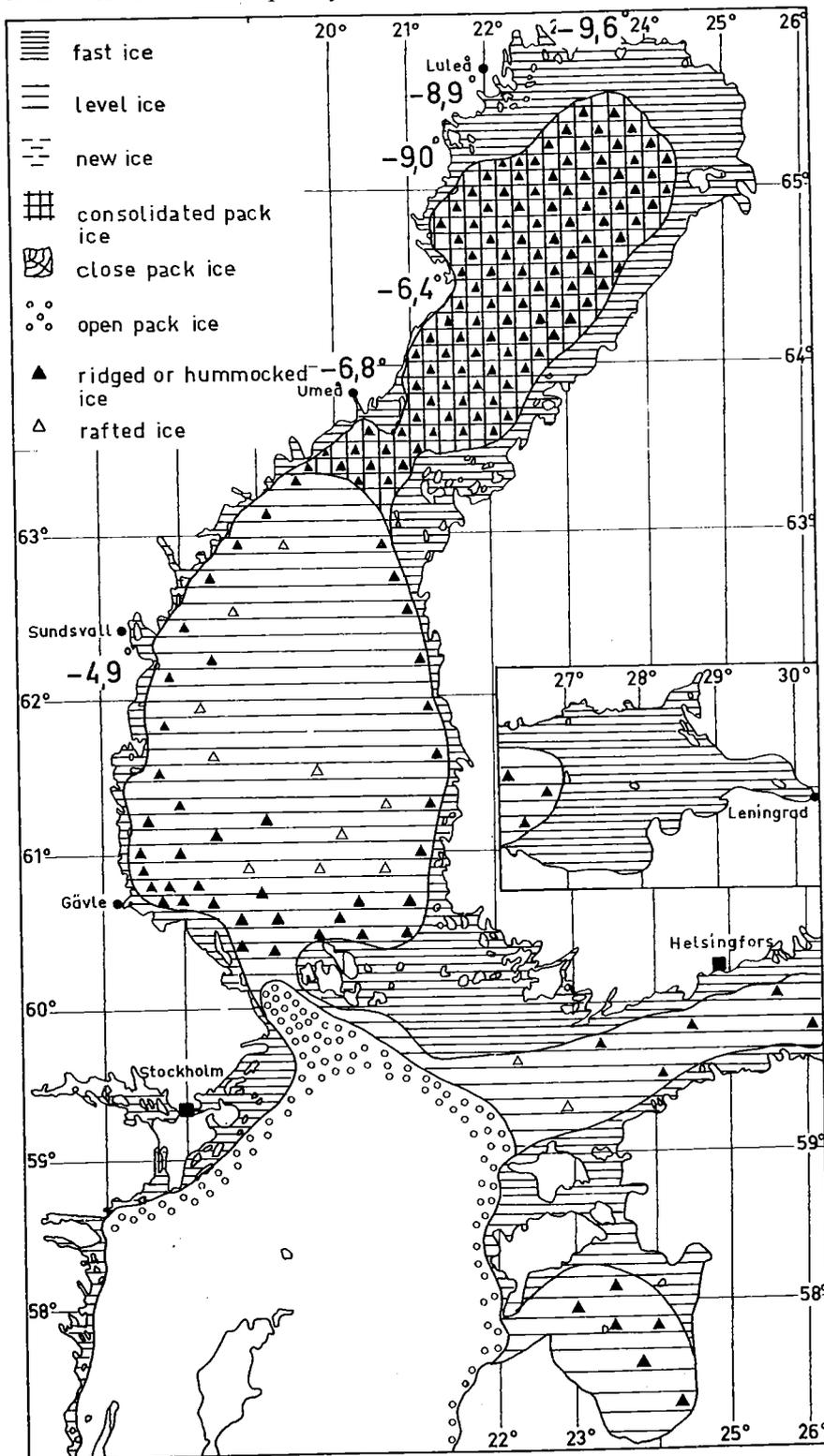
**Figure 2.** The icebreaker TOR served as a camp for the research group and was stationed in the ice the whole period.



## 2. Background

### 2.1 Weather and Ice

The Bay and Sea of Bothnia are climatically situated in the northern part of the westerlies. Consequently the weather is influenced by the meande-



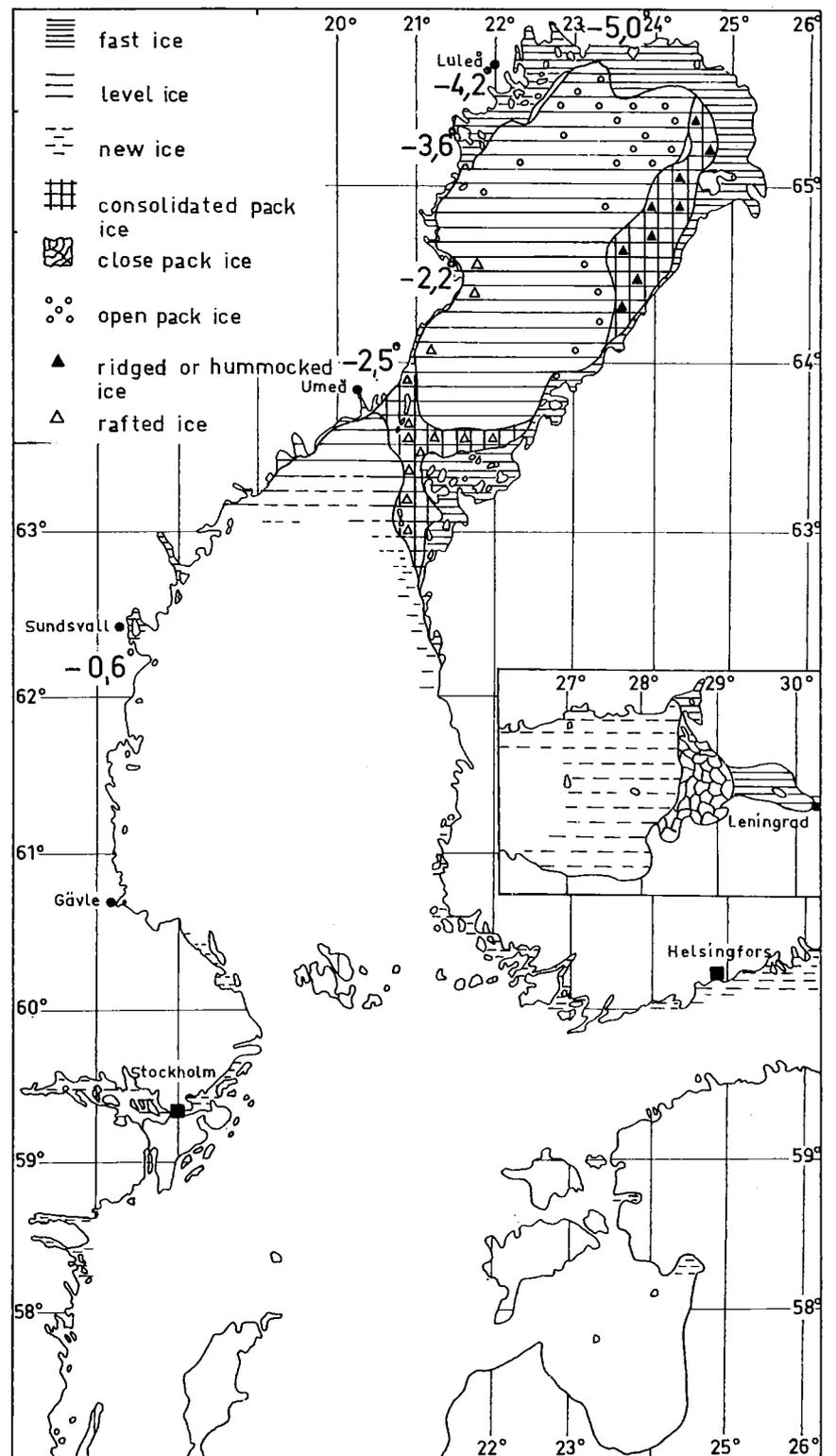
**Figure 3.** Map over the maximal ice extension and the ice types during a normal winter. The figures on the shores are climatic daily mean temperatures for the period January—March.

ring polar front and the disturbances on it. During the winter the disturbances (low pressure systems) normally pass south of the area and cold air masses cover the Bay and Sea of Bothnia. From time to time lows pass over the area causing strong winds and precipitation.

Normal air-temperatures for the winter period (January—March) from selected stations along the Swedish coast are shown in figure 3. The maximal ice extension during a normal winter is seen in the same figure. Typical thickness for level ice in the Bay of Bothnia is 50—70 cm and in the Sea of Bothnia 20—40 cm.

The disturbances on the polar front often cause strong winds. Table 1 shows wind statistics for 5 years from the caisson lighthouse Sydstöbrotten and from the table is seen that Sydstöbrotten during January has a statistical wind of more than 12 m/s in 35 % of the cases. The wind makes the ice move and during the motion rafting, ridging and hummocking occur. In the Bay of Bothnia pressure ridges with a depth of 10 m often

**Figure 4.** Map over the maximal ice extension and the ice types the winter 1975. The figures on the shores are daily mean temperatures for January—March 1975.



Wind speed (m/s)	Calm	1-2	3-5	6-8	9-11	12-14	15-17	18-20	21-23	24-26	27-29	30-32	SUM
DEC n %	5 0.9	34 6.1	75 13.4	94 16.8	128 22.9	93 16.7	60 10.8	48 8.6	19 3.4	1 0.2	0 0.0	1 0.2	558 100.0
JAN n %	10 1.8	54 9.7	74 13.3	97 17.4	130 23.3	99 17.7	65 11.6	25 4.5	4 0.7	0 0.0	0 0.0	0 0.0	558 100.0
FEB n %	9 1.8	47 9.3	91 17.9	111 21.9	109 21.5	76 15.0	45 8.9	9 1.8	8 1.6	2 0.4	0 0.0	0 0.0	507 100.0
MAR n %	9 1.6	31 5.6	100 17.9	127 22.8	140 25.1	78 14.0	51 9.1	18 3.2	4 0.7	0 0.0	0 0.0	0 0.0	558 100.0
APR n %	21 3.9	70 13.0	104 19.3	105 19.4	115 21.3	77 14.3	29 5.4	17 3.1	2 0.4	0 0.0	0 0.0	0 0.0	540 100.0

**Table 1.** Wind statistics from the caisson lighthouse Sydostbrotten ( $n$  = number of cases).

appear and 25—30 m ridges have been observed (ref. 5).

The winter 1975 was extremely mild as can be seen from figure 4. The mean temperatures for January—March were 4—5°C above normal in the Bay and Sea of Bothnia. As can be seen from the figure the maximal ice extension was much less than normal and the thickness of level ice was 20—40 cm.

During the field period, March 10—20, the weather was first dominated by a high pressure and temperatures some degrees below 0°C. From March 15 disturbances on the polar front caused a more variable weather. A cold front passed the area on March 15 and cold air moved southward with a northerly gale on March 16 and 17. On March 18 a southerly gale preceded a warm front and was followed by a westerly gale behind a cold front. As will be seen below the period after March 15 was very interesting from a dynamical point of view, as the strong winds created a considerable motion of water and ice.

## 2.2 Hydrography

The Gulf of Bothnia is the northern extension of the Baltic (figure 5). It represents together with the Åland Sea a special hydrographical area, which is separated from the rest of the Baltic Sea by a sill.

The Gulf of Bothnia consists of two main basins, the Bay of Bothnia and the Sea of Bothnia, both rather shallow with a mean depth of 42 and 69 meters respectively (ref. 6).

Fresh water enters the Gulf from rivers. Salt water enters from the rest of the Baltic. The yearly fresh water supply is some per cent of the Gulf's total volume, while the salt water supply is of the order of ten per cent (ref. 7). Due to this the salinity increases from north to south. Normal salinity values in the Bay are about 3—3.5 ‰ and in the Sea of Bothnia about 5—5.5 ‰.

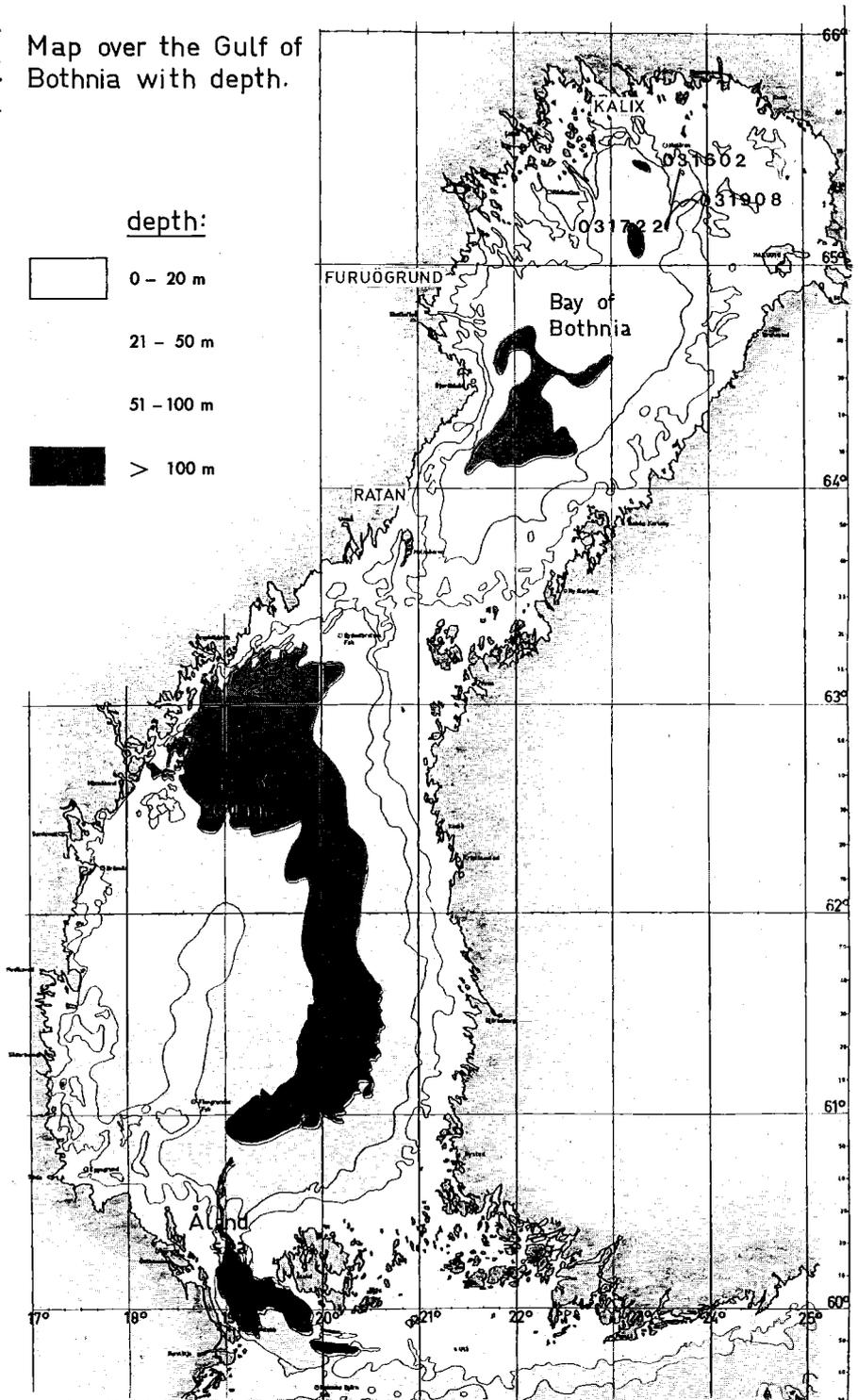
The temperature and salinity stratification is weak during the winter which makes it possible for a total convection to occur except in deeper parts of the Sea of Bothnia.

The currents in the Gulf are variable as the disturbances on the polar front cause wind and air pressure changes on a time scale of days. Due to the fact that the yearly mean wind is southwesterly the yearly mean surface currents show up a counter clockwise circulation both in the Bay and the Sea of Bothnia (ref. 8). When studying the ice motion on a time scale of days this circulation is of no interest.

Large water level variations are found in the Gulf of Bothnia, especially the northern part, where variations in the order of meters occur. They are mainly caused by the wind, but also by differences in air pressure and water density (ref. 9). Tidal effects are negligible in the Gulf of Bothnia.

**Figure 5.** Map over the bottom topography in the Gulf of Bothnia. The movement of the icebreaker TOR is also given, the figures indicate month, day and hour.

Map over the Gulf of Bothnia with depth.



### 3. The Ice Mass

One important parameter, for navigation in ice covered waters and for numerical modelling of sea ice, is the mass of ice and its distribution (ref. 10). The mass,  $m$ , can be written

$$m = \rho_i \cdot NH \quad (2)$$

where  $\rho_i$  = ice density  
 $N$  = ice concentration  
 $H$  = ice thickness

With known density the concentration and thickness in the area must be known to enable computations. For navigation purpose small scale (tens of meters) information is required, but for modelling purposes larger scale (some kilometers) information is sufficient. The results from a numerical model can anyhow contain small scale information. Ice mapping, requirements and methods will more thoroughly be described in the remote sensing report.

For the dynamical and physical studies, ice information was collected from the following sources

on concentration,

- LANDSAT-2<sup>1</sup> pictures
- NOAA VHR<sup>2</sup> and SR<sup>3</sup> pictures (visual and infrared)
- ice reconnaissance flights
- routine ice charts and messages

on thickness,

- routine ice measurements
- measurements at several places during the field experiment

LANDSAT-2 passed over the area March 14, 15 and 16 and pictures from all three days have been received. However, the pictures only cover the northern part of the Bay. As seen from fig. 6 the information on the ice concentration is very detailed (resolution 70—100 m). From the picture it is also possible to distinguish between various types of ice.

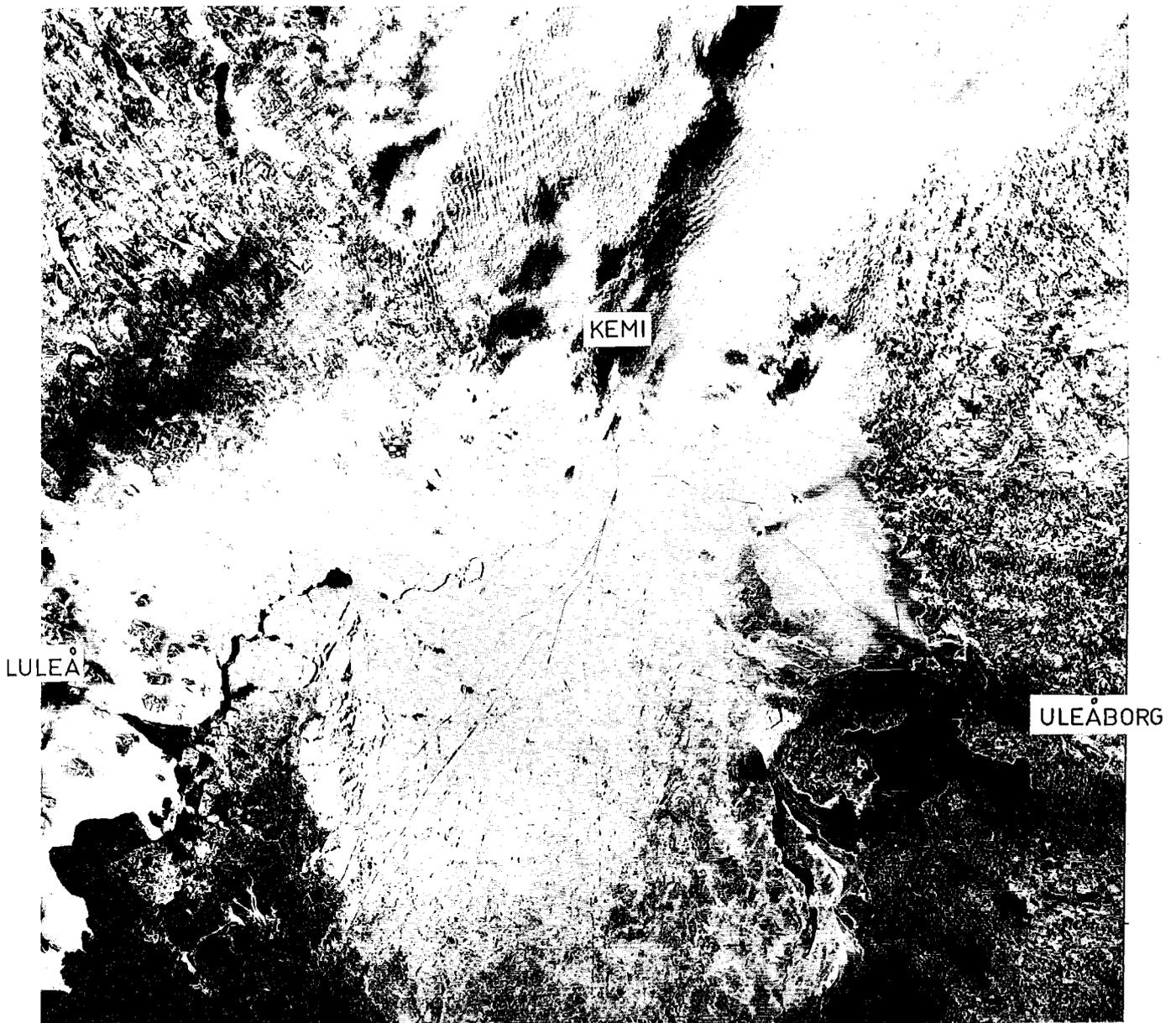
For the whole period March 10—20 visual and infrared NOAA VHR pictures have been collected. The resolution of the VHR pictures is about 900 m and consequently less good than LANDSAT pictures by one order of magnitude but the information on the concentration has still a better resolution than the routine ice maps. During the whole period the weather was suitable for satellite registrations and the information is therefore very valuable. Figure 7 shows the Bay of Bothnia seen from NOAA on March 17.

Ice reconnaissance flights were made mainly in the area around TOR in the middle part of the Bay of Bothnia. The flights were made with helicopter and the ice boundaries and types of ice were drawn on maps. Spot thickness measurements were also made.

Together with the above mentioned information on concentration and ice thickness the routine ice messages and charts were used to obtain an information as complete as possible.

The changes in the ice occurred mainly during the later part of the period. The period March 15—19 has been selected as an interesting situation for dynamical studies. For each day of the period two ice charts have been prepared, one showing ice concentration and the other level ice

- 1) *Earth resources satellite with multispectral scanner.*
- 2) *Weather satellite with very high resolution radiometer.*
- 3) *Weather satellite with scanning radiometer.*



**Figure 6.** A registration made by the Satellite LANDSAT-2 (MSS 7) on March 15. The picture covers the northern part of the Bay of Bothnia and is taken from a height of 900 km.



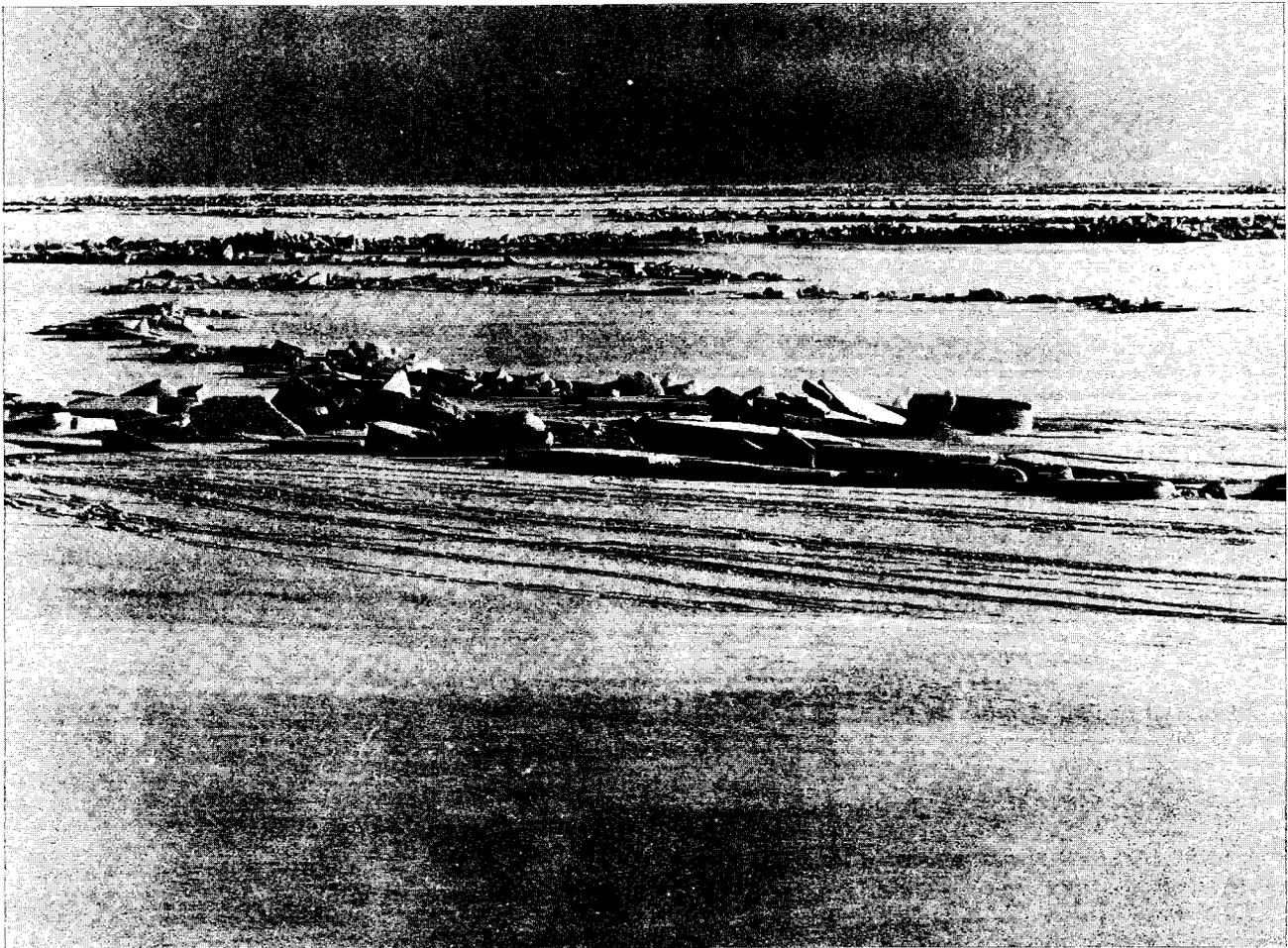
**Figure 7.** A VHRR visual registration received from the satellite NOAA 4 on March 17. It covers the Bay and the northern part of the Sea of Bothnia.

thickness. The concentration has a very high accuracy since it is based on good satellite pictures. The level ice thickness has an estimated accuracy of  $\pm 10\text{--}15\%$ .

The ice charts for the period March 15—19 are shown in attachments 1—5.

Small — scale thickness measurements were made in a  $1 \times 1$  km area around TOR. The ice thickness was measured every 200 meters but along one line holes were drilled and the thickness measured for every 10 meters. The results are shown in attachment 6. The measurements show a considerable variation over a rather small area. The level ice thickness was 25—30 cm but the mean value over the area was 43.5 cm. In connection with small ridges thickness of more than one meter was measured. The area was rather smooth compared to usual conditions in the Bay of Bothnia. A typical ice view is seen in figure 8. When modelling sea ice drift on the mesoscale the mean ice thickness over some kilometers must be known. From drill measurements it is obviously very difficult to determine the mean ice thickness in a representative way. This has been commented upon earlier (ref. 3). A rather well defined measure is the level ice thickness. This will however underrepresent the total mass, but using the level ice thickness together with the roughness of the ice surface and assuming hydrostatic balance the ice mass may yet be estimated with an acceptable accuracy.

**Figure 8.** *Sea ice. Level ice with ridges is characteristic for the Gulf of Bothnia.*



## 4. The Wind

The wind is one of the driving forces on sea ice and it enters equation (1) in the wind stress term. Wind measurements were made with an anemometer on the icebreaker TOR during the period March 10—20. The instrument was placed 24 m above sea level. The speed and direction was read every fifteenth minute. Observations were also made at the meteorological coast stations Rödkallen (12 m above sea level) and Bjuröklubb (55 m above sea level) at ordinary synoptic hours, that is every third hour.

Winds from the TOR, during the period of considerable ice drift, are presented in attachment 7 as one hour mean values. Winds from the TOR and the coastal stations for the whole period are presented in attachment 8. In attachment 8 also the temperature and the atmospheric pressure at Bjuröklubb are given. The accuracy in the values are comparable with routine meteorological measurements.

From the attachment 8 can be seen that the wind in the beginning of the period, March 10—15, was variable but mainly with directions between south and west. The speed never exceeded 10 m/s. During March 16 the wind turned to northwest and north and increased to gale force (19 m/s). It decreased during the 17th but increased again on March 18 to gale force (15 m/s) between south and west. At the end of the period the winds were mainly westerly and northwesterly 7—10 m/s.

The wind caused a considerable ice motion, especially in the middle of the period as will be seen below.

## 5. The Ice Motion

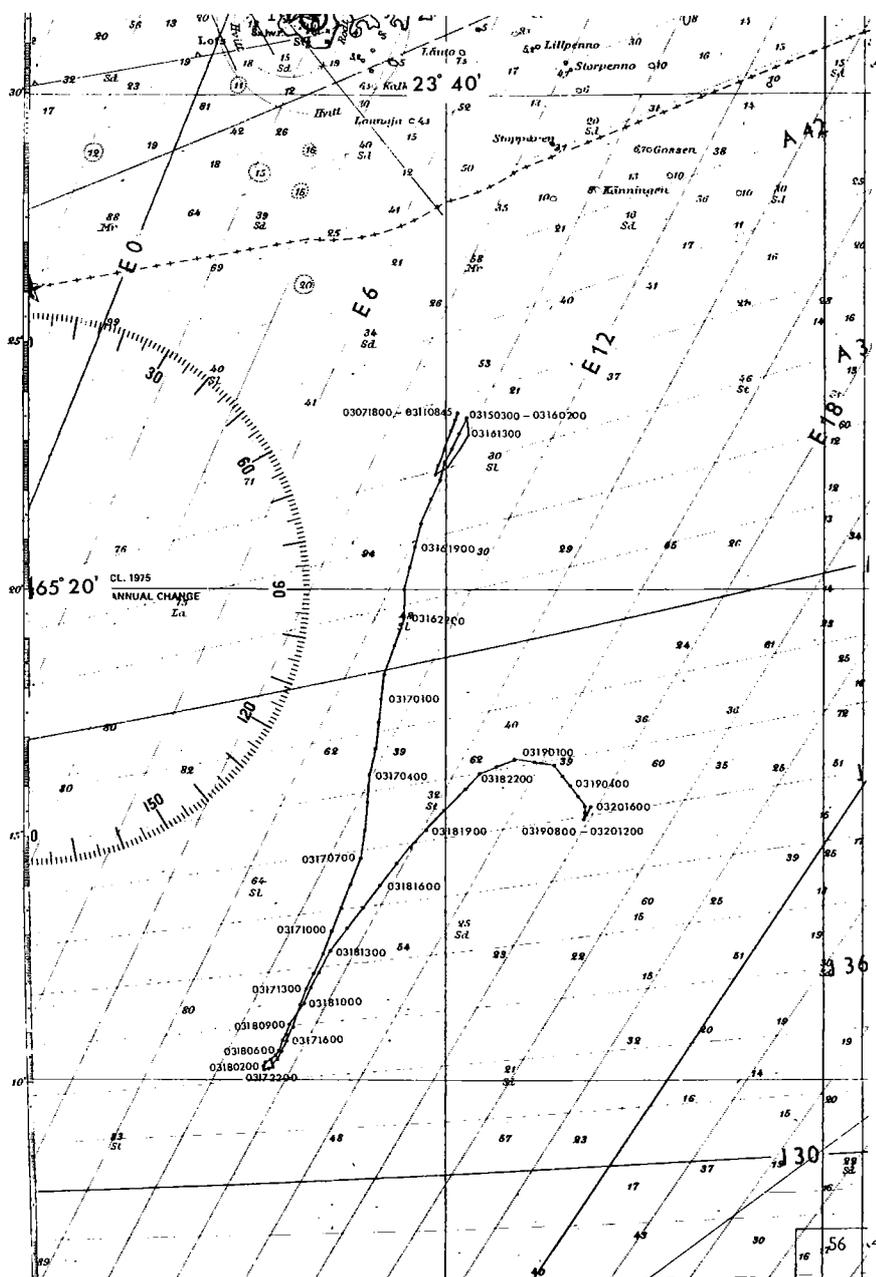
The ice motion is a factor entering equation (1) in the acceleration term, the stress terms, the coriolis term and the internal ice stress term.

The motion of the ice in the studied area was measured in two different ways.

- the position of the icebreaker TOR was observed with a DECCA navigator equipment every 15th minute
- the positions of eight radar reflectors on the ice were observed with one 3 cm and one 10 cm ship radar on board TOR every hour.

### a) The motion of the ice in the vicinity of the TOR

The drift of the icebreaker TOR with the ice during March 7—20 is shown in fig. 9. The drift was small except for the period March 16—19. The ice then moved totally 45 km due to strong northerly winds



**Figure 9.** The drift of the TOR with the ice during March 7—20. The figures on the trajectory refer to month, day and time of the day.

followed by southerly and westerly winds. The maximum speed during the drift was 30 cm/s.

The ice drift compared to the wind is shown in fig. 10. Under nonaccelerated conditions the drift direction is to the right of the wind direction with a mean value about  $30^\circ$  (attachment 7). Under accelerated conditions the values may vary and the drift may even be to the left of the wind direction as can be seen on the 18th in the evening.

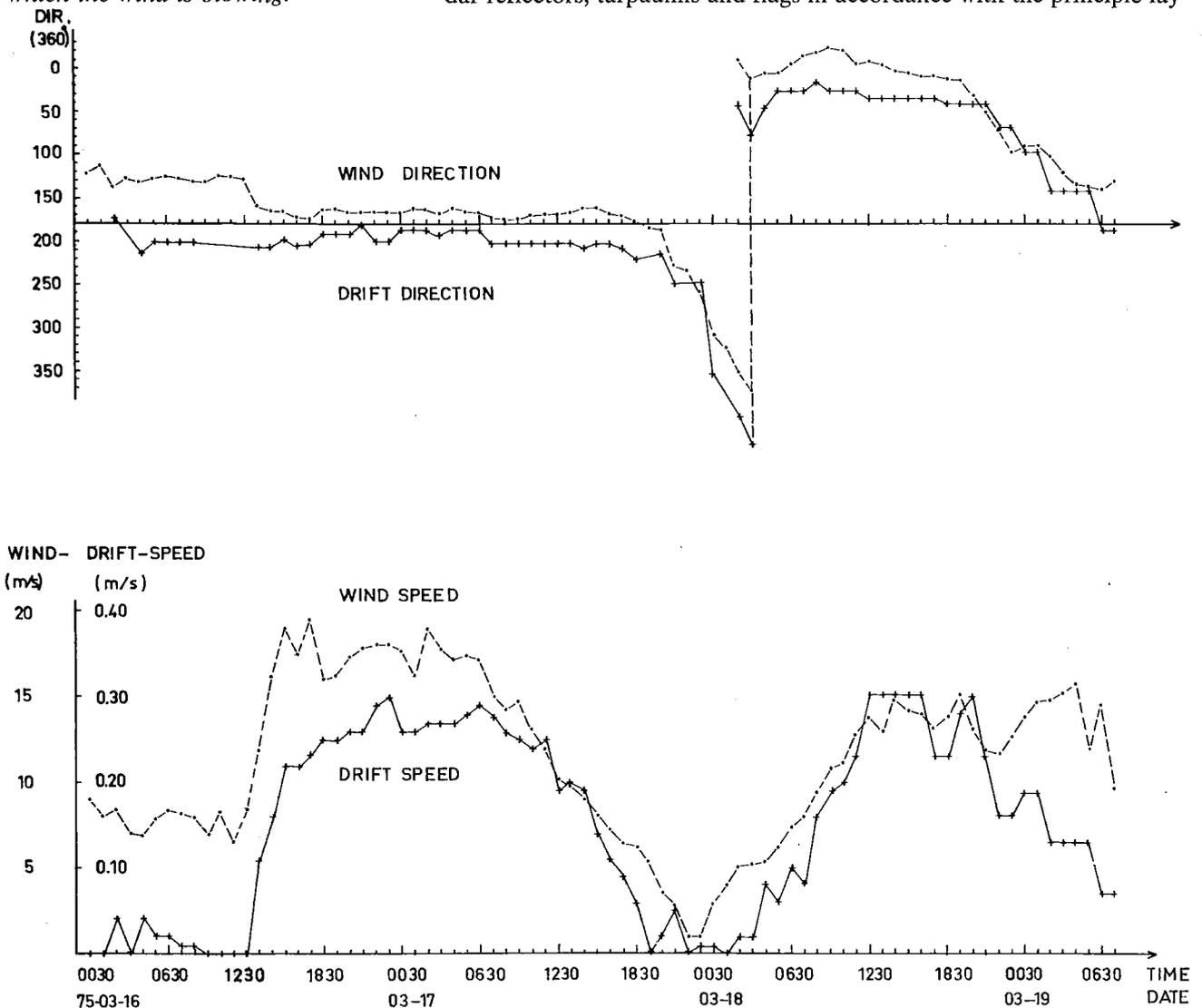
The drift speed is approximately 1.8 % of the wind velocity with lower values when the ice is breaking up and when it is pressing (see for example the 16th and the morning on the 17th, the evening on the 18th and the 19th) and higher values when the ice is freely floating (see for example the 17th in the afternoon and the 18th in the afternoon). The deflection angle and the windfactor is well in agreement with other measurements (ref. 11).

The response of the ice drift to wind changes may also be seen in the figure 10 but it is important to take into account the effect of the currents below the ice. The curves indicate a very rapid adjustment at some places a more or less immediate response is seen in other the response time is one to two hours. Theoretical estimates point towards an equilibrium state after a little more than 3 hours (ref. 11). Earlier field measurements point towards 3 hours (ref. 12). Our wind and ice drift values, which are hourly mean values based on measurements made every fifteenth minute, consequently indicate a more rapid adjustment. In the morning on the 18th drift response is rather slow but as shown in chapter 6 the currents were in the opposite direction of the ice drift and affected the response time.

**Figure 10.** A comparison between icedrift and wind measured from the TOR. In this figure the wind direction is the direction towards which the wind is blowing.

**b) The motion of the ice around the TOR**

Around the icebreaker TOR one small area ( $1 \times 1$  km), one medium area ( $5 \times 5$  km) and one large area ( $15 \times 15$  km) were marked with radar reflectors, tarpaulins and flags in accordance with the principle lay-



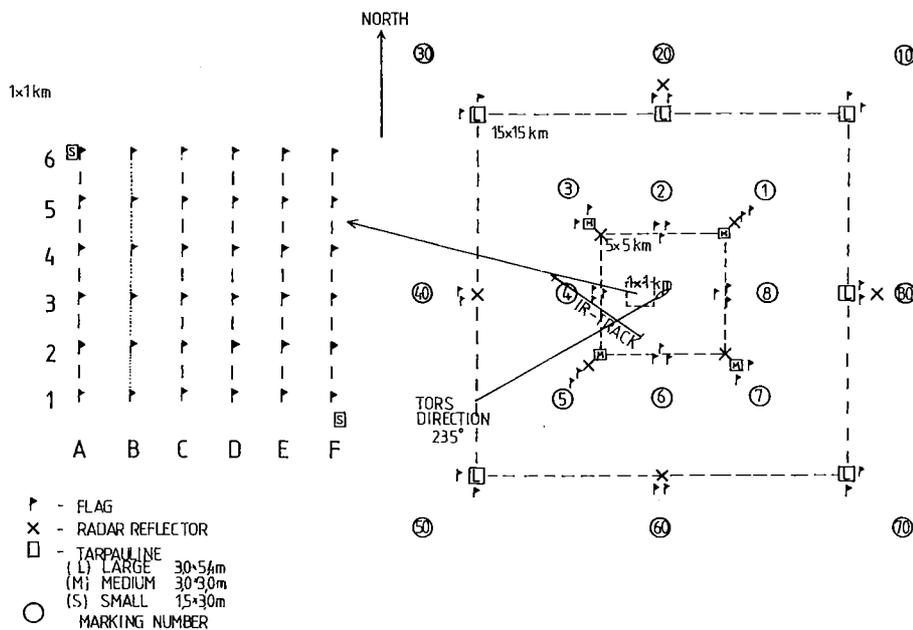


Figure 11. Principle layout of the test area around TOR.

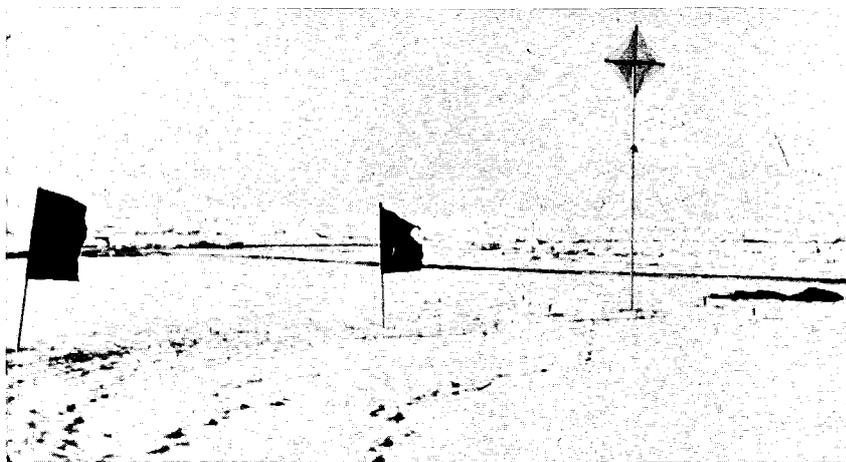


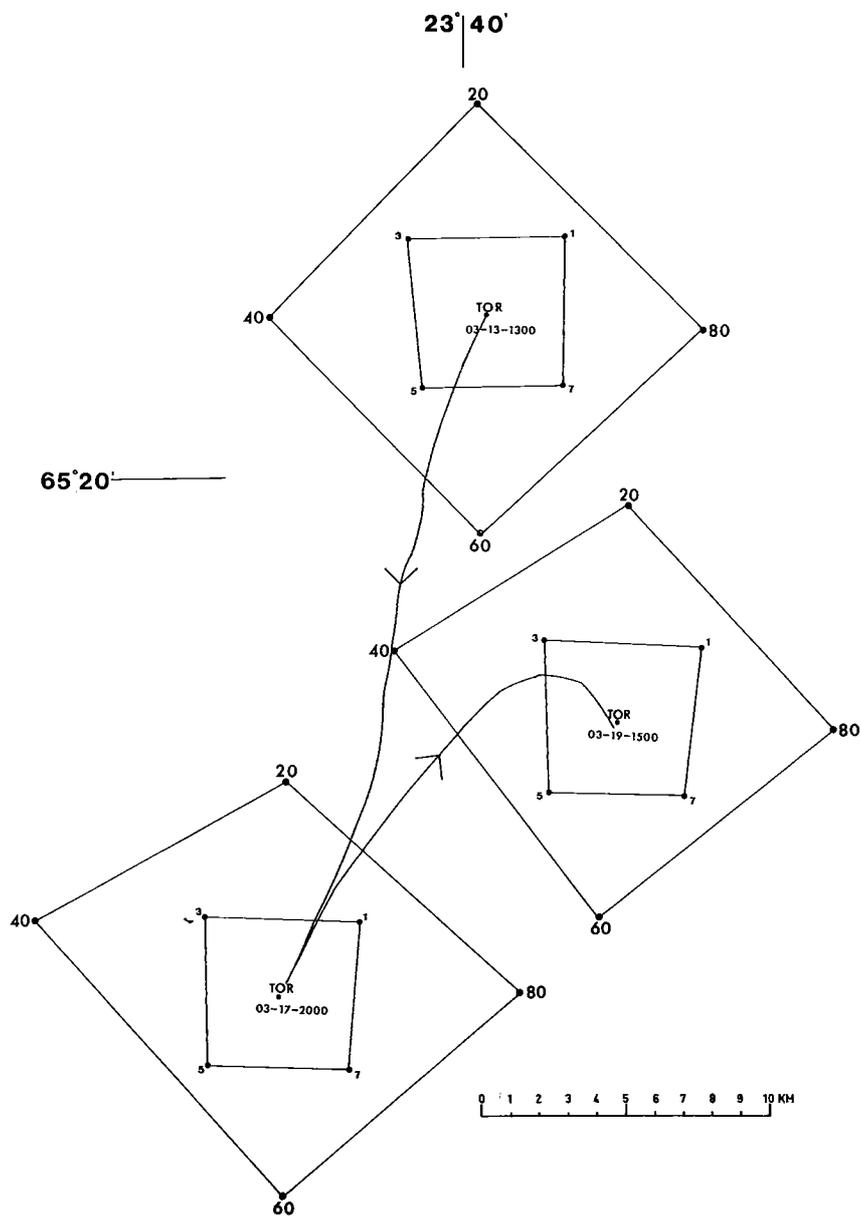
Figure 12. Marking number 3 with a net reflector, flags and tarpauline.

out shown in fig. 11. The aim with the markings was doublefold. They defined the area in which ground truth work was carried out during the remote sensing project, and the radar reflectors in the large and medium area were followed by the radars on board the TOR to study the motion and the deformation of the ice around the TOR. The ice-breaker was equipped with two radars, one 3 cm and one 10 cm. The distance and direction to the reflectors were measured on a PPI every hour. The reflectors were of the net type mounted on the top of an aluminium pipe and kept on the ice with four wires (fig. 12).

Figure 13 shows the position of the reflectors around the TOR at three different occasions. Lines have been drawn joining the reflectors in order to show the area enclosed and its changes. As seen from the figure the medium size area was rather unchanged during the movement but the large one was deformed, especially in its western parts. In the large area both a rotation and deformation occurred during the period. This area increased about 10 % during the motion southward and decreased 10 % during the return. From airphotos and visual observations it could also be seen that ridges and leads formed in the large area but not in the medium one.

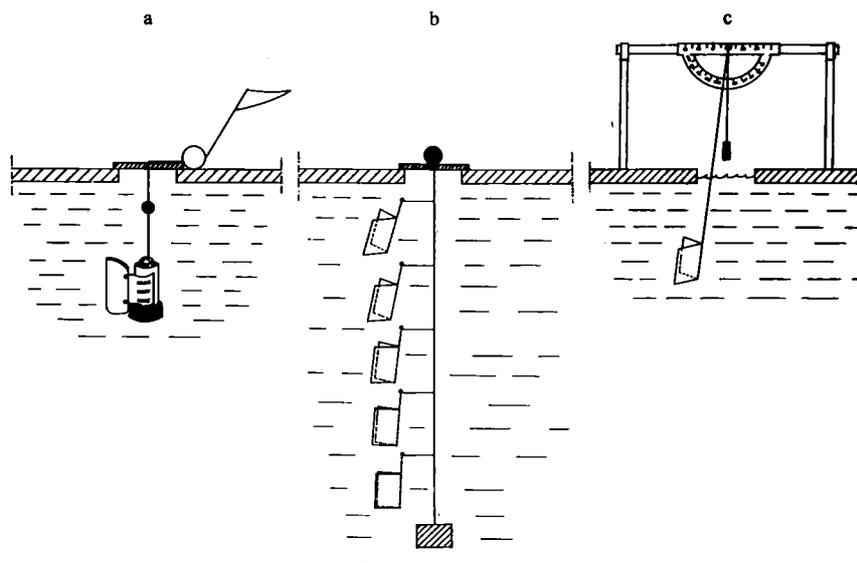
As the accuracy in the position of the icebreaker based on the DECCA navigator readings is about 100 meters, the accuracy in the velocity is about 3 cm/s independent of the ice velocity. The uncertainty in the reflector position is due to the radar approximately 100 m.

**Figure 13.** The deformation of the  $5 \times 5$  km and the  $15 \times 15$  km area during the ice drift. The arrowed line shows the drift of the TOR.



## 6. The Current

The drift of the ice is also influenced by the water. Generally the effect from the water acts as a retarding drag force but it may also, due to currents, act as a driving force. The influence from the water enters equation (1) in the water stress and the gravitational term. Different methods were used to study the currents (fig. 14).



**Figure 14.** Different methods for current measurements from ice used during SEA ICE-75.

- a) Continuously with an Alexejev current meter
- b) Discretely with gelatine pendulums at different levels
- c) Discretely with a simple pendulum adjustable to different depths.

**a) Continuous measurements with an Alexejev current meter (ref. 13)**

The instrument was handled by the Finnish Institute for Marine Research and was placed 5 meters below the ice surface. The current meter made a registration every 10 minute during the period March 11—20. The threshold speed for this instrument is about 3—4 cm/s. During the period March 11—16 there was hardly any current speeds higher than the threshold speed, but later from March 16 higher values were registered. They are presented as one hour mean values (attachment 9).

**b) Discrete measurements with gelatine pendulums (ref. 14)**

The pendulums were fixed to a rope and lowered into the water so that were hanging at 0.5, 1.5, 2.5, 5.0, 7.5, 10, 15 and 20 meters below the ice surface. The measurements are presented in appendix A and in attachment 10, which gives vertically integrated currents between 0—20 meters.

**c) Discrete measurements with a simple pendulum**

The pendulum consisted of a plough, a rope, a protractor and a wooden stand placed on the ice surface. The plough was easily lowered down to chosen depths and as the instrument could measure current speeds less than 1 cm/s, the instrument was used to detect low currents. 13 measurements were made from March 4—14. On one single day, March 11, current speeds above 1 cm/s were measured. The measurements made with the simple pendulum are listed in appendix A.

The current under moving ice can be measured in two different ways.

- By anchoring the current meter at the bottom (absolute velocity)
- By hanging the instruments at the ice surface (relative velocity)

Experiments with anchored gelatine pendulums were made but it appeared impracticable to use this method under drifting sea ice, because of the difficulties of taking up the pendulums. For that reason the second method was used for all current measurements.

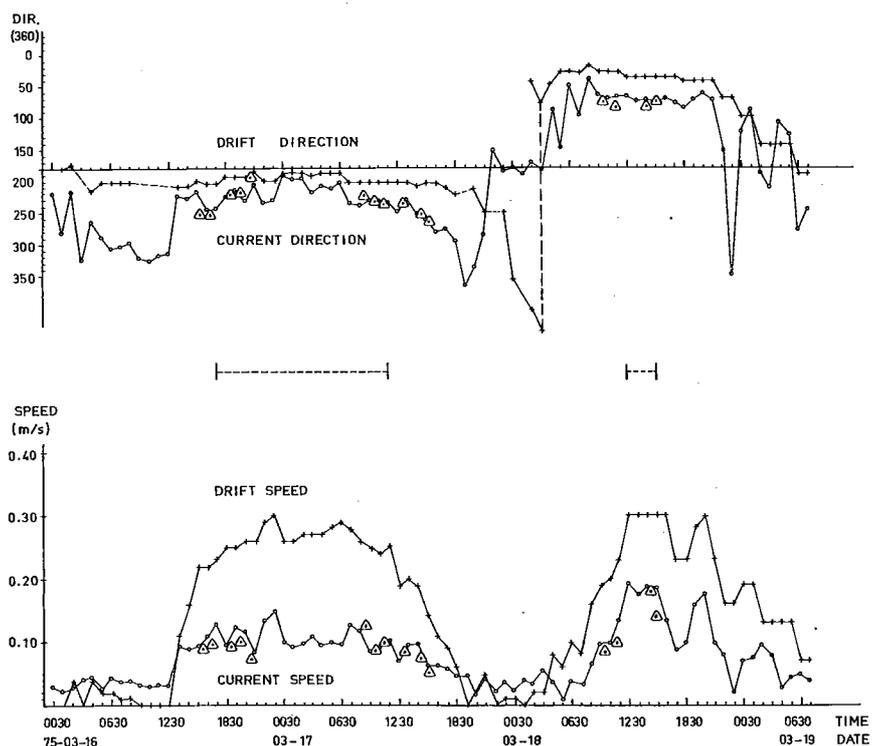
A disadvantage with hanging current meters is, that the relative current speed will be measured, which means, that the ice drift must be well known, the absolute current shall be calculated. It also means that the accuracy of the absolute current will depend both on the accuracy of the current meter and on the accuracy in the ice drift. The later one is less correct, see chapter 5, and will therefore determine the accuracy in the current measurements.

The results from the measurements are presented in different diagrams.

- I The Alexejev current meter values are plotted against ice drift in figure 15. During the periods with high ice velocities high current velocities occurred. When the ice was drifting almost constantly, the current speed was 40—60 % lower than the ice speed and the current direction deviated to the right of the ice direction. In the figure vertically integrated values from the gelatine current meters are plotted as triangles in the diagram. One can see that they agree quite well with the Alexejev values. This indicates that the depth of 5 meters, where the Alexejev current meter was hanging, represent the mean current under the ice surface down to 20 meters.
- II The pendulum values are plotted against wind and ice velocity in attachments 11—26. Looking from the atmosphere down to the sea one can clearly see a clockwise spiral structure between wind, ice and water velocity. The attachments also show, in most cases, a clockwise spiral structure in the upper layer of the sea.
- III The pendulum values are also plotted against the depth both in linear depth diagrams (attachments 11—26) and in logarithmic depth diagrams (attachments 27—28). The linear diagrams show a current down to more than 20 meters and a sharp velocity gradient just under the ice. From attachments 27—28 one can see a nearly logarithmic current profile down to some meters below the ice. A logarithmic profile is from dimensional consideration a necessity in the boundary layer, not too near and not too far from the ice (ref. 15). Provided the relative current under the ice is time independent and horizontally homogeneous the roughness parameter, the friction velocity and the friction coefficient between ice and water can be determined. In figure 15 the periods, which have been selected to satisfy above conditions, are marked with dashed lines.

From these few measurements the roughness velocity is 0.72 cm/s ranging from 0.56 to 0.89 cm/s. It should be noted, that during the periods when the relative currents were selected as time independent and homogeneous, there are two measurements where the velocity gradients are so weak that it is not relevant to determine any roughness velocity. They has been omitted when calculating the above values.

**Figure 15.** A comparison between ice-drift and current measured at the TOR. The triangles are vertically integrated values from gelatine measurements. The dashed horizontal lines mark nonaccelerated conditions.



From the friction velocity and the current at the bottom of the friction layer the friction coefficient in the water has been calculated. Besides the friction coefficient in air and water have been calculated in a number of cases assuming a balance between wind stress, water stress and coriolis force and using known currents below or at the bottom of the friction layer (ref. 21). The friction coefficient values obtained with the two methods agree and was  $1.4 \cdot 10^{-3}$  and  $4.1 \cdot 10^{-3}$  for air and water respectively. Those values correspond to roughness parameters of the size 0.06 cm and 0.6 cm. The above values have been used when computing the wind and water stress in chapter 8.

In table 2 a comparison is made between roughness parameters obtained by different authors. It can be seen that our values are in good agreement with values representing smooth ice in the Arctic.

The Ekman transport determined from the wind stress and the coriolis factor has been studied. By comparing it with the transport in the ice, received from our measurements it is seen that only a part of the Ekman transport is in the ice. This means that momentum is transferred from the air to the water.

UPPER ICE SURFACE

REFERENCE	ROUGHNESS PARAMETER (cm)		REMARK
	range	mean	
Udin & Omstedt 1975		0.06	Ice in the Bay of Bothnia
Reed & Campbell 1960 (ref. 8)	0.02-2.65		
Liljeqvist 1962 (ref. 13)		0.01	Smooth snow surface
Untersteiner & Badgley 1965 (ref. 14)	$\sim 10^{-4}$ -10	0.02	Arctic ice
Ling & Untersteiner 1974 (ref. 15)	0.008-0.018	0.0118	90% confidence interval

**Table 2.** Comparison of roughness parameters determined by different investigators.

LOWER ICE SURFACE

REFERENCE	ROUGHNESS PARAMETER (cm)		REMARK
	range	mean	
Udin & Omstedt 1975		0.6	Ice in the Bay of Bothnia
Campbell 1965 (ref. 1)	0.1-2.65		
Untersteiner & Badgley 1965 (ref. 14)	0.1-10	2.0	
Johannessen 1970 (ref. 16)	8.1-10.0	9.4	Very rough ice
- " -	1.0-6.1	3.2	Quite rough ice
- " -	1.5-4.7	3.0	Rough ice
- " -	0.2-1.4	0.7	Smooth ice
Hunkins 1972 (ref. 17)		0.15	
Ling & Untersteiner 1974 (ref. 15)	0.817-1.93	1.255	90% confidence interval

## 7. The Sea Surface Tilting

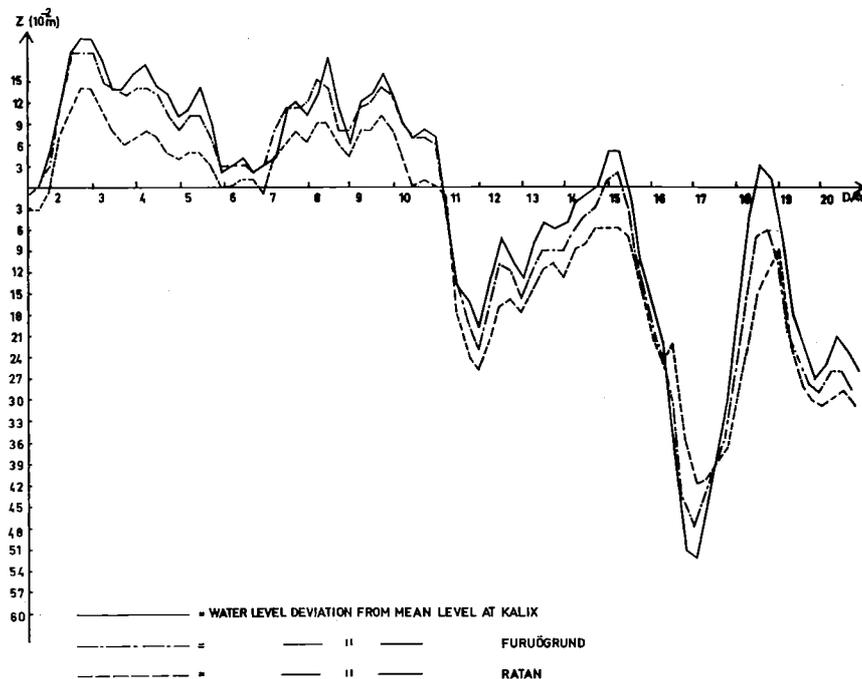
The sea surface, upon which the ice floats is tilting due to differences in the sea level. From the tilting a gravitational force arises, which works to move the ice in the direction towards lower sea surface. The force appears in equation (1) as a gradient of the sea level.

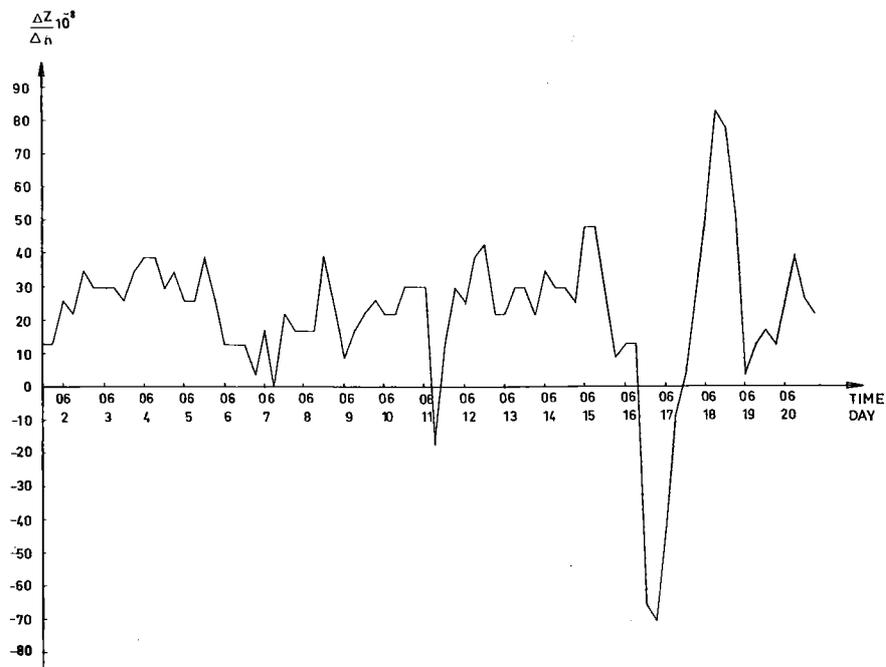
In order to study the force, water level records from Ratan, Furögrund and Kalix have been examined for the period. The sea level deviations from statistical mean values at the stations are presented in figure 16. It shows water level changes at Kalix of 72 cm during the period, while the changes at the other stations are smaller. The curves show large fluctuations on March 11 and from March 15 until the end of the period.

The large scale sea surface tilting in the Bay of Bothnia has been calculated from the water level records. Sea level deviations at Ratan and Kalix, have been divided with the distance between the stations (figure 17). If the values are multiplied with the ice mass and the acceleration of gravity ( $g=9,8 \text{ m/s}^2$ ) they will correspond to the gravitational force  $G$ , mentioned in equation (1). In the figure large values are seen on March 11 and from March 15 until the end of the period. The magnitude of the gravitational force during the last days was of the same order of magnitude as the coriolis force caused by the earth's rotation.

The drift speed, the current speed and the tilting of the sea surface are compared in figure 18. The components in the length direction of the Gulf of Bothnia (SSW-NNE) are given.

**Figure 16.** The sea level deviations at Ratan, Furögrund and Kalix during March 1—21 1975.

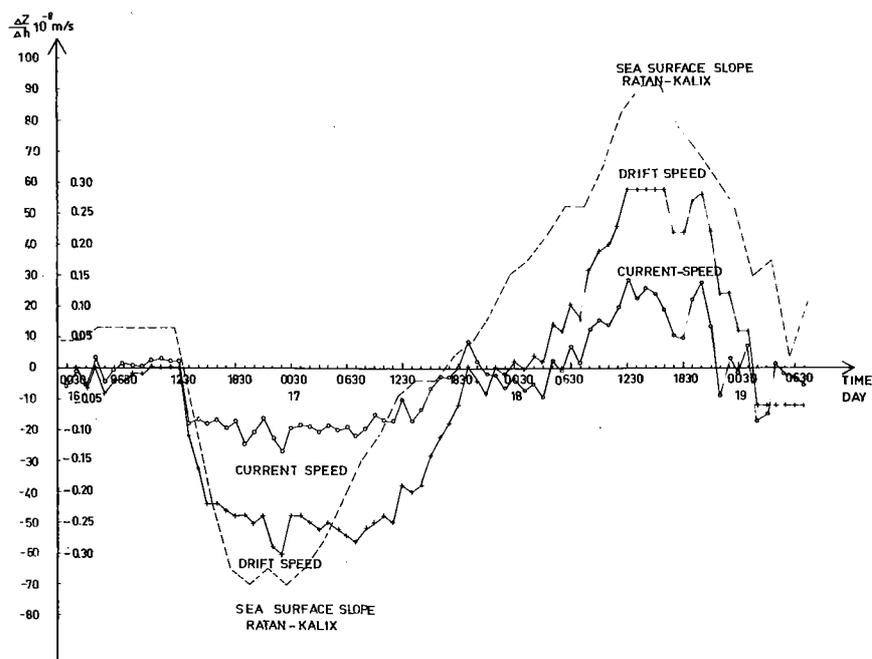




**Figure 17.** The sea surface slope between Kalix and Ratan during March 1—21 1975.

$\Delta Z$  - DIFFERENCE IN THE SEA LEVEL BETWEEN KALIX AND RATAN

$\Delta n$  - DISTANCE BETWEEN KALIX AND RATAN



**Figure 18.** A comparison between the sea surface slope, the drift speed and the current speed are shown during March 16—19 1975. The components are in the direction of the Gulf of Bothnia (SSW-NNE).

## 8. The Force Balance

The forces and parameters in equation (1) are discussed above. Of utmost interest when studying ice dynamics and forecasting is how the ingoing forces balance each other and what order of magnitude they have. Those things, of course, depend on the length and time scale studied. In our computation of the forces (ref. 21) the mesoscale has been considered.

When computing the forces in equation (1) a residue,  $\sigma$ , arises due to i.e. errors in the measurements. Thus,

$$\sigma = m \frac{dv}{dt} - \tau_a - \tau_w - C - G - R \quad (3)$$

If the internal ice stress is put together with the residue to a rest term,  $\tau$

$$\sigma + R = \tau = m \frac{dv}{dt} - \tau_a - \tau_w - C - G \quad (4)$$

In equation (4) the stress terms  $\tau_a$  and  $\tau_w$  have been calculated with a ordinary boundary layer approach. Thus,

$$\tau = C_f \cdot \rho \cdot \gamma \cdot v |v| \quad (5)$$

where  $C_f$  is the friction coefficient and  $\gamma$  the stability in the air or the water. The values of the friction coefficients are  $1.4 \cdot 10^{-3}$  and  $4.1 \cdot 10^{-3}$  for air and water respectively.

The stratification in the water during the winter is almost neutral but in the air inversions in many cases cause stable stratification.

The coriolis term has been computed from the knowledge of the ice velocity, concentration, thickness and density. In the computation it is of great importance to realize that the ice thickness on the mesoscale in most cases deviates from the level ice thickness. As mentioned above (chapter 3) the mean thickness due to deformation, ice ridges etc. may differ with an order of magnitude.

The gravitational force has been computed in the way presented in chapter 7 and with

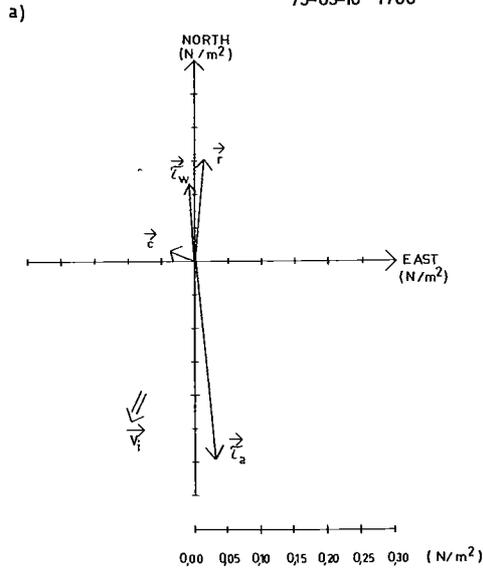
$$G = -mg \nabla z \quad (6)$$

where  $\nabla z$  is the surface slope.

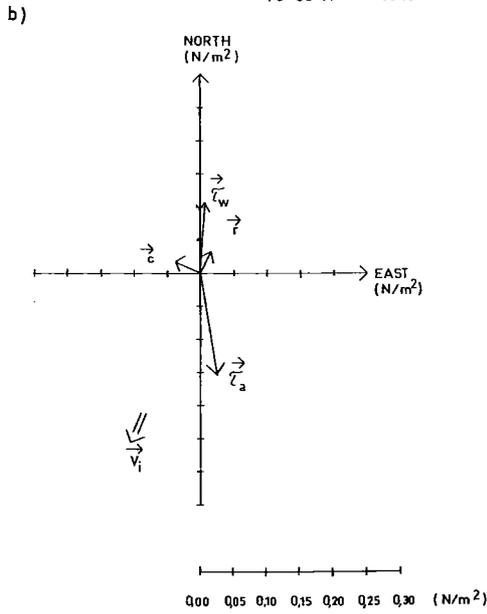
The forces in equation (4) have been plotted in diagrams for fifteen different occasions. All studied cases show that  $\tau_a$  and  $\tau_w$  are approximately of the same size and opposite directed. The coriolis force is smaller than the stress terms but in almost all of the cases at least one order of magnitude larger than the acceleration and gravitational terms. The rest term,  $\tau$ , varies in a systematic way. It is comparable to  $C$  when the ice field is freely floating and increases when the ice starts to break. With the reservation that the coefficients are chosen improperly the variation of  $\tau$  indicate that the internal ice stress (or a part of it) could be treated as a viscous force, since  $\tau$  during the movement acted both as a driving and as a retarding force in such a way that the momentum exchange between the ice floes seems physically acceptable.

Three of the diagrams mentioned above are presented in figure 19. They are chosen from the beginning of the drift period a), from the middle b) and from the end of the period c).

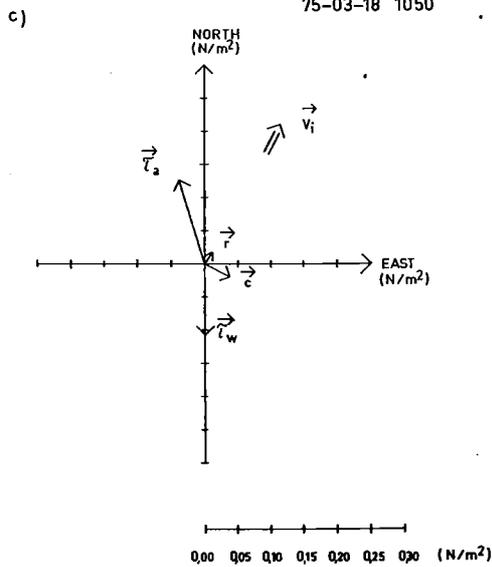
DATE: TIME:  
75-03-16 1700



DATE: TIME:  
75-03-17 1015



DATE: TIME:  
75-03-18 1050



**Figure 19.** The forces in the equation of motion together with the ice drift direction at three occasions during SEA ICE-75. The lengths of the arrows are proportional to the magnitude of the forces.

## 9. Temperature and Salinity

In order to study how the water under the ice was stratified, how the salinity varied in the ice and how the temperature varied in different ice types, measurements of salinity and temperature were made in the ice and under the ice.

The salinity and temperature at different depths under the ice were measured with an electrical thermometer and salinometer, type MC5 from Electronic Switzgear.

The accuracy of this instrument is  $\pm 0.1$  °C and  $\pm 0.1$  ‰. The measurements are presented in attachments 29—32, which show a neutral stratification in the water layers under the ice.

The salinity of the ice was measured in the following way. Two areas with level ice thickness of 27 cm, were choosen. The ice was picked up, cleaned at top and bottom and then cut in four different slices. From the slices two small (10×10×10 cm) pieces were put in plastic bags and melted. The salinity was then determined in laboratory with an accuracy of  $\pm 0.005$  ‰. Two separate determinations were made for each level. The results are presented in table 3. The table shows extreme low ice salinity, less than 0.5 ‰. One can also see that the ice salinity varies with depths in the ice.

**Table 3.** Ice salinity in different layers and areas in the northern part of the Bay of Bothnia.

LEVEL (counted from top)	AREA 1, S(‰)	AREA 2, S(‰)
1 (2-7cm)	0.435	0.452
2 (8-13cm)	0.292	0.195
3 (14-19cm)	0.440	0.365
4 (20-25cm)	0.251	0.273

The ice temperature was measured at five different points with Pt100 transducers, coupled to an electric temperature meter. Measurements were made continuously between March 8 and March 19 excluding some stops. The sensors were placed at different points on the ice, two sensors were placed on an ice ridge, two on level ice with different thicknesses and one 1.5 m above the ice surface. The results are presented on paper records with registrations every second minute. One can see, that the ice temperature follows the air temperature and that the temperature in different ice types are differnt. The changes and lags seem however not to be systematic.

## 10. Conclusions and Discussion

The field experiment carried out in the Bay of Bothnia was a part of a project concerning sea ice dynamics. The aim was to study the assumptions made in a numerical ice drift model under development at SMHI and to collect sufficient input data for test runs.

The **adjustment** of the ice drift to wind changes is rather rapid. The registrations indicate sometimes an almost immediate adjustment and sometimes a total response after one or two hours. Assuming steady state i.e. neglecting the first term in equation (1), seems therefore not critical when working on a time scale of more than 6 hours.

From the registrations the angle between wind and ice drift, called the **drift angle** and the relation between ice and wind velocities, called the **wind factor**, are calculated. Under nonaccelerated conditions their mean values are  $30^\circ$  to the right of the wind and 1.8 % of the wind speed. The values agree well with values reported from Arctic studies.

**Currents** under the ice were measured both continuously at five meters and intermittently at different depths. Under moving ice the current velocities at five meters were of the same order of magnitude as the ice velocity and even at twenty meters considerable currents were measured. Under nonmoving ice no currents were observed. The measurements also show a weak clockwise spiral structure and indicate logarithmic velocity profiles down to some meters below the ice surface.

Temperature and salinity at different depths were measured. The results show **neutral stability** condition in the water. In the atmosphere, the meteorological radio soundings studied show that **stable stratification** is most common in the area when the sea is ice covered. When computing the stress terms the assumption of neutral stability in the sea consequently seems relevant but in the atmosphere the stable stratification must be taken into account.

Frequent measurements of **ice thickness** show that it is important to take into account the amount of deformed ice and not only to use the level-ice thickness in the mass computations. The thickness of level-ice and the mean thickness may differ up to one order of magnitude. The deformed ice also plays an important role for parameters in the boundary layers both above and below the ice. In the computations of the coriolis term the mean ice thickness must be used.

The **slope of the sea surface** and the gravitational force have been studied. Differences of the sea level in the Bay of Bothnia may in extreme cases cause a gravitational force which is of the same order of magnitude as the coriolis term. In most cases however the tilting of the sea surface cause a force which is one order of magnitude smaller than the coriolis term. Consequently it seems not critical to omit the gravitational force in the equation of motion as a first approximation.

The **balance of the forces** in the equation of motion for sea ice has been studied in a number of cases. The study shows that the two main forces were the wind stress and the water stress and that those together with the coriolis force and the internal ice stress mainly balanced each other.

From the study variations in the rest term (including the internal ice stress) are clearly seen. When the ice field was breaking up the force was large but in free-floating ice it was smaller. It acted both as a driving and as a retarding force.

When modelling sea ice dynamics on the mesoscale the equation of motion may therefore be reduced to

$$\tau_a + \tau_w + C + R = 0 \quad (7)$$

In the computation of the stress terms the field experiment support a boundary layer approach assuming an Ekman layer in both air and water with logarithmic velocity profiles near the ice surfaces.

The results are in agreement with the approach made in the numerical ice forecasting model developed at SMHI (ref. 1) but are in great contrast with the model presented by Valli and Leppäranta (ref. 22).

By their assumption they mix the water stress and the internal ice stress to one new force which they treat in a viscous way. This treatment of the problem is totally unacceptable in a physical sense.

The data obtained during the field experiment will be used for further studies e.g. the currents under the ice need a more thorough treatment and probably increased field studies. They will also be used as initial and verification data to the numerical model, for recalculation of certain constants and parameters etc.

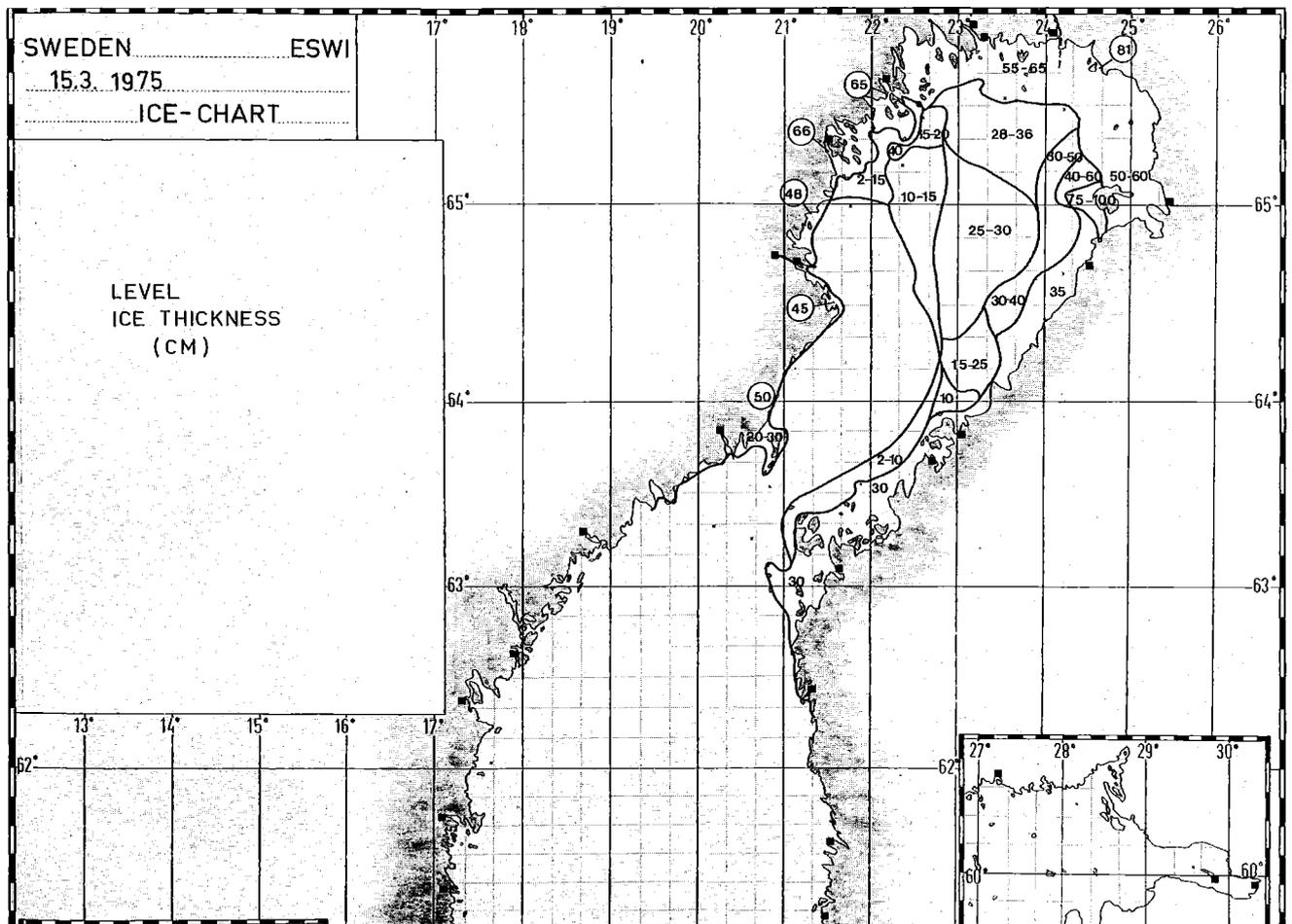
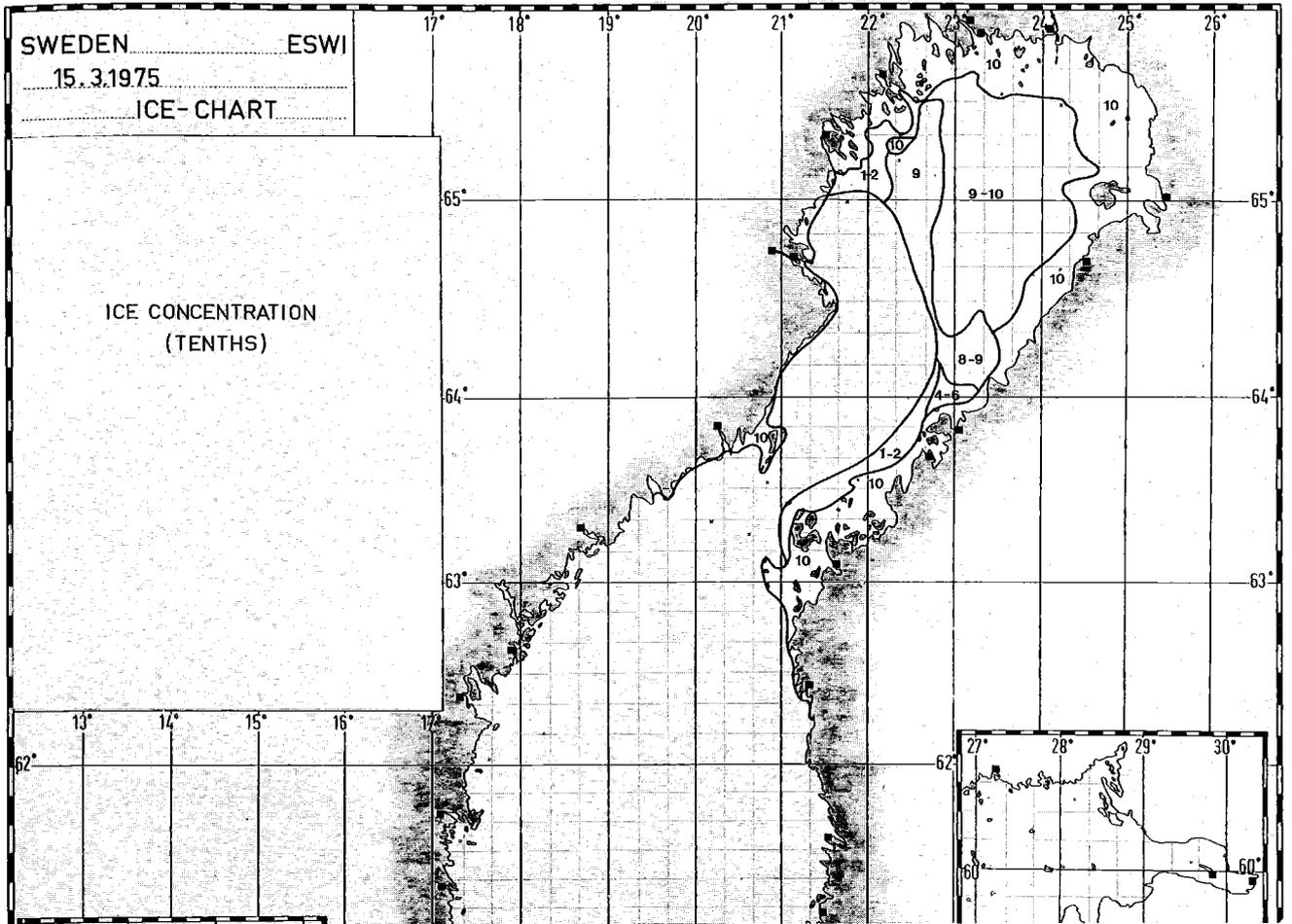
## Acknowledgements

Outside the Swedish Meteorological and Hydrological Institute the authors wish to thank the Swedish Icebreaking Service, its Director and the captain and crew on board icebreaker TOR for their valuable support both during the experiment and during the planning. The authors are also indebted to Dr. Gösta Walin and to Dr. Johan Rodhe at the Institute of Oceanography, University of Gothenburg for valuable discussions, suggestions and support.

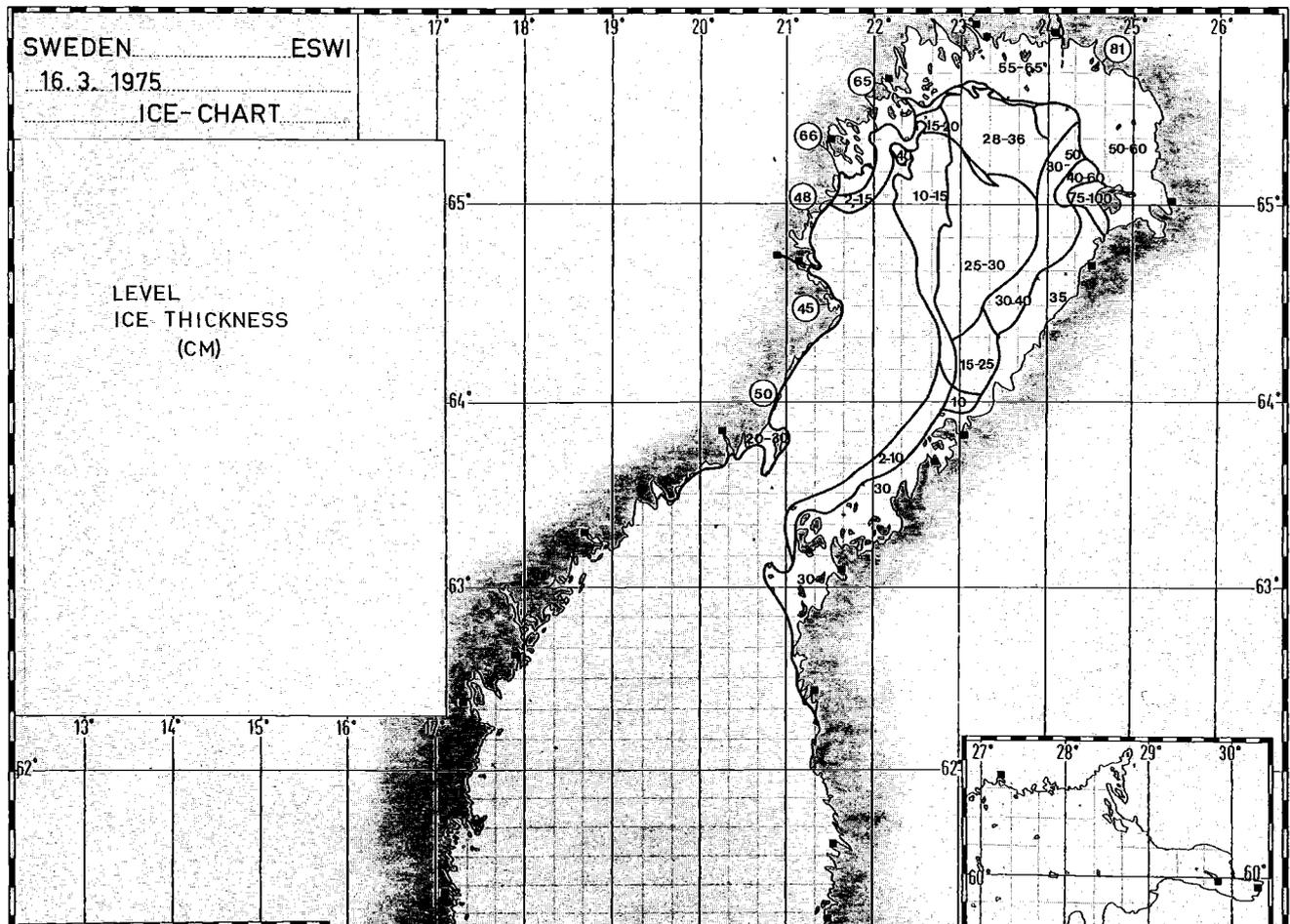
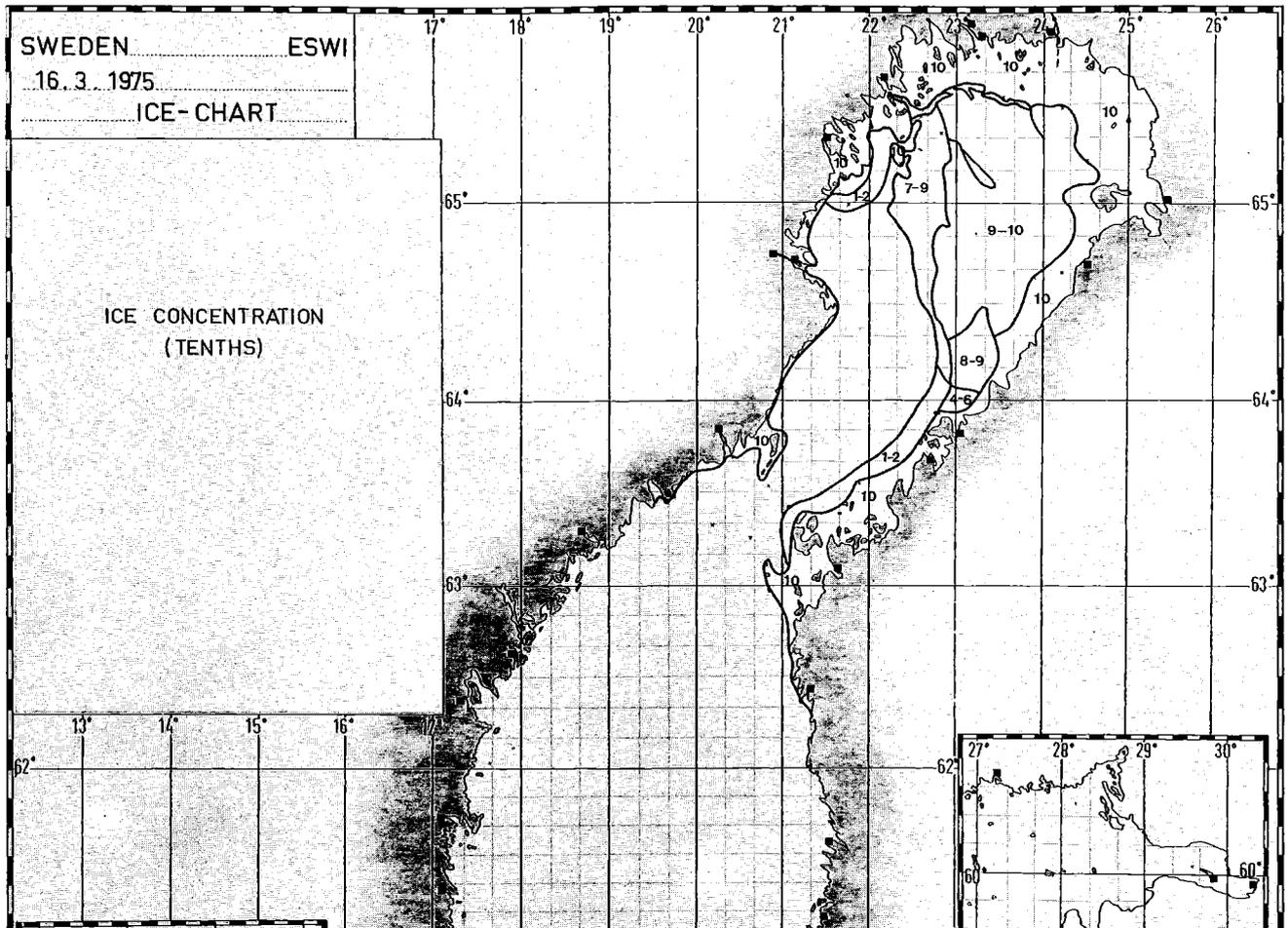
## References

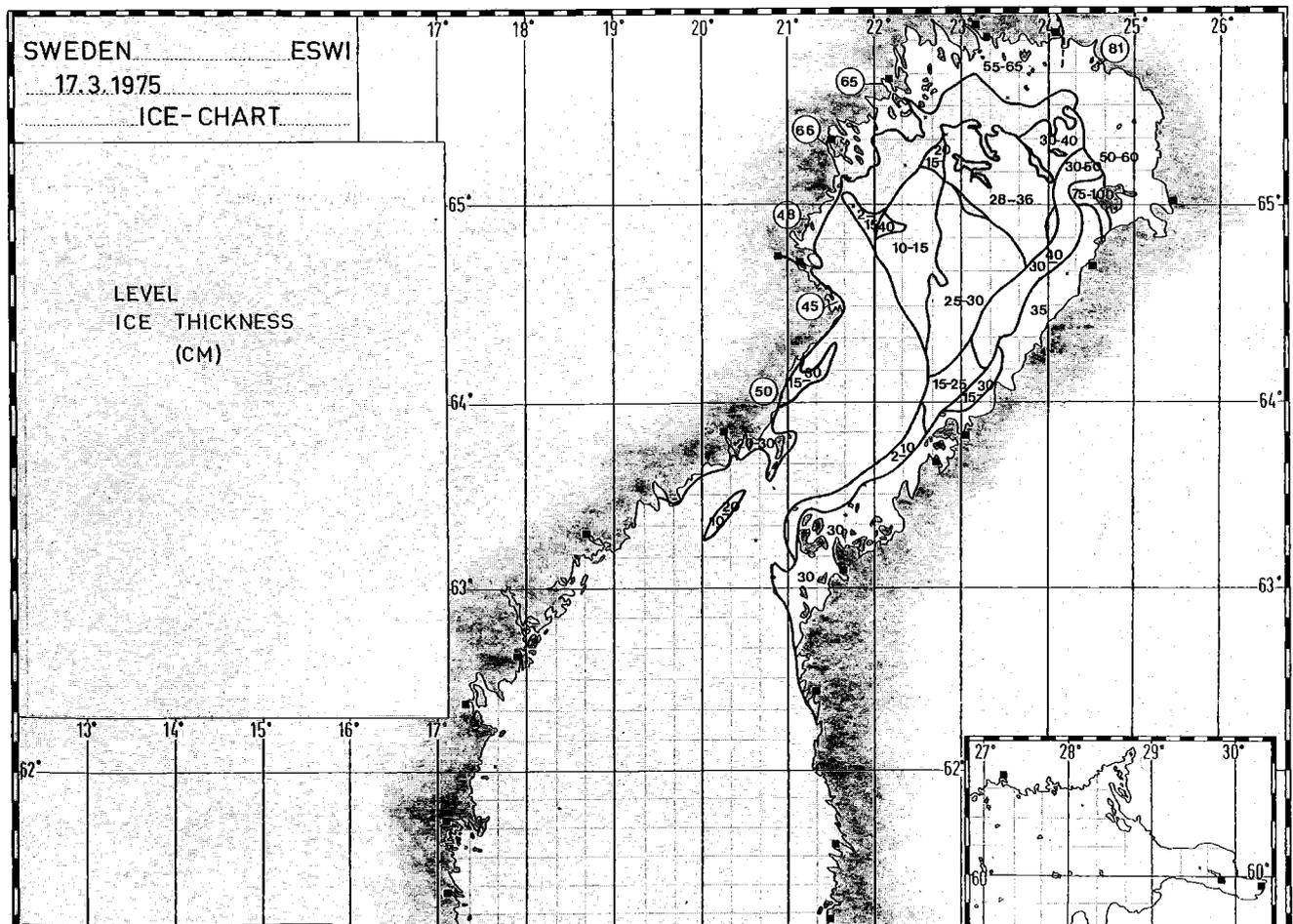
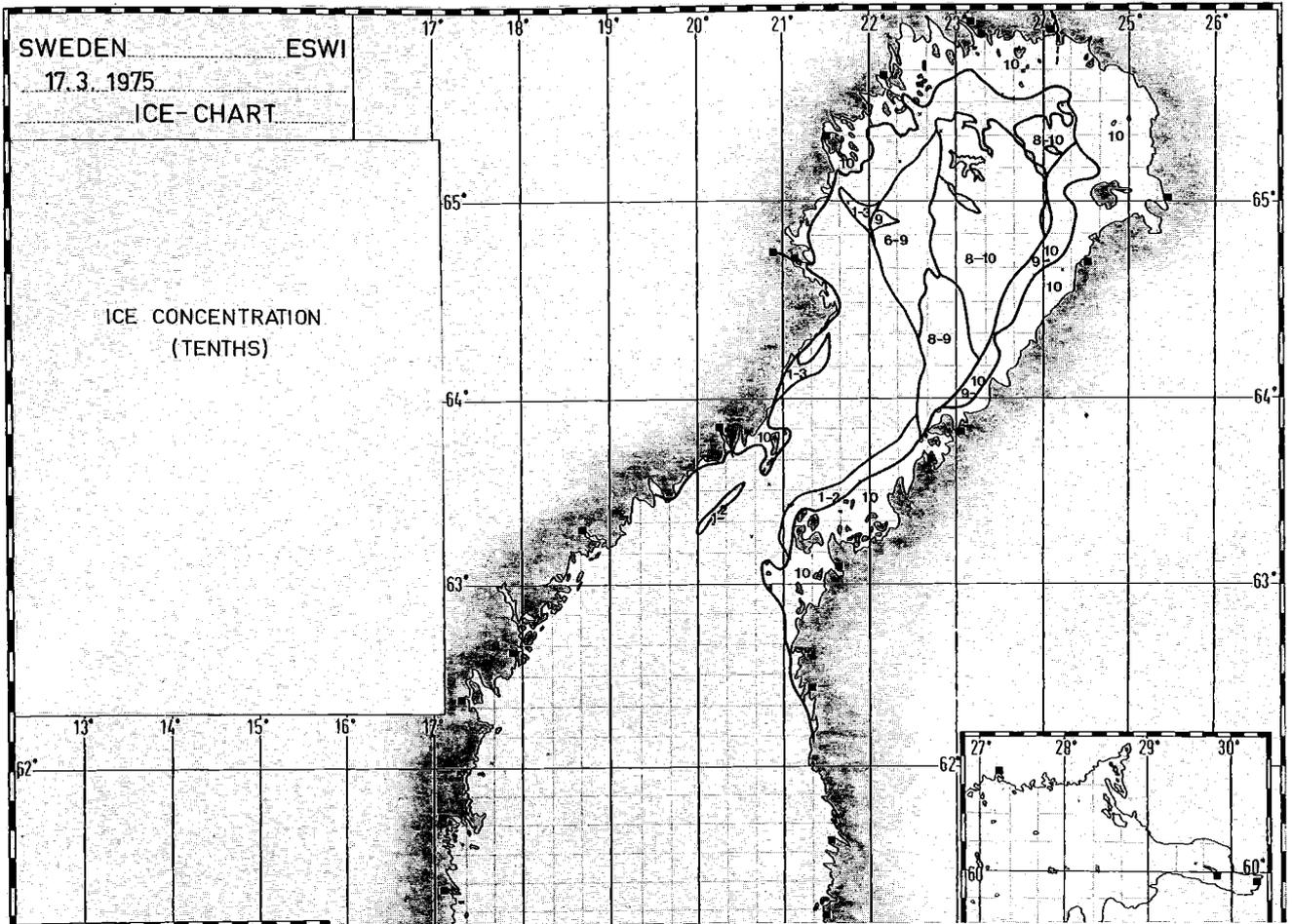
1. Udin, I. och Ullerstig, A., 1973: Isdynamik. PM 1/1973 SMHI/VBM, Fack, S-601 01 Norrköping, Sweden.
2. Campbell, W.J., 1965: The Wind-Driven Circulation of Ice and Water in a Polar Ocean. *Journ. of Geophysical Research*. Vol. 70. no. 14. July 15, 1965.
3. Omstedt, A., Thompson, T. och Udin, I., 1974: Havsisundersökningen i Bottenviken vintern 1974. Styrelsen för Vintersjöfartsforskning, Sjöfartsverket i Sverige och Sjöfartsstyrelsen i Finland. Forskningsrapport nr 8.
4. Blomquist, Å., Pilo, C. and Thompson, T., 1975: SEA ICE-75. Programme. Swedish-Finnish Board for Winter Navigation Research 1975.
5. Palousuo, E., 1975: Formation and structure of ice ridges in the Baltic. Finnish Board of Navigation and Swedish Administration of Shipping and Navigation. Rep. no. 12.
6. Fonselius, S.H., 1974: Oceanografi. Generalstabens Litografiska Anstalt, Stockholm 1974.
7. Fonselius, S.H., 1971: Om Östersjöns och speciellt Bottniska vikens Hydrografi. *Vatten* nr. 3, 1971.
8. Wessel, L., 1971: Havsströmmar. ISF. Ubj: Hydrografi. Marinstaben, Stockholm.
9. Lizitzin, E., 1957: The annual variation of the slope of the water surface in the Gulf of Bothnia. *Soc. Scie. Fennica. Com. Phys. Mat.* XX 6 Helsingfors 1957.
10. Rothrock, D.A., 1970: The kinematics and mechanical behavior of pack ice: The state of the subject. *Aidjex bull.* No. 2, Oct 1970, Univ. of Wash. Seattle, Washington 98105.
11. Reed, R.J. and Campbell, W.J., 1960: Theory and Observations of the drift of ice stations Alpha. Final Report prepared for the Office of Naval Research under Task Number No 307—250. Department of Met. and Clim. Univ. of Wash. Dec. 1960.
12. Tabata, T., 1971: Observations of deformation and movement of ice field with Sea Ice Radar Network. *Sea Ice. Proceeding of an international conference.* Reykjavik, Iceland, May 10—13, 1971. National Research Council Reykjavik 1972.
13. Aleksejvs system: Current Recorders types G 11 B-2 and G 11 B-2P. Description and Operating Instructions KGO, 278.000 T01, USSR, 1955.
14. Haamer, J., 1972: Ny typ av momentan strömmätare, gelatin pendeln. In: *Meddelanden från Svenska Havsforskningsföreningen*, No 7, Sweden.
15. Tennekes, H. and Lumley, J.L., 1972: *A First Course in Turbulence.* The MIT Press. Cambridge, Massachusetts, and London, England.
16. Liljeqvist, G.H., 1962: *Meteorologi*, Generalstabens Litografiska Anstalts Förlag, Stockholm.
17. Untersteiner, N. and Badgley, F.I., 1965: The Roughness Parameters of Sea Ice. *Journal of Geophysical Research*. Vol. 70, No. 18. Sept. 15, 1965.
18. Ling, Chi-Hai and Untersteiner, N., 1974: On the calculation of the roughness parameters of sea ice. *Aidjex bull.* no. 23. Jan 1974. Univ. of Wash. Seattle, Washington 98105.
19. Johannessen, O.M., 1970: Note on Some Vertical Profiles below ice floes in the Gulf of St. Lawrence and near the North Pole. *Journal of Geophysical Research.*, Vol. 75, No 15, May 20, 1970.
20. Hunkins, K., 1972: Water stress and ocean current measurements at camp 200. *Aidjex bull.* No. 12. Febr. 1972. Univ. of Wash. Seattle, Washington 98105.

21. Omstedt, A. och Udin, I., 1975: Beräkningar av kraftbalanser i samband med SEA ICE-75. PM 1/1975 SMHI/VBM, Fack, S-601 01 Norrköping, Sweden.
22. Valli, A. and Leppäranta, M., 1975: Calculation of Ice Drift in the Bothnian Bay and the Quark. Swedish Administration of Shipping and Navigation and Finnish Board of Navigation. Rep. No. 13.

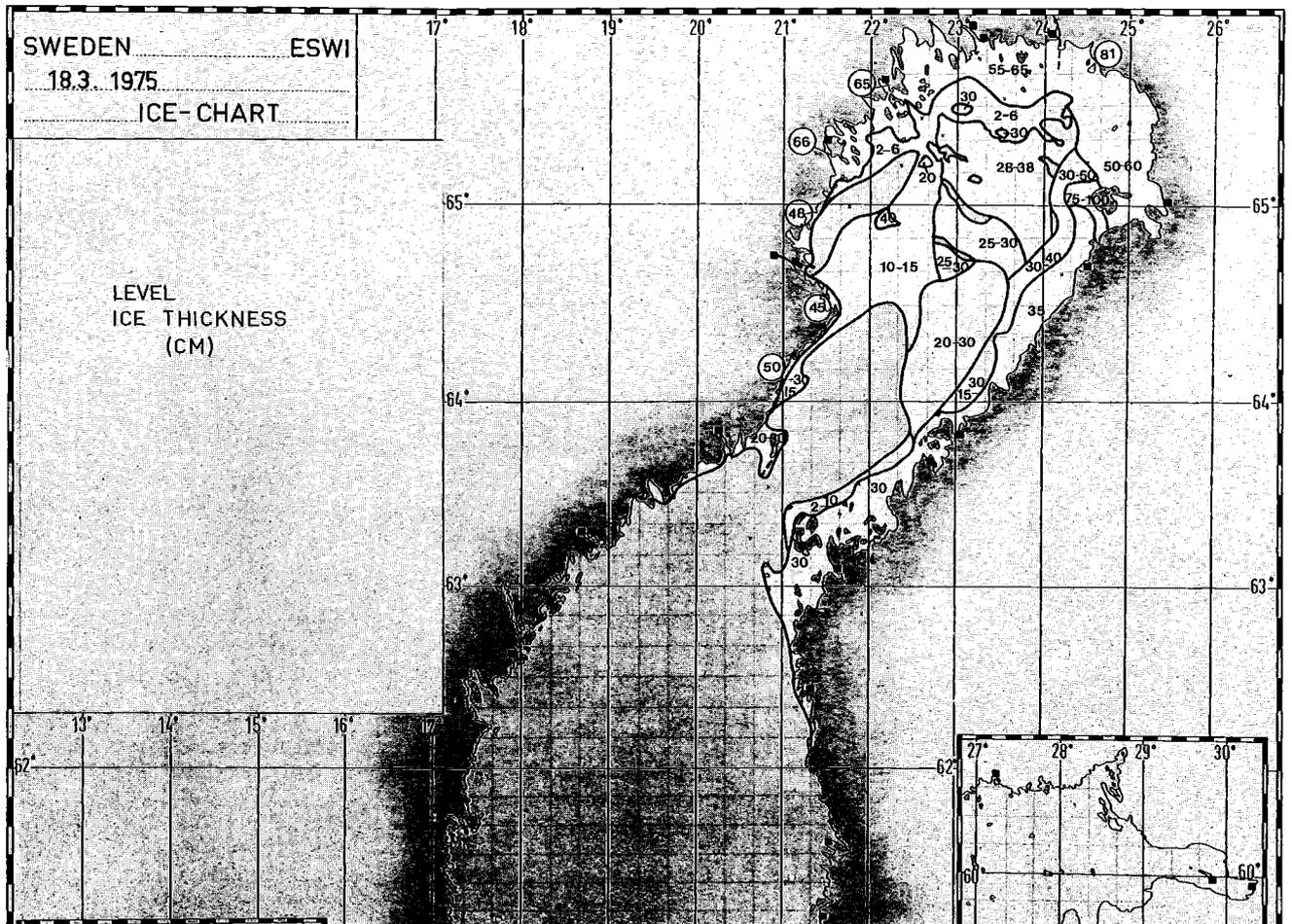
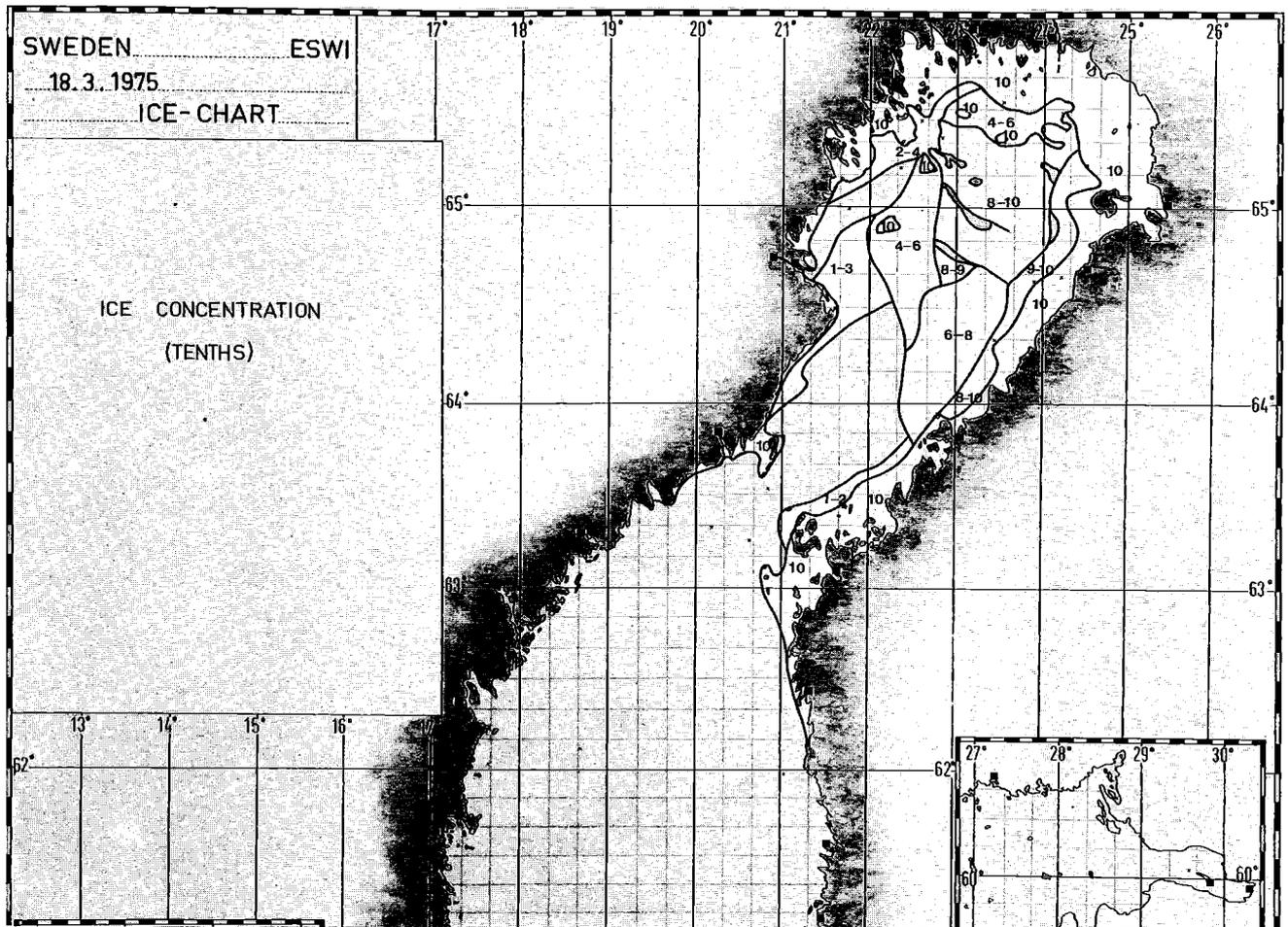


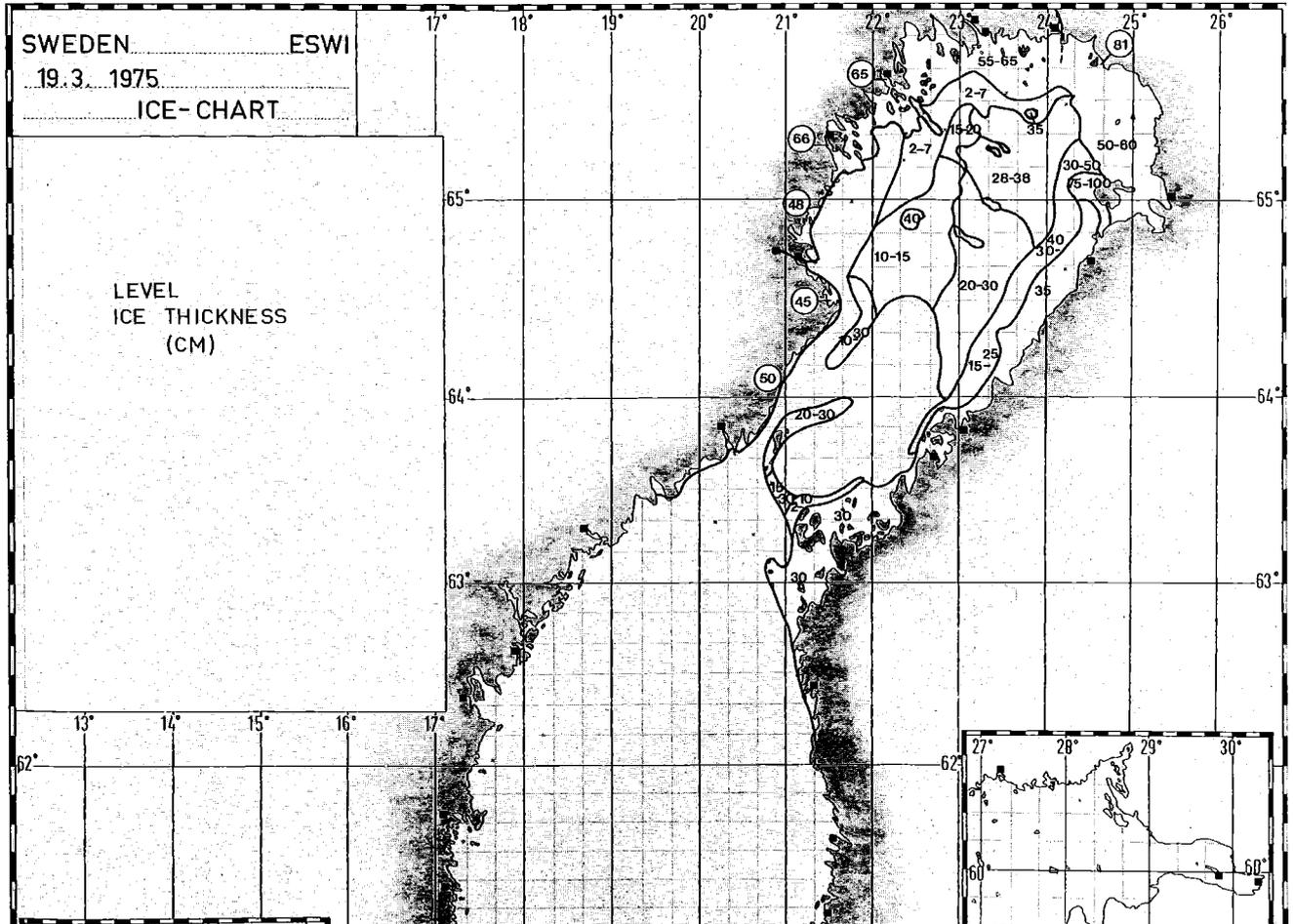
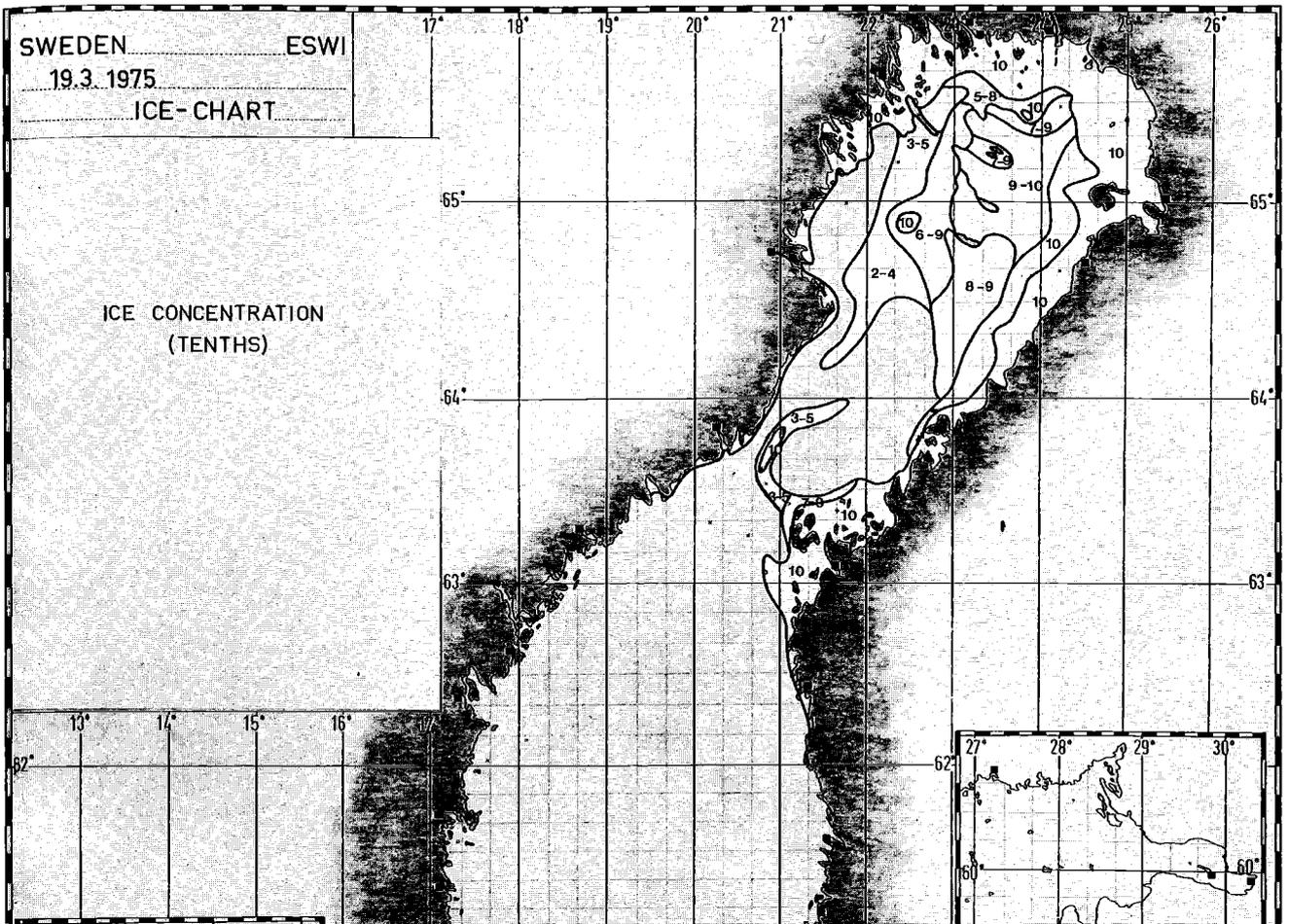
# Attachment 2



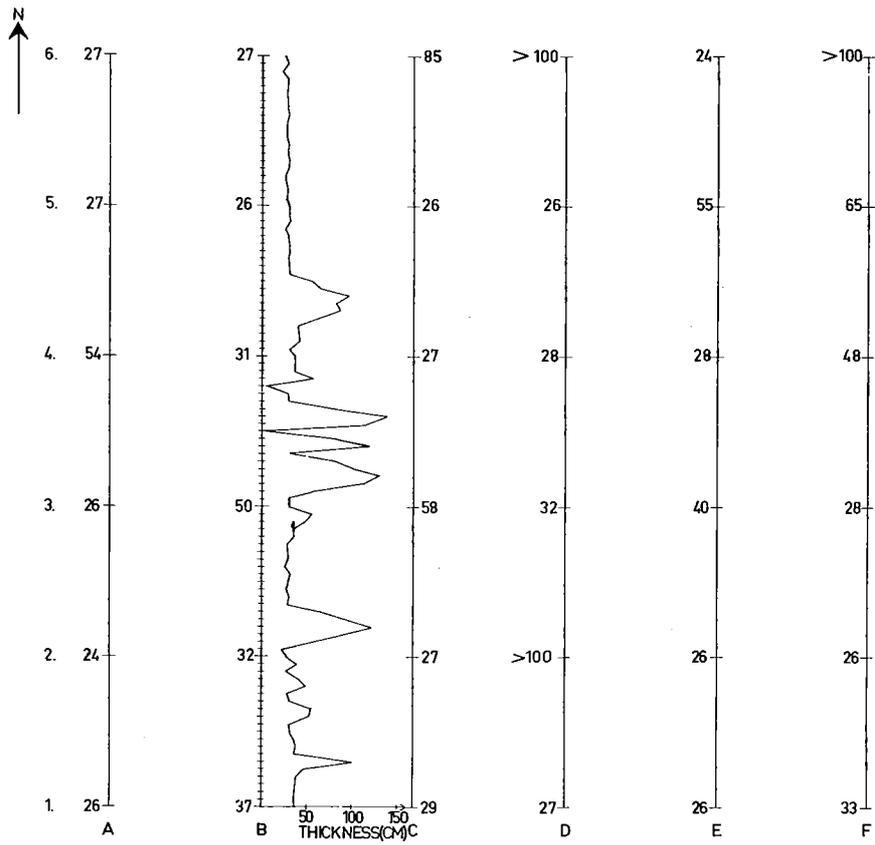


Attachment 4





# Attachment 6



# Attachment 7

WIND AND ICE VELOCITY BETWEEN 75-03-16 - 75-03-19

DATE	TIME	WIND VELOCITY		ICE VELOCITY		ANGULAR DIFFERENCE $\theta_i - (\theta_a - 180^\circ)$	WINDFACTOR $\left  \frac{\vec{v}_i}{\vec{v}_a} \right  \cdot 100$
		SPEED(m/s) $ \vec{v}_a $	DIR(360°) $\theta_a$	SPEED(m/s) $ \vec{v}_i $	DIR(360°) $\theta_i$		
16/3-75	0030	9.0	300	0.00	-	-	0.0
	0130	8.0	305	0.00	-	-	0.0
	0230	8.4	319	0.04	173	034	0.5
	0330	7.0	310	0.00	-	-	0.0
	0430	6.9	312	0.04	214	082	0.6
	0530	7.9	308	0.02	201	073	0.2
	0630	8.4	305	0.02	201	076	0.2
	0730	8.2	307	0.01	201	074	0.1
	0830	8.0	310	0.01	201	071	0.1
	0930	7.0	311	0.00	-	-	0.0
	1030	8.2	303	0.00	-	-	0.0
	1130	6.5	305	0.00	-	-	0.0
	1230	8.4	308	0.00	-	-	0.0
	1330	12.0	340	0.11	207	047	0.9
	1430	16.2	345	0.16	207	042	1.0
	1530	19.0	346	0.22	199	033	1.2
	1630	17.5	353	0.22	204	031	1.2
	1730	19.5	353	0.23	204	031	1.2
	1830	16.0	344	0.25	194	030	1.6
	1930	16.2	343	0.25	194	031	1.5
	2030	17.2	345	0.26	194	029	1.5
	2130	17.8	345	0.26	182	017	1.5
	2230	18.0	345	0.29	200	035	1.6
2330	18.0	345	0.30	200	035	1.7	
17/3-75	0030	17.8	346	0.26	186	020	1.5
	0130	16.2	342	0.26	186	024	1.6
	0230	19.0	342	0.27	186	024	1.4
	0330	17.8	349	0.27	193	024	1.5
	0430	17.2	342	0.27	186	024	1.6
	0530	17.5	345	0.28	186	021	1.6
	0630	17.2	347	0.29	186	019	1.7
	0730	15.0	352	0.28	202	030	1.9
	0830	14.2	355	0.26	202	027	1.8
	0930	14.8	355	0.25	202	027	1.7
	1030	13.0	350	0.24	202	032	1.8
	1130	12.0	350	0.25	202	032	2.1
	1230	10.1	348	0.19	202	034	1.9
	1330	9.7	346	0.20	202	036	2.1
	1430	9.0	342	0.19	208	046	2.1
	1530	8.1	342	0.14	203	041	1.7
	1630	7.2	348	0.11	203	035	1.5
	1730	6.5	351	0.09	208	037	1.4
	1830	6.2	357	0.06	220	043	1.0
	1930	5.3	005	0.00	-	-	0.0
	2030	3.6	008	0.02	214	026	0.6
	2130	2.9	049	0.05	249	020	1.7
	2230	1.0	055	0.00	-	-	0.0
2330	1.0	078	0.01	249	-009	1.0	

DATE	TIME	WIND VELOCITY		ICE VELOCITY		ANGULAR DIFFERENCE $\theta_i - (\theta_a - 180^\circ)$	WINDFACTOR $\left  \frac{\vec{v}_i}{\vec{v}_a} \right  \cdot 100$
		SPEED(m/s) $ \vec{v}_a $	DIR(360°) $\theta_a$	SPEED(m/s) $ \vec{v}_i $	DIR(360°) $\theta_i$		
18/3-75	0030	2.9	131	0.01	355	044	0.3
	0130	4.0	145	-	-	-	0.0
	0230	5.1	171	0.02	044	053	0.4
	0330	5.2	193	0.02	078	065	0.4
	0430	5.4	188	0.08	047	039	1.5
	0530	6.1	187	0.06	028	021	1.0
	0630	7.3	178	0.10	028	030	1.4
	0730	7.9	167	0.08	028	041	1.0
	0830	9.4	161	0.16	018	037	1.7
	0930	10.8	158	0.19	029	051	1.8
	1030	11.2	160	0.20	029	049	1.8
	1130	12.8	175	0.23	029	034	1.8
	1230	13.8	174	0.30	037	043	2.2
	1330	13.0	177	0.30	037	040	2.3
	1430	14.7	184	0.30	037	033	2.0
	1530	14.3	186	0.30	037	031	2.1
	1630	14.0	190	0.30	037	027	2.1
	1730	13.2	190	0.23	037	027	1.7
	1830	13.9	194	0.23	044	030	1.6
	1930	15.0	195	0.28	044	029	1.9
	2030	13.0	213	0.30	044	011	2.3
	2130	11.9	231	0.23	044	-007	1.9
	2230	11.7	252	0.16	069	-003	1.4
2330	12.5	277	0.16	069	-028	1.3	
19/3-75	0030	13.9	271	0.19	099	008	1.4
	0130	14.8	270	0.19	099	009	1.3
	0230	14.9	281	0.13	142	041	0.9
	0330	15.2	300	0.13	142	022	0.9
	0430	15.8	315	0.13	142	007	0.8
	0530	12.1	316	0.13	142	006	1.1
	0630	14.5	320	0.07	186	046	0.5
	0730	9.7	312	0.07	186	054	0.7

# Attachment 8

WIND VELOCITY, AIR TEMPERATURE AND AIR PRESSURE BETWEEN 75-03-10 - 75-03-20.

Month	Day	Time (GMT)	Icebreaker TOR	Rödskallen	Bjuröklubb	Bjuröklubb Pressure(mb)
			Dir(360°)/Speed(m/s) temp	Dir(360°)/Speed(m/s) temp	Dir(360°)/Speed(m/s) temp	
03	10	00	229/03 1	-	250/06 -1	1001.0
		03	-	270/04 -2	270/06 -1	1002.4
		06	239/04 -2	270/04 -3	250/06 -2	1004.0
		09	290/04 -1	270/04 -2	270/08 1	1006.5
		12	230/05 3	250/04 0	270/07 5	1008.0
		15	220/05 2	250/03 1	270/05 6	1008.9
		18	230/01 -2	270/06 -2	210/07 0	1010.0
		21	250/03 -3	-	210/06 -1	1010.2
		00	070/00 -3	-	210/06 -3	1010.4
	11	03	180/03 -3	220/04 -4	210/06 -4	1011.0
		06	240/07 -3	340/05 -3	320/10 -1	1012.2
		09	340/12 -2	340/09 -2	320/10 1	1016.0
		12	330/10 -1	340/06 -1	320/10 2	1020.2
		15	310/09 -2	340/05 -1	320/08 2	1021.4
		18	300/10 -3	270/06 -2	300/07 -2	1022.5
		21	280/09 -3	-	300/06 -3	1023.4
		00	280/10 -3	-	300/08 -3	1023.4
		03	250/08 -4	320/08 -1	300/08 -4	1023.0
	12	06	270/07 -3	270/06 -1	300/08 -2	1022.8
		09	240/08 -1	270/06 0	300/08 2	1022.5
		12	250/08 4	320/07 2	320/10 4	1022.7

WIND VELOCITY, AIR TEMPERATURE AND AIR PRESSURE BETWEEN 75-03-10 - 75-03-20.

Month	Day	Time (GMT)	Icebreaker TOR	Rödskallen	Bjuröklubb	Bjuröklubb Pressure(mb)	
			Dir(360°)/Speed(m/s) temp	Dir(360°)/Speed(m/s) temp	Dir(360°)/Speed(m/s) temp		
03	12	15	240/08 3	300/07 2	270/08 3	1021.2	
		18	240/09 1	270/07 2	270/06 1	1020.8	
		21	270/10 1	-	300/06 2	1020.5	
	13	00	280/08 1	-	300/06 1	1021.4	
		03	280/07 0	270/04 0	300/05 0	1021.6	
		06	310/06 0	270/04 0	300/05 2	1022.0	
		09	270/05 1	270/03 1	300/02 6	1022.2	
		12	-	270/03 2	270/04 8	1021.9	
		15	245/05 2	270/03 3	320/02 8	1021.9	
		18	230/06 -2	270/05 2	270/03 3	1022.1	
		21	270/08 -1	-	270/05 1	1021.8	
		14	00	247/08 -2	-	270/04 0	1021.1
			03	237/07 -3	270/08 -1	270/03 -1	1020.5
			06	247/07 -3	250/06 -2	270/04 -2	1019.7
	09		246/06 0	270/04 0	270/06 2	1019.5	
	12		196/03 3	230/02 1	230/03 5	1018.5	
	15		206/07 -1	250/04 2	180/03 5	1017.2	
	18		206/07 1	250/05 1	180/04 0	1015.8	
	21		192/07 0	-	180/08 -1	1013.6	
	15		00	197/07 -1	-	-	1011.7
		03	193/07 -1	230/04 0	180/06 -2	1008.7	
		06	187/08 -1	230/06 0	180/06 -3	1006.5	
		09	197/10 0	230/06 0	210/05 1	1004.6	

WIND VELOCITY, AIR TEMPERATURE AND AIR PRESSURE BETWEEN 75-03-10 - 75-03-20.

Month	Day	Time (GMT)	Icebreaker TOR	Rödskallen	Bjuröklubb	Bjuröklubb Pressure(mb)	
			Dir(360°)/Speed(m/s) temp	Dir(360°)/Speed(m/s) temp	Dir(360°)/Speed(m/s) temp		
03	15	12	180/10 1	230/08 1	180/08 2	1003.5	
		15	188/09 -1	230/07 1	210/05 2	1001.4	
		18	188/07 -1	270/04 1	270/06 1	1000.3	
		21	310/06 3	-	320/05 1	999.0	
	16	00	300/07 -2	-	340/08 -1	997.0	
		03	310/08 -3	320/05 -2	340/08 -2		
		06	297/08 -1	320/05 -5	320/08 -4	994.8	
		09	300/07 -3	320/06 -3	320/08 -2	995.2	
		12	340/10 -1	360/09 -1	360/12 0	996.6	
		15	353/15 -2	020/12 -1	020/18 0	998.6	
		18	340/16 -3	360/11 -3	360/17 -1	1002.2	
		21	345/18 -5	-	360/18 -3	1005.3	
		17	00	342/17 -6	-	360/18 -4	1008.3
	03		341/17 -6	340/07 -8	360/18 -4	1010.5	
	06		350/16 -6	340/07 -8	360/16 -4	1013.3	
	09		350/13 -5	340/06 -6	360/13 -4	1016.1	
	12		353/10 -3	340/05 -4	340/11 -2	1018.3	
	15		340/07 -3	020/02 -4	340/07 -2	1019.5	
	18		360/06 -5	lugnt -6	340/04 -4	1020.4	
	21		030/02 -3	-	250/02 -6	1022.1	
	18		00	140/03 -5	-	230/03 -6	1022.3
			03	190/05 -7	230/08 -4	230/04 -8	1021.7

WIND VELOCITY, AIR TEMPERATURE AND AIR PRESSURE BETWEEN 75-03-10 - 75-03-20.

Month	Day	Time (GMT)	Icebreaker TOR	Rödskallen	Bjuröklubb	Bjuröklubb Pressure(mb)
			Dir(360°)/Speed(m/s) temp	Dir(360°)/Speed(m/s) temp	Dir(360°)/Speed(m/s) temp	
03	18	06	170/08 -6	210/08 -4	210/07 -6	1020.3
		09	160/11 -4	210/09 -3	210/04 -2	1019.0
		12	-	210/08 0	210/08 0	1017.0
		15	190/14 -2	210/08 0	230/07 0	1014.7
		18	195/15 -1	210/08 1	230/10 1	1011.8
		21	240/11 4	-	250/10 2	1010.6
	19	00	270/14 4	-	270/11 2	1010.3
		03	305/14 -1	320/11 0	320/10 1	1012.1
		06	320/10 -3	320/08 -3	320/12 -2	1015.5
		09	310/10 -2	320/08 0	320/10 0	1017.8
		12	300/10 0	320/07 0	320/10 2	1019.7
		15	315/09 -1	320/05 1	320/10 2	1020.6
		18	300/08 -4	320/05 -2	300/08 -2	1022.3
		21	310/09 -4	-	320/07 -3	1024.0
		20	00	310/08 -5	-	320/04 -5
	03		300/07 -6	300/05 -4	300/05 -6	1026.7
	06		260/07 -5	300/05 -5	300/04 -6	1028.4
	09		250/07 -3	300/05 -3	270/05 -2	1029.3
	12		240/07 -1	270/05 -1	270/04 1	1029.0
	15		220/09 -1	230/05 1	250/04 4	1027.7
		18	-	230/04 1	250/07 0	1027.2
21		235/09 -1	-	270/06 0	1027.1	

# Attachment 9

## CURRENT OBSERVATIONS

with Alexejev current meter

one hour mean values

DATE	TIME	RELATIVE VELOCITY		ABSOLUTE VELOCITY		ABSOLUTE VELOCITY	
		VEL. EAST (cm/s)	VEL. NORTH (cm/s)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)	DIR. (360°)	VEL. (cm/s)
75-03-16	0030	- 1.9	- 2.3	- 1.9	- 2.3	220	3.0
	0130	- 2.4	+ 0.5	- 2.4	+ 0.5	282	2.4
	0230	- 2.3	+ 1.8	- 1.8	- 2.2	219	2.8
	0330	- 2.5	+ 3.3	- 2.5	+ 3.3	323	4.1
	0430	- 2.3	+ 2.9	- 4.5	- 0.4	265	4.5
	0530	- 1.8	+ 2.8	- 2.5	+ 0.9	290	2.6
	0630	- 2.8	+ 4.4	- 3.5	+ 2.5	306	4.3
	0730	- 2.7	+ 2.9	- 3.1	+ 2.0	303	3.7
	0830	- 3.0	+ 2.7	- 3.4	+ 1.8	298	3.8
	0930	- 1.7	+ 2.6	- 1.7	+ 2.6	321	3.1
	1030	- 1.7	+ 2.5	- 1.7	+ 2.5	326	3.0
	1130	- 2.2	+ 2.4	- 2.2	+ 2.4	318	3.2
	1230	- 2.1	+ 2.1	- 2.1	+ 2.1	315	3.0
	1330	- 1.6	+ 3.3	- 6.6	- 6.5	225	9.3
	1430	+ 0.7	+ 8.2	- 6.6	- 6.0	228	8.9
	1530	+ 1.5	+13.6	- 5.7	- 7.2	218	9.2
	1630	- 1.2	+15.9	-10.1	- 4.2	247	10.9
	1730	- 2.1	+15.7	-11.5	- 5.3	245	12.7
	1830	- 0.7	+17.8	- 6.7	- 6.4	226	9.3
	1930	- 1.1	+14.2	- 7.1	-10.0	215	12.3
	2030	- 2.8	+18.0	- 9.1	- 7.2	232	11.6
	2130	- 2.7	+18.6	- 3.6	- 7.4	206	8.2
	2230	- 1.2	+19.8	-11.1	- 7.4	236	13.3
2330	- 1.1	+18.6	-11.4	- 9.6	230	14.9	
75-03-17	0030	+ 0.8	+16.0	- 1.9	- 9.8	191	10.0
	0130	- 0.4	+17.0	- 3.1	- 8.8	199	9.3
	0230	+ 0.1	+17.6	- 2.7	- 9.2	196	9.6
	0330	- 0.8	+18.1	- 6.9	- 8.2	220	10.7
	0430	- 1.7	+18.5	- 4.5	- 8.3	208	9.4
	0530	- 2.2	+19.2	- 5.1	- 8.6	211	10.0
	0630	- 0.9	+20.1	- 3.9	- 8.7	204	9.5
	0730	0.0	+19.0	-10.5	- 7.0	236	12.6
	0830	- 0.3	+18.2	-10.0	- 5.9	239	11.6
	0930	+ 2.8	+18.0	- 6.6	- 5.2	232	8.4
	1030	+ 1.6	+16.7	- 7.4	- 5.5	233	9.2
	1130	+ 1.2	+17.4	- 8.2	- 5.8	235	10.0
	1230	+ 0.6	+15.3	- 6.5	- 2.3	250	6.9
	1330	+ 0.3	+12.5	- 7.2	- 6.0	230	9.4
	1430	- 0.3	+13.8	- 9.2	- 3.0	252	9.7
	1530	- 0.8	+12.1	- 6.3	- 0.8	263	6.4
	1630	- 1.9	+11.3	- 6.2	+ 1.2	281	6.3
	1730	- 1.6	+ 8.8	- 5.8	+ 0.9	279	5.9
	1830	+ 0.4	+ 6.6	- 4.2	+ 2.0	296	4.6
	1930	+ 0.3	+ 4.5	- 0.3	+ 4.5	4	4.5
	2030	+ 0.4	+ 3.2	- 0.7	+ 1.6	337	1.7
	2130	+ 0.6	+ 2.9	- 4.1	+ 1.1	285	4.2
	2230	+ 1.0	- 1.8	+ 1.0	- 1.8	151	2.0
2330	+ 0.8	- 3.2	- 0.1	- 3.6	182	3.6	

DATE	TIME	RELATIVE	VELOCITY	ABSOLUTE VELOCITY		ABSOLUTE VELOCITY	
		VEL.EAST (cm/s)	VEL.NORTH (cm/s)	VEL.EAST (cm/s)	VEL.North (cm/s)	DIR. (360°)	VEL. (cm/s)
75-03-18	0030	+ 0.1	- 3.2	0.0	- 2.2	180	2.2
	0130	- 0.7	- 3.6	- 0.7	- 3.6	191	3.7
	0230	- 0.9	- 4.9	+ 0.5	- 3.5	172	3.5
	0330	- 2.2	- 5.6	- 0.2	- 5.2	182	5.2
	0430	- 2.7	- 5.3	+ 3.1	+ 0.1	88	3.1
	0530	- 2.3	- 6.1	+ 0.5	- 0.8	148	0.9
	0630	- 1.8	- 6.4	+ 2.9	+ 2.4	50	3.8
	0730	- 0.7	- 7.6	+ 3.1	- 0.5	99	3.1
	0830	- 0.8	-10.3	+ 4.1	+ 4.9	40	6.4
	0930	- 0.5	-12.3	+ 8.7	+ 4.3	64	9.7
	1030	+ 0.5	-14.1	+ 9.2	+ 3.4	70	9.8
	1130	+ 1.0	-15.4	+12.2	+ 4.7	69	13.1
	1230	- 0.1	-17.1	+17.9	+ 6.9	69	19.2
	1330	- 1.4	-19.4	+16.6	+ 4.6	75	17.2
	1430	- 0.3	-18.1	+17.7	+ 5.9	72	18.6
	1530	- 0.1	-19.4	+17.9	+ 4.6	76	18.5
	1630	- 5.5	-19.7	+12.5	+ 4.3	71	13.2
	1730	- 5.4	-16.4	+ 8.4	+ 2.0	77	8.6
	1830	- 6.2	-15.8	+ 9.8	+ 0.7	86	9.8
	1930	- 4.3	-15.3	+15.1	+ 4.8	72	15.8
	2030	- 5.1	-14.0	+15.7	+ 7.6	64	17.4
	2130	- 7.2	-13.4	+ 8.8	+ 3.1	71	9.3
	2230	-11.1	-12.6	+ 3.8	- 6.9	151	7.9
2330	-15.3	- 3.7	- 0.4	+ 2.0	349	2.0	
75-03-19	0030	-13.2	- 0.6	+ 5.6	- 3.6	123	6.6
	0130	-11.6	+ 3.4	+ 7.2	+ 0.4	87	7.2
	0230	- 8.9	+ 1.0	- 0.9	- 9.2	186	9.2
	0330	-11.8	+ 3.6	- 3.8	- 6.6	210	7.6
	0430	- 5.8	+ 9.5	+ 2.2	- 0.7	108	2.3
	0530	- 4.6	+ 7.6	+ 3.4	- 2.6	127	4.3
	0630	- 3.9	+ 7.5	- 4.6	+ 0.5	276	4.6
	0730	- 2.8	+ 5.4	- 3.5	- 1.6	245	3.8

# Attachment 10

## CURRENT OBSERVATIONS

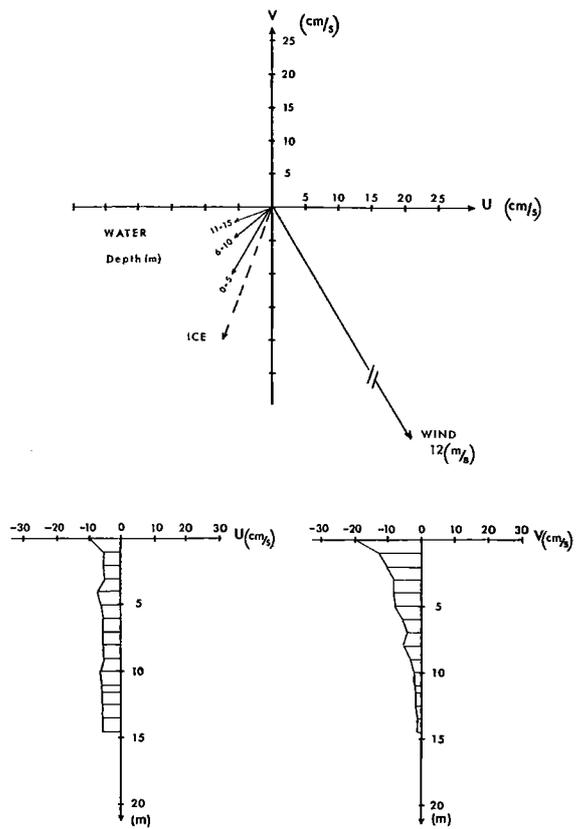
with gelatine pendelums

vertically integrated values between 0 - 20 meters

DATE	TIME	ABSOLUTE VELOCITY		ABSOLUTE VELOCITY	
		VEL. EAST (cm/s)	VEL. NORTH (cm/s)	DIR. (360°)	VEL. (360°)
75-03-16	1600	-8.4	-2.5	253	8.8
	1700	-9.1	-2.8	253	9.5
	1905	-6.2	-6.8	222	9.2
	2000	-6.4	-7.4	221	9.8
	2115	-1.7	-6.9	194	7.1
75-03-17	0900	-8.8	-9.0	224	12.6
	1015	-7.0	-5.3	233	8.8
	1100	-8.0	-5.8	234	9.9
	1310	-7.1	-4.7	236	8.5
	1445	-7.0	-2.1	253	7.3
	1540	-5.3	-0.6	264	5.3
75-03-18	1000	8.0	2.0	076	8.2
	1050	9.8	0.9	085	9.8
	1440	17.5	2.9	081	17.7
	1530	13.7	2.8	078	14.0

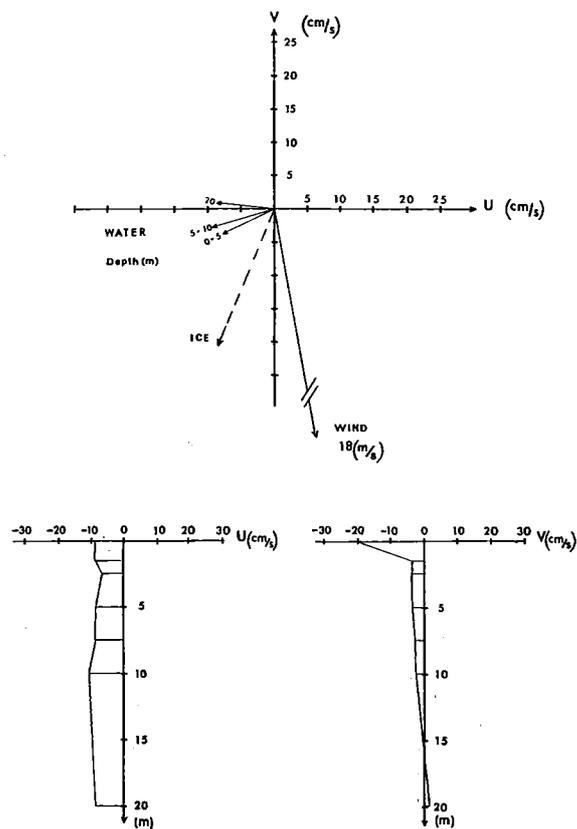
# Attachment 11

CURRENT MEASUREMENTS  
WITH PENDULUM  
DATE: 75-03-11 TIME: 1100



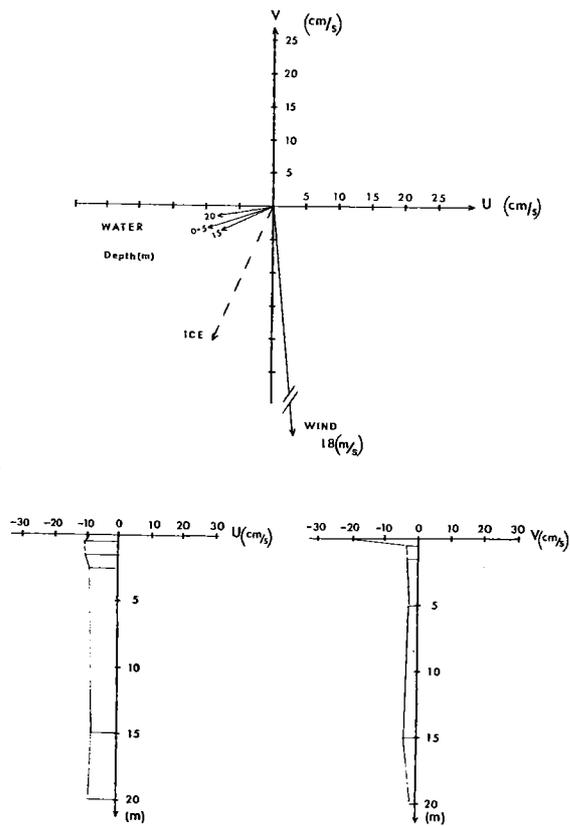
# Attachment 12

CURRENT MEASUREMENTS  
WITH GELATINE PENDULUMS  
DATE: 75-03-16 TIME: 1600



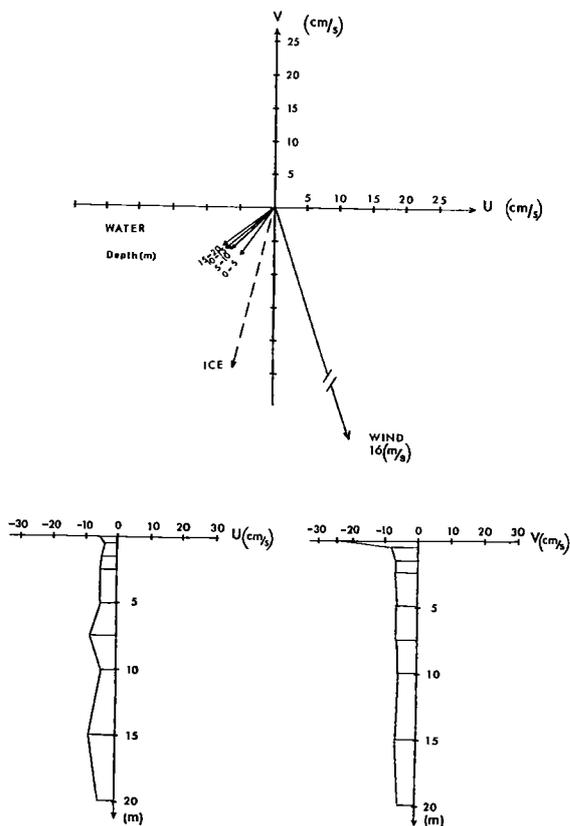
# Attachment 13

CURRENT MEASUREMENTS  
WITH GELATINE PENDULUMS  
DATE: 75-03-16 TIME: 1700



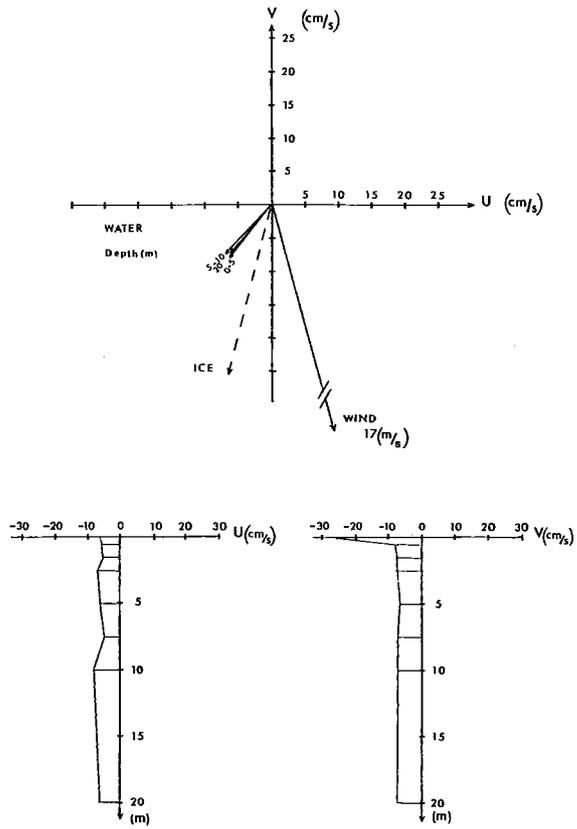
# Attachment 14

CURRENT MEASUREMENTS  
WITH GELATINE PENDULUMS  
DATE: 75-03-16 TIME: 1905



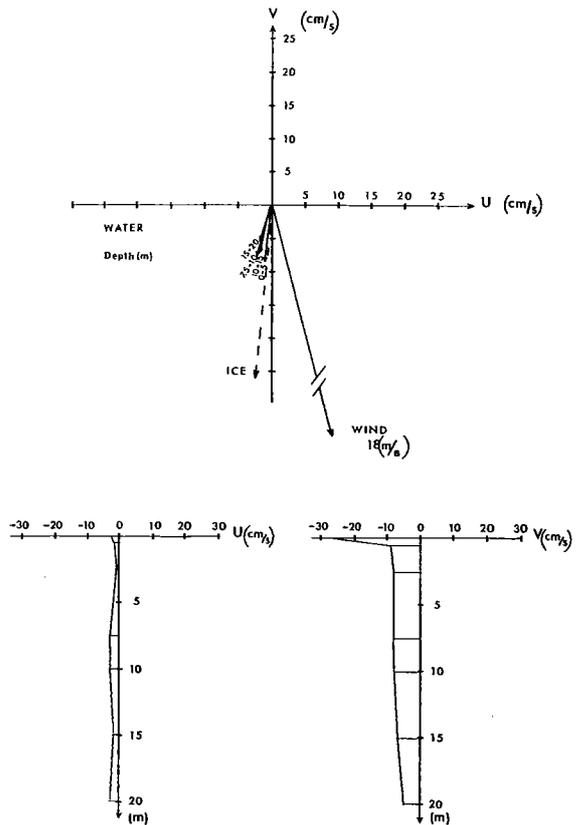
# Attachment 15

CURRENT MEASUREMENTS  
WITH GELATINE PENDULUMS  
DATE: 75-03-16 TIME: 2000



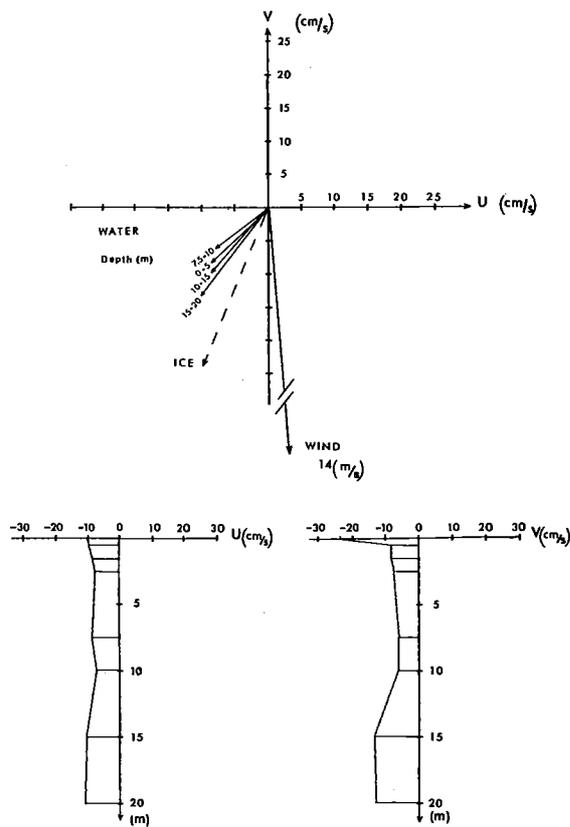
# Attachment 16

CURRENT MEASUREMENTS  
WITH GELATINE PENDULUMS  
DATE: 75-03-16 TIME: 2115



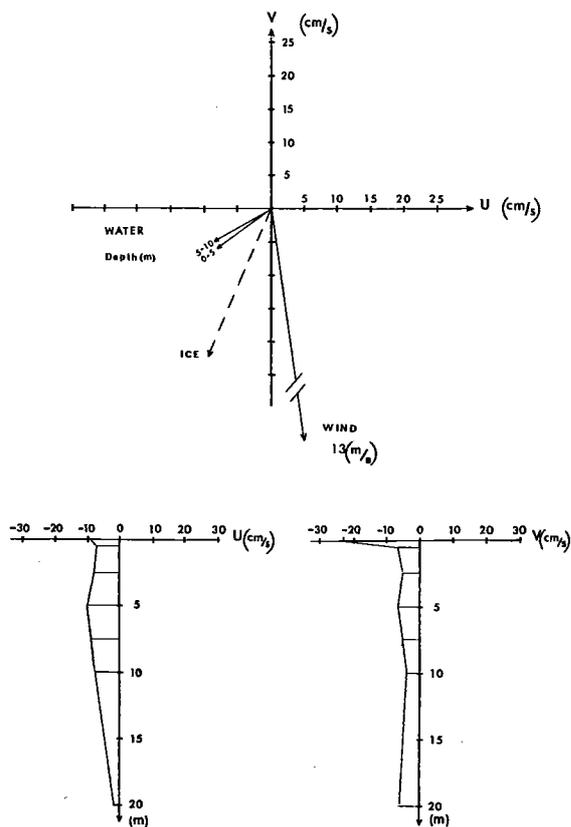
# Attachment 17

CURRENT MEASUREMENTS  
WITH GELATINE PENDULUMS  
DATE: 75-03-17 TIME: 0900



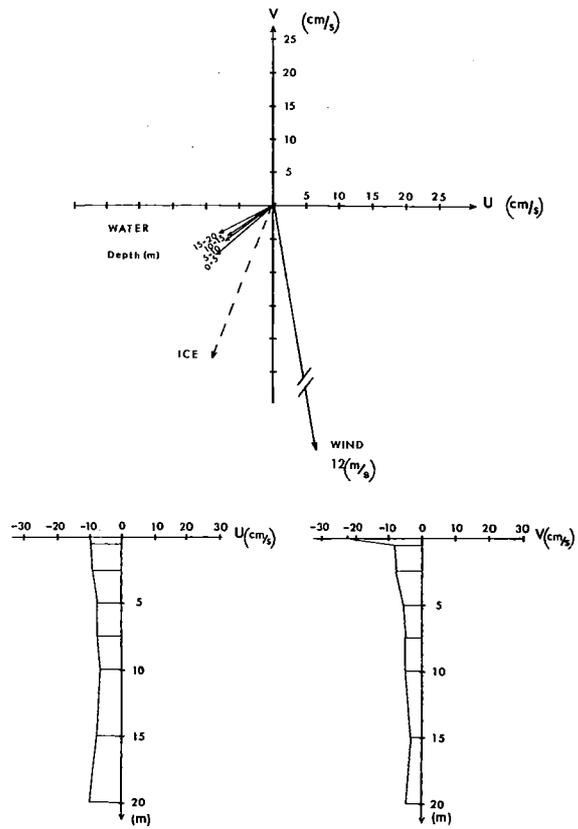
# Attachment 18

CURRENT MEASUREMENTS  
WITH GELATINE PENDULUMS  
DATE: 75-03-17 TIME: 1015



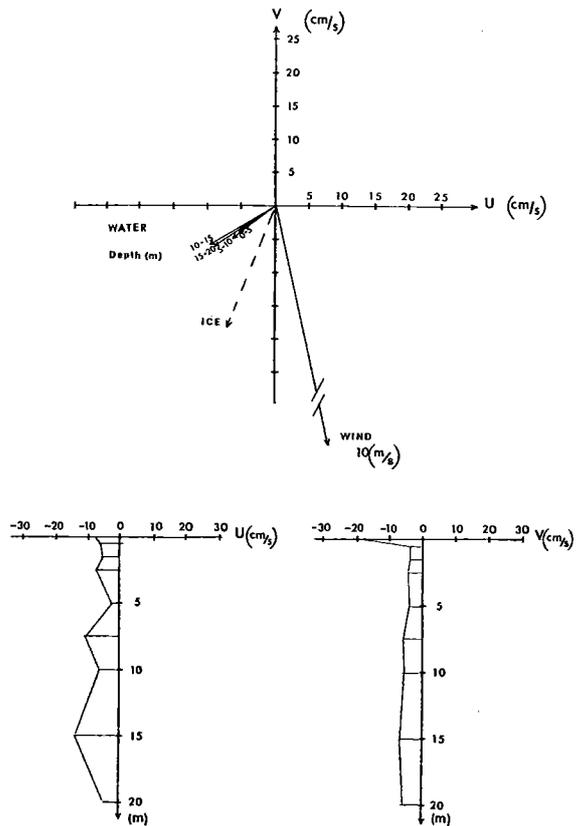
# Attachment 19

CURRENT MEASUREMENTS  
WITH GELATINE PENDULUMS  
DATE: 75-03-17 TIME: 1100



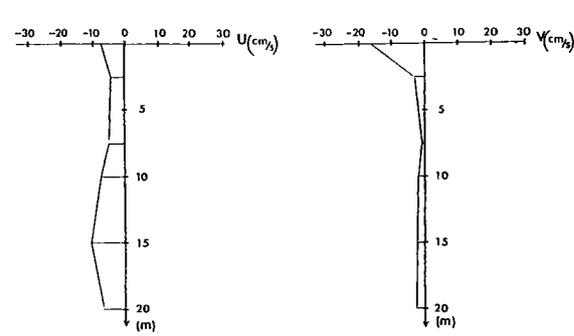
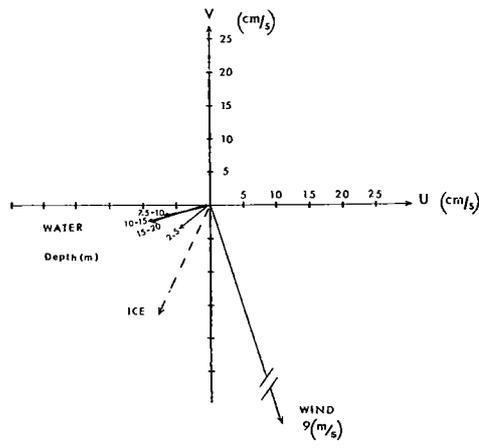
# Attachment 20

CURRENT MEASUREMENTS  
WITH GELATINE PENDULUMS  
DATE: 75-03-17 TIME: 1310



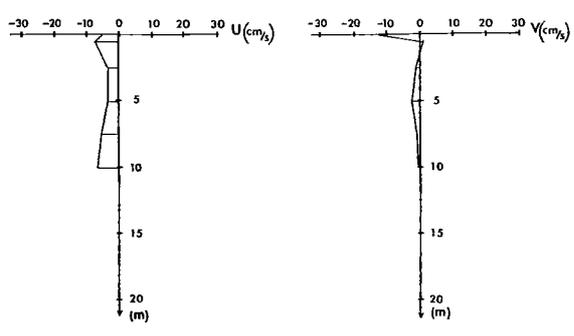
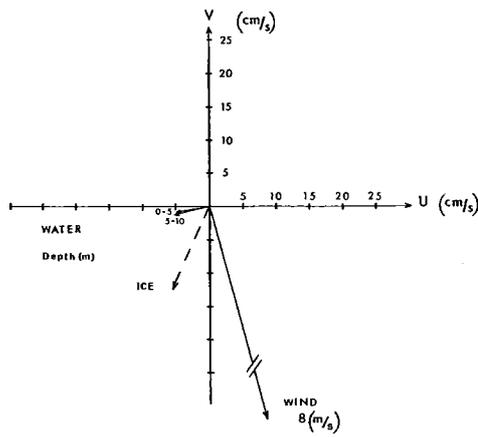
# Attachment 21

CURRENT MEASUREMENTS  
WITH GELATINE PENDULUMS  
DATE: 75-03-17 TIME: 1445



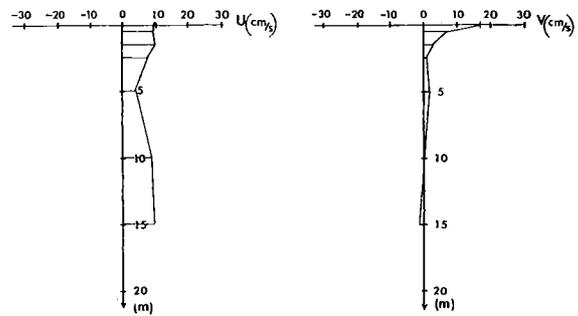
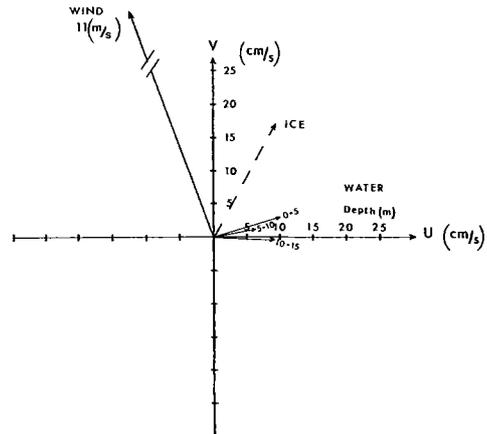
# Attachment 22

CURRENT MEASUREMENTS  
WITH GELATINE PENDULUMS  
DATE: 75-03-17 TIME: 1540



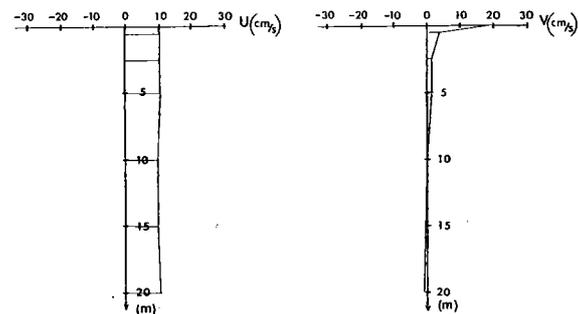
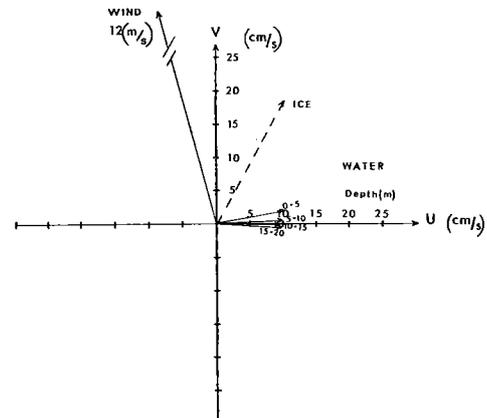
# Attachment 23

CURRENT MEASUREMENTS  
WITH GELATINE PENDULUMS  
DATE: 75-03-18 TIME: 1000



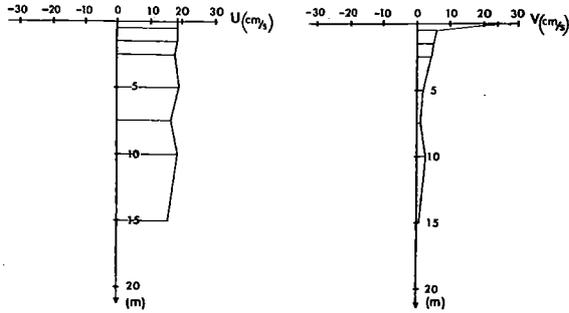
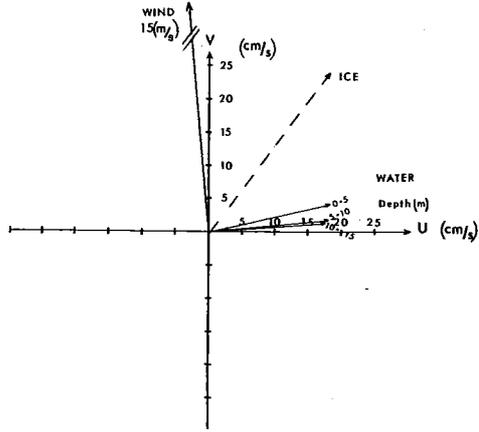
# Attachment 24

CURRENT MEASUREMENTS  
WITH GELATINE PENDELUMS  
DATE: 75-03-18 TIME: 1050



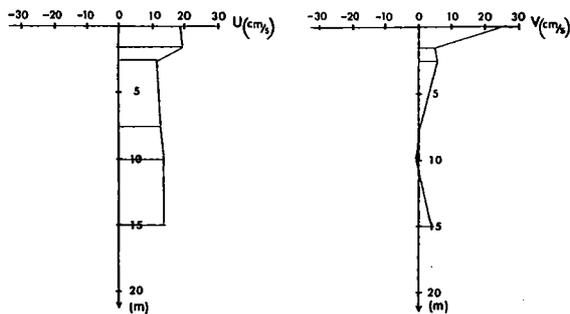
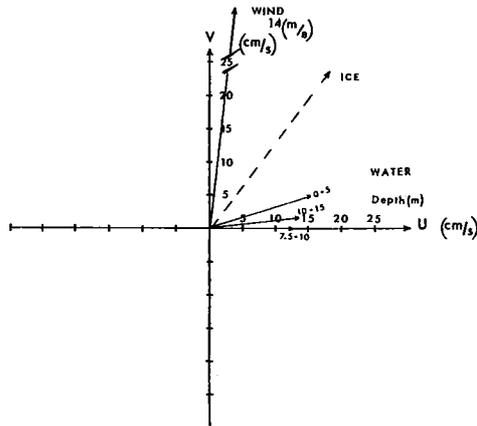
# Attachment 25

CURRENT MEASUREMENTS  
WITH GELATINE PENDULUMS  
DATE: 75-03-18 TIME: 1440



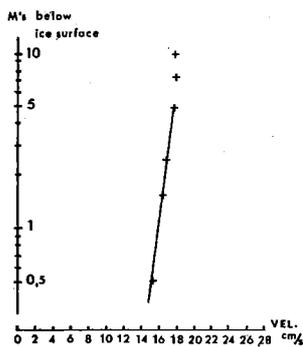
# Attachment 26

CURRENT MEASUREMENTS  
WITH GELATINE PENDULUMS  
DATE: 75-03-18 TIME: 1530

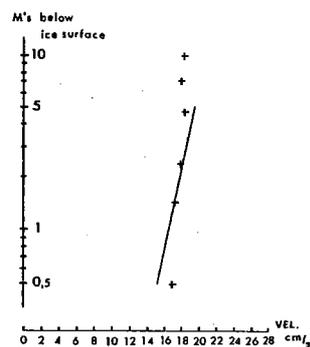


## VELOCITY PROFILES BELOW ICE SURFACE

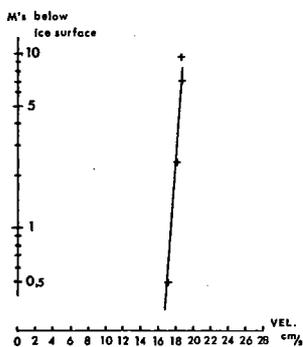
DATE: 75-03-16  
TIME: 1905



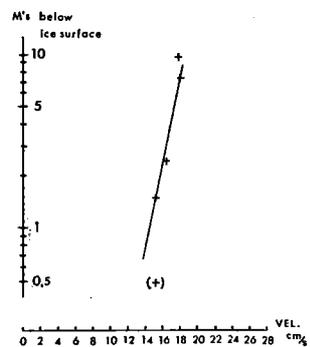
DATE: 75-03-16  
TIME: 2000



DATE: 75-03-16  
TIME: 2115

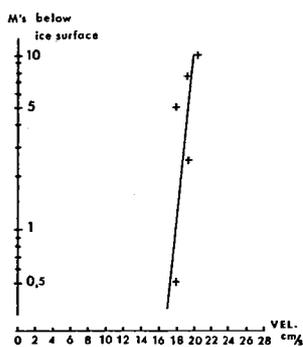


DATE: 75-03-17  
TIME: 0900

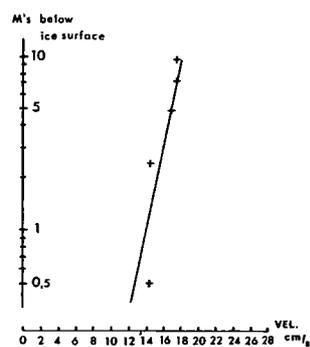


## VELOCITY PROFILES BELOW ICE SURFACE

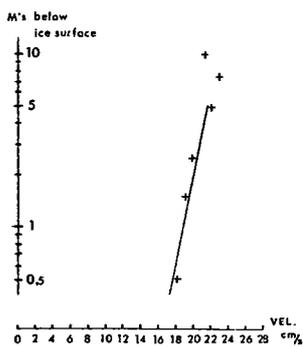
DATE: 75-03-17  
TIME: 1015



DATE: 75-03-17  
TIME: 1100



DATE: 75-03-18  
TIME: 1440



# Attachment 29-32

## HYDROGRAPHIC OBSERVATIONS

DATE: 75-03-04

TIME: 1000

DEPTH (m)	TEMPERATURE (°C)	SALINITY (S <sup>o</sup> /oo)
0	0.0	3.4
1	0.0	3.4
2	0.0	3.4
3	0.0	3.4
4	0.0	3.4
5	0.0	3.4
7	0.0	3.4
9	0.0	3.4
11	0.0	3.4
15	0.0	3.4
20	0.0	3.4
25	-0.1	3.4
30	-0.1	3.4
35	-0.1	3.4

## HYDROGRAPHIC OBSERVATIONS

DATE: 75-03-04

TIME: 1700

DEPTH (m)	TEMPERATURE (°C)	SALINITY (S <sup>o</sup> /oo)
1	-0.1	3.4
2	-0.1	3.4
3	-0.1	3.4
4	-0.1	3.4
5	-0.1	3.4
10	-0.1	3.4
15	-0.1	3.4
20	-0.1	3.4
25	-0.1	3.4
30	-0.1	3.4
35	-0.1	3.4
40	-0.1	3.4

DATE: 75-03-05

TIME: 1030

DEPTH (m)	TEMPERATURE (°C)	SALINITY (S <sup>o</sup> /oo)
0	-0.1	3.4
1	-0.1	3.4
5	-0.1	3.4
10	-0.1	3.4
15	-0.1	3.4
20	-0.1	3.4
24	-0.1	3.4

DATE: 75-03-04

TIME: 1315

DEPTH (m)	TEMPERATURE (°C)	SALINITY (S <sup>o</sup> /oo)
0	0.0	3.4
1	0.0	3.4
2	0.0	3.4
3	0.0	3.4
4	0.0	3.4
5	0.0	3.4
10	0.0	3.4
15	0.0	3.4
20	-0.1	3.4
30	-0.1	3.4
35	-0.1	3.4
40	-0.1	3.4

DATE: 75-03-05

TIME: 1300

DEPTH (m)	TEMPERATURE (°C)	SALINITY (S <sup>o</sup> /oo)
0	-0.2	3.4
1	-0.2	3.4
2	-0.2	3.4
3	-0.2	3.4
4	-0.2	3.4
5	-0.2	3.4
10	-0.2	3.4
15	-0.2	3.4
20	-0.2	3.4
24	-0.2	3.4

HYDROGRAPHIC OBSERVATIONS

DATE: 75-04-07 TIME: 2000

DEPTH (m)	TEMPERATURE (°C)	SALINITY (S°/oo)
0		3.4
1		3.4
2		3.4
3		3.4
4		3.4
5		3.4
10		3.4

DATE: 75-03-08 TIME: 1315

DEPTH (m)	TEMPERATURE (°C)	SALINITY (S°/oo)
0	-0.1	3.4
1	-0.1	3.4
2	-0.1	3.4
3	-0.1	3.4
4	-0.1	3.4
5	-0.1	3.4
10	-0.1	3.4
15	-0.1	3.4
20	-0.1	3.4
25	-0.1	3.4
30	-0.1	3.4

DATE: 75-03-09 TIME: 1430

DEPTH (m)	TEMPERATURE (°C)	SALINITY (S°/oo)
1	-0.1	3.4
3	-0.1	3.4
5	-0.1	3.4
10	-0.1	3.4
15	-0.1	3.4
20	-0.1	3.4
25	-0.1	3.4
29	-0.1	3.4

HYDROGRAPHIC OBSERVATIONS

DATE: 75-03-10 TIME: 1600

DEPTH (m)	TEMPERATURE (°C)	SALINITY (S°/oo)
0	-0.1	3.5
1	-0.1	3.5
2	-0.1	3.5
3	-0.1	3.5
4	-0.1	3.5
5	-0.1	3.5
10	-0.1	3.5
15	-0.1	3.5
20	-0.1	3.5
25	-0.1	3.5
30	-0.1	3.5
35	-0.1	3.5

DATE: 75-03-14 TIME: 1700

DEPTH (m)	TEMPERATURE (°C)	SALINITY (S°/oo)
0	0.0	3.5
1	0.0	3.5
3	0.0	3.5
5	0.0	3.5
10	0.0	3.5
15	0.0	3.5
20	+0.1	3.5

# Appendix A

WITH GELATINE PENDULUMS

DATE: 75-03-04 TIME: 1000

DEPTH (m)	ABSOLUTE VEL. (cm/s)	VELOCITY DIR. (360°)
5	< 3	-
7	-"	-
9	-"	-
11	-"	-
13	-"	-
15	-"	-
20	-"	-
25	-"	-
30	-"	-
35	-"	-

WITH PFNDULUM

DATE: 75-03-05 TIME: 1300

DEPTH (m)	ABSOLUTE VEL. (cm/s)	VELOCITY DIR. (360°)
1	< 1	-
2	-"	-
3	-"	-
4	-"	-
5	-"	-
10	-"	-
15	-"	-
20	-"	-

WITH PENDULUM

DATE: 75-03-04 TIME: 1700

DEPTH (m)	ABSOLUTE VEL. (cm/s)	VELOCITY DIR. (360°)
1	< 1	-
2	-"	-
3	-"	-
4	-"	-
5	-"	-
10	-"	-
15	-"	-

WITH GFLATINE PENDULUMS

DATE: 75-03-08 TIME: 0915

DEPTH (m)	ABSOLUTE VEL. (cm/s)	VELOCITY DIR. (360°)
5	< 3	-
7	-"	-
9	-"	-
11	-"	-
13	-"	-
15	-"	-
20	-"	-
25	-"	-
30	-"	-

WITH PENDULUM

DATE: 75-03-08 TIME: 1900

DEPTH (m)	ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)
1	<1	-
3	-"	-
5	-"	-
7	-"	-
9	-"	-
11	-"	-
13	-"	-
15	-"	-

WITH PENDULUM

DATE: 75-03-09 TIME: 0830

DEPTH (m)	ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)
1	<1	-
3	-"	-
5	-"	-
10	-"	-
15	-"	-
20	-"	-
25	-"	-

WITH GELATINE PENDULUMS

DATE: 75-03-08 TIME: 1900

DEPTH (m)	ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)
5	<3	-
7	-"	-
9	-"	-
11	-"	-
13	-"	-
15	-"	-
20	-"	-
25	-"	-
30	-"	-

WITH PENDULUM

DATE: 75-03-09 TIME: 1430

DEPTH (m)	ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)
1	<1	-
3	-"	-
5	-"	-
10	-"	-
15	-"	-
20	-"	-
25	-"	-
30	-"	-

WITH PENDULUM

DATE: 75-03-09 TIME: 1645

DEPTH (m)	ABSOLUTE VEL. (cm/s)	VELOCITY DIR. (360°)
1	< 1	-
3	-"-	-
5	-"-	-
10	-"-	-
15	-"-	-
20	-"-	-
25	-"-	-

WITH PENDULUM

DATE: 75-03-10 TIME: 1600

DEPTH (m)	ABSOLUTE VEL. (cm/s)	VELOCITY DIR. (360°)
1	<1	-
3	-"-	-
5	-"-	-
10	-"-	-
15	-"-	-
20	-"-	-
25	-"-	-

WITH PENDULUM

DATE: 75-03-10 TIME: 0930

DEPTH (m)	ABSOLUTE VEL. (cm/s)	VELOCITY DIR. (360°)
1	< 1	-
3	-"-	-
5	-"-	-
10	-"-	-
15	-"-	-
20	-"-	-
25	-"-	-

WITH PENDULUM

DATE: 75-03-10 TIME: 2000

DEPTH (m)	ABSOLUTE VEL. (cm/s)	VELOCITY DIR. (360°)
1	< 1	-
3	-"-	-
5	-"-	-
10	-"-	-
15	-"-	-
20	-"-	-
25	-"-	-

WITH PENDULUM

DATE: 75-03-14 TIME: 0830

DEPTH (m)	ABSOLUTE VEL. (cm/s)	VELOCITY DIR. (360°)
1	< 1	-
3	-"-	-
5	-"-	-
10	-"-	-
15	-"-	-
20	-"-	-

WITH PENDULUM

DATE: 75-03-14 TIME: 1700

DEPTH (m)	ABSOLUTE VEL. (cm/s)	VELOCITY DIR. (360°)
1	< 1	-
3	-"-	-
5	-"-	-
10	-"-	-
15	-"-	-
20	-"-	-

WITH PENDULUM

DATE: 75-03-14 TIME: 1315

DEPTH (m)	ABSOLUTE VEL. (cm/s)	VELOCITY DIR. (360°)
1	< 1	-
2	-"-	-
3	-"-	-
4	-"-	-
5	-"-	-
10	-"-	-
15	-"-	-

WITH PENDULUM

DATE: 75-03-11 TIME: 1100

DEPTH (m)	RELATIVE VELOCITY		RELATIVE VELOCITY		ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)
1	7.8	016	2.1	7.5	- 5.4	- 12.3
2	9.3	010	1.6	9.2	- 5.9	- 10.6
3	11.1	010	1.9	10.9	- 5.6	- 8.9
4	11.1	000	0	11.1	- 7.5	- 8.7
5	11.6	006	1.2	11.5	- 6.3	- 8.3
6	14.0	007	1.7	13.9	- 5.8	- 6.0
7	15.5	007	1.9	15.4	- 5.7	- 4.4
8	14.0	007	1.7	13.9	- 5.8	- 5.9
9	16.1	007	2.0	16.0	- 5.5	- 3.8
10	17.3	004	1.2	17.2	- 6.3	- 2.6
11	17.3	005	1.5	17.2	- 6.0	- 2.6
11.5	17.8	005	1.6	17.7	- 5.9	- 2.1
12.5	17.8	005	1.6	17.7	- 5.9	- 2.1
13.5	18.4	005	1.6	18.3	- 5.9	- 1.5
14.5	18.8	005	1.6	18.0	- 5.9	- 1.8

WITH GELATINE PENDULUMS

DATE: 75-03-16 TIME: 1600

DEPTH (m)	RELATIVE VELOCITY		RELATIVE VELOCITY		ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)
1.5	17.0	000	0.0	17.0	- 8.2	- 3.4
2.5	16.7	006	1.7	16.6	- 6.5	- 3.8
5.0	17.0	000	0.0	17.0	- 8.2	- 3.4
7.5	17.6	000	0.0	17.6	- 8.2	- 2.8
10	18.4	352	- 2.6	18.2	-10.8	- 2.2
20	21.1	000	0.0	21.1	- 8.2	0.7

WITH GELATINE OBSERVATIONS

DATE: 75-03-16 TIME: 1700

DEPTH (m)	RELATIVE VELOCITY		RELATIVE VELOCITY		ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)
0.5	-	-	-	-	-	-
1.5	16.7	355	- 1.4	16.6	-10.3	- 3.5
2.5	17.0	356	- 1.2	17.0	-10.1	- 3.1
5.0	17.5	000	0.0	17.5	- 8.9	- 2.6
7.5	-	-	-	-	-	-
10	-	-	-	-	-	-
15	16.6	004	1.2	16.6	- 7.7	- 3.5
20	18.6	002	0.6	18.6	- 8.3	- 1.5

WITH GELATINE PENDULUMS

DATE: 75-03-16 TIME: 1905

DEPTH (m)	RELATIVE VELOCITY		RELATIVE VELOCITY		ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)
0.5	15.5	005	1.4	15.4	- 4.6	- 8.8
1.5	16.8	003	0.9	16.8	- 5.1	- 7.4
2.5	17.0	002	0.6	17.0	- 5.4	- 7.2
5.0	17.8	003	0.9	17.8	- 5.1	- 6.4
7.5	18.0	351	- 2.8	17.8	- 8.8	- 6.4
10	18.0	002	0.6	18.0	- 5.4	- 6.2
15	18.0	351	- 2.8	17.8	- 8.8	- 6.4
20	18.5	000	0.0	18.5	- 6.0	- 5.7

WITH GELATINE PENDULUMS

DATE: 75-03-16 TIME: 2000

DEPTH (m)	RELATIVE VELOCITY		RELATIVE VELOCITY		ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)
0.5	17.0	001	0.3	17.0	- 6.0	- 8.2
1.5	17.3	002	0.6	17.3	- 5.7	- 7.9
2.5	18.0	357	- 0.9	18.0	- 7.2	- 7.2
5.0	18.3	000	0.0	18.3	- 6.3	- 6.9
7.5	17.8	004	1.2	17.8	- 5.1	- 7.4
10	18.2	352	- 2.5	18.0	- 8.8	- 7.2
15	-	-	-	-	-	-
20	18.0	001	0.3	18.0	- 6.0	- 7.2

WITH GELATINE PENDULUMS

DATE: 75-03-16 TIME: 2115

DEPTH (m)	RELATIVE VELOCITY		RELATIVE VELOCITY		ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)
0.5	17.2	002	0.6	17.2	- 1.6	- 8.6
1.5	-	-	-	-	-	-
2.5	18.2	005	1.6	18.1	- 0.6	- 7.7
7.5	18.6	000	0.0	18.6	- 2.2	- 7.2
10	18.5	000	0.0	18.5	- 2.2	- 7.3
15	19.7	003	1.0	19.7	- 1.2	- 6.1
20	21.4	000	0.0	21.4	- 2.2	- 4.4

WITH GELATINE PENDULUMS

DATE: 75-03-17 TIME: 0900

DEPTH (m)	RELATIVE VELOCITY		RELATIVE VELOCITY		ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)
0.5	15.2	001	0.3	15.2	- 9.3	- 8.4
1.5	15.0	005	1.3	15.0	- 8.3	- 8.6
2.5	16.1	006	1.7	16.0	- 7.9	- 7.6
5.0	-	-	-	-	-	-
7.5	17.7	004	1.2	17.6	- 8.4	- 6.0
10	17.7	008	2.5	17.5	- 7.1	- 6.1
15	18.1	358	- 0.6	18.0	-10.2	-13.4
20	19.6	358	- 0.7	19.6	-10.3	-13.3

WITH GELATINE PENDULUMS

DATE: 75-03-17 TIME: 1015

DEPTH (m)	RELATIVE VELOCITY		RELATIVE VELOCITY		ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)
0.5	16.2	007	2.0	16.1	- 7.1	- 6.3
1.5	-	-	-	-	-	-
2.5	17.5	004	1.2	17.4	- 7.9	- 5.0
5.0	16.1	000	0.0	16.1	- 9.1	- 6.3
7.5	17.4	002	0.6	17.4	- 8.5	- 5.0
10	18.7	004	1.3	18.6	- 7.8	- 3.8
15	-	-	-	-	-	-
20	18.5	023	7.2	17.0	- 1.9	- 5.4

WITH GELATINE PENDULUMS

DATE: 75-03-17 TIME: 1100

DEPTH (m)	RELATIVE VELOCITY		RELATIVE VELOCITY		ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)
0.5	14.5	000	0.0	14.5	- 9.2	- 8.2
1.5	-	-	-	-	-	-
2.5	14.7	001	0.2	14.7	- 9.0	- 8.0
5.0	17.1	006	1.8	17.0	- 7.4	- 5.7
7.5	17.6	006	1.8	17.5	- 7.4	- 5.2
10	17.7	009	2.8	17.5	- 6.4	- 5.2
15	19.0	354	-2.0	18.9	- 7.2	- 3.8
20	18.0	000	0.0	18.0	- 9.2	- 4.7

WITH GELATINE PENDULUMS

DATE: 75-03-17 TIME: 1310

DEPTH (m)	RELATIVE VELOCITY		RELATIVE VELOCITY		ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)
0.5	14.5	005	1.3	14.4	- 6.1	- 3.8
1.5	14.5	007	1.8	14.4	- 5.6	- 3.8
2.5	14.0	359	-0.2	14.0	- 7.6	- 4.2
5.0	15.1	017	4.4	14.4	- 3.0	- 3.8
7.5	13.0	348	-2.7	12.7	-10.1	- 5.5
10	13.0	003	0.7	13.0	- 6.7	- 5.2
15	13.5	334	-5.9	12.1	-13.3	- 6.1
20	13.0	012	2.7	12.7	- 4.7	- 5.5

WITH GELATINE PENDULUMS

DATE: 75-03-17 TIME: 1445

DEPTH (m)	RELATIVE VELOCITY		RELATIVE VELOCITY		ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)
0.5	-	-	-	-	-	-
1.5	-	-	-	-	-	-
2.5	13.4	014	3.2	13.0	- 4.7	- 3.2
5.0	-	-	-	-	-	-
7.5	15.5	010	2.7	15.3	- 5.2	- 0.9
10	14.2	000	0.0	14.2	- 7.9	- 2.0
15	14.3	349	- 2.7	14.0	-10.6	- 2.2
20	14.0	005	1.2	13.9	- 6.7	- 2.3

WITH GELATINE PENDULUMS

DATE: 75-03-17 TIME: 1540

DEPTH (m)	RELATIVE VELOCITY		RELATIVE VELOCITY		ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)
0.5	13.3	351	- 2.1	13.1	- 7.2	1.1
1.5	-	-	-	-	-	-
2.5	11.0	008	1.5	10.9	- 3.6	- 1.1
5.0	10.0	008	1.4	9.9	- 3.7	- 2.1
7.5	11.2	359	- 0.2	11.2	- 5.3	- 0.8
10	12.0	353	- 1.5	11.9	- 6.6	- 0.1
15	-	-	-	-	-	-
20	-	-	-	-	-	-

WITH GELATINE PENDULUMS

DATE: 75-03-18 TIME: 1000

DEPTH (m)	RELATIVE VELOCITY		RELATIVE VELOCITY		ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)
0.5	10.0	181	- 0.2	-10.0	9.2	7.0
1.5	14.5	179	0.2	-14.5	9.6	2.5
2.5	16.5	188	- 2.3	-16.3	7.1	0.7
5.0	16.2	200	- 5.5	-15.2	3.9	1.8
7.5	-	-	-	-	-	-
10	16.2	182	- 0.6	-16.2	8.8	0.8
15	18.0	180	0.0	-18.0	9.4	- 1.0
20	-	-	-	-	-	-

WITH GELATINE PENDULUMS

DATE: 75-03-18 TIME: 1050

DEPTH (m)	RELATIVE VELOCITY		RELATIVE VELOCITY		ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)
0.5	14.4	180	0.0	-14.4	10.0	3.8
1.5	-	-	-	-	-	-
2.5	17.0	180	0.0	-17.0	10.0	1.2
5.0	17.1	180	0.0	-17.1	10.0	1.1
7.5	-	-	-	-	-	-
10	18.4	182	- 0.6	-18.4	9.4	- 0.2
15	18.2	182	- 0.6	-18.2	9.4	0.0
20	18.5	180	0.0	-18.5	10.0	- 0.3

WITH GELATINE PENDULUMS

DATE: 75-03-18 TIME: 1440

DEPTH (m)	RELATIVE VELOCITY		RELATIVE VELOCITY		ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)
0.5	18.3	180	0.0	-18.3	18.0	5.7
1.5	19.2	180	0.0	-19.2	18.0	4.8
2.5	20.0	181	- 0.3	-20.0	17.7	4.0
5.0	22.2	178	0.8	-22.2	18.8	1.8
7.5	23.1	185	- 2.0	-23.0	16.0	1.0
10	21.4	179	0.4	-21.4	18.4	2.6
15	23.7	185	- 2.1	-23.6	15.9	0.4

WITH GELATINE PENDULUMS

DATE: 75-03-18 TIME: 1530

DEPTH (m)	RELATIVE VELOCITY		RELATIVE VELOCITY		ABSOLUTE VELOCITY	
	VEL. (cm/s)	DIR. (360°)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)	VEL. EAST (cm/s)	VEL. NORTH (cm/s)
0.5	-	-	-	-	-	-
1.5	19.5	178	0.7	-19.5	18.7	4.5
2.5	19.7	200	- 6.7	-18.5	11.3	5.5
5.0	-	-	-	-	-	-
7.5	24.3	194	- 5.9	-23.6	12.1	0.4
10	25.0	191	- 4.8	-24.5	13.2	- 0.5
15	20.6	193	- 4.6	-20.1	13.4	3.9

SWEDISH/FINNISH WINTER NAVIGATION  
RESEARCH BOARD  
REPORTS

- | No.  | Titel  |
|------|--|
| 1.   | HAVSISKONFERENS. Protokoll (1972).   |
| 2.   | VINTERSJOFART I BOTTENHAVET — Erfarenheter av SCA:s distributionssystem — L. Sjöstedt och S. Hammarsten (1972).  |
| 3.   | ISSKADOR PÅ FARTYG I ÖSTERSJÖN, BOTTENHAVET OCH BOTTENVIKEN. — Statistisk analys av skadefrekvenser — L. Sjöstedt och S. Hammarsten (1973).  |
| 4.   | PROPELLERPROBLEM. Propellerverkningsgradens beroende av bladutformningen. H.P. Loid (1973).  |
| 5.   | FARTYGS FRAMDRIVNINGSMOTSTÅND I IS. E. Enkvist (1974).   |
| 6.   | VINTERSJOFART MED STORA FARTYG I BOTTENVIKEN. (1974).  |
| 7.   | VINTERSJOFART I BOTTENVIKEN. Symposium Luleå (1974).   |
| 8.   | HAVSISUNDERSÖKNINGEN I BOTTENVIKEN VINTERN 1974. A. Omstedt, T. Thompson och I. Udin (1974).   |
| 9.   | KARTERING AV YTVATTENTEMPERATUREN I VATTNEN RUNT SVERIGE. J-E. Lundqvist, A. Omstedt och I. Udin (1974).   |
| 10.  | EXPERIMENTS ON REMOTE SENSING OF SEA ICE USING A MICROWAVE RADIOMETER. M. Tiuri, M. Hallikainen and K. Kaski (1974).   |
| 11.  | BOTTENVIKENS STÅLFYRAR — HÅLLFASTHETSANALYS OCH FÖRBÄTTRINGSFÖRSLAG. M. Määttänen (1974).  |
| 12.  | FORMATION AND STRUCTURE OF ICE RIDGES IN THE BALTIC. E. Palosuo (1975).  |
| 13.  | CALCULATION OF ICE DRIFT IN THE BOTHNIAN BAY AND THE QUARK. A. Valli and M. Leppäranta (1975).   |
| 14.  | A NARROW BEAM SONAR TO MEASURE THE SUBMARINE PROFILE OF AN ICE RIDGE. E. Palosuo, T. Pousi and M. Luukkala (1976).   |
| 15.  | THE AVERAGE SURFACE TEMPERATURE IN THE AUTUMN AND THE EARLY WINTER ON THE GULF OF BOTHNIA, THE NORTHERN BALTIC SEA AND THE GULF OF FINLAND (1966—1974). H. Grönvall and E. Palosuo (1976). |
| 16:1 | SEA ICE -75. Programme. Å. Blomquist, C. Pilo and T. Thompson (1975).  |
| 16:2 | SEA ICE -75. Ground truth report. I. Udin (1976).  |
| 16:3 | SEA ICE -75. Ice detection by SLAR. R.H.J. Morra and G.P. de Loor (1976).  |
| 16:4 | SEA ICE -75. Analysis of SLAR data. S. Parashar (1976).  |
| 16:5 | SEA ICE -75. FLAR, ODAR, ship's radar. J. Nilsson, T. Hagman and Y. Nilsson (1976).  |
| 16:6 | SEA ICE -75. IR-scanner results. E. Fagerlund and G. Lundholm (1976).  |
| 16:7 | SEA ICE -75. Radaraltimeter results. S. Axelsson (1976).   |
| 16:8 | SEA ICE -75. Dynamical report. I. Udin and A. Omstedt (1976).  |
| 16:9 | SEA ICE -75. Summary report. Å. Blomquist, C. Pilo and T. Thompson (1976).   |