

Ground truth report

by Ingemar Udin
Norrköping 1976

Cover picture:

The icebreaker TOR in the middle of the test area for SEA ICE-75 and the principle layout of the ground truth areas.

SMHI
Fack
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SEA ICE 75

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Foreword

The Winter Navigation Research Board presents report no. 16:2. This report is one of the many resulting from the remote sensing experiment SEA ICE-75, that was carried out in the Bay of Bothnia in March 1975. It presents the ground truth that was necessary in order to judge the capability of the various remote sensing techniques that were tested during the experiment.

The maritime section of the Swedish Meteorological and Hydrological Institute (SMHI) was responsible for the preparation and the execution of the ground truth programme which included in situ measurements on the ice, air reconnaissance, high and low level air photography and collection of satellite data. The ground truth work was concentrated to one main area around the icebreaker TOR and a secondary area south of TOR for which personnel from the Finnish Marine Research Institute was responsible.

The Winter Navigation Research Board wish to express its appreciation to the author of this report and its thank to The Swedish Meteorological and Hydrological Institute, the Swedish Air Force, the Land Survey of Sweden, the Finnish Marine Research Institute, the Swedish Administration of Shipping and Navigation as well as the captain and the crew on the icebreaker TOR, for their valuable contributions to the ground truth programme.

Norrköping and Helsingfors, July 1976.

Lennart Johansson

Helge Jääsalo

Summary

A remote sensing project over sea ice was carried out between March 10 and 20, 1975. Several sensors, microwave, visual and infrared, were tested. Simultaneously an extensive ground truth work was carried out. This report gives information on all ground truth data including the satellite and air photo information.

A short background presents the water area studied and gives some statistical data about the ice conditions. The ice parameters which are of interest for the winter navigation and the ice forecasters and consequently should be interesting to map by remote sensing technique are presented. Three different ground truth areas inside each other were studied, one 1×1 km, one 5×5 and one 15×15 km. The 1×1 km area was located within the 5×5 km area, which in turn was located within the 15×15 km area. The ice information decrease in details and accuracy with increasing area.

Satellite data were collected. The data from the scanning radiometer and very high resolution radiometer of NOAA 4 and the multispectral scanner of LANDSAT -2 are listed. The data are exemplified with photos.

Air photos were taken over the ice. High altitude photography from 9000 and 12000 m was carried out by the Swedish Air Force. Photography from 4.600 m with a Wild camera and multispectral photography from 1.500 m with a set of four Hasselblad cameras were carried out by the National Land Survey of Sweden. All data available are listed. Examples of the results are given in figures and photos.

Ice observations and measurements were made in the ground truth areas. During the work helicopter, hydrocopter and snow scooter were used. The following ice parameters were determined, ice thickness, concentration, roughness, ridge height and width, snow depth. The ice information received has been analysed and the results are shown in tables, figures and as overlays to photomaps.

In addition to ice measurements and observations a number of meteorological and oceanographical parameters affecting the remote sensing recordings were measured and observed.

Some remarks to the work and the data have been made and also some suggestions when planning future experiments.

1 Introduction

The winter navigation in the waters surrounding Sweden needs a good mapping of the ice situation in order to plan the activity and to ship economically and safely. The sea ice mapping is required mainly on two different scales, one small scale (resolution tens of meters) covering areas of the order 5000 km² for direct operational use and one larger scale (resolution hundreds of meters) covering the Gulf of Bothnia or the whole Baltic for forecasting of the ice situation some days in advance.

The present ice mapping, mainly based on visual observations from landstations, ships, airplanes and satellites, has many drawbacks. The resolution is poor except in small areas, the coverage is not sufficient except when good satellite photos are available, the observations are weather and light dependent and all ice parameters of interest can not be mapped with the present observation system (1).

Remote sensing techniques, which successfully have been used on Arctic ice and in other disciplines, seem to offer good possibilities for mapping sea ice in the waters around Sweden. Especially the microwave sensors, which are light and weather independent may improve the ice mapping considerably. In order to test different remote sensing methods and to evaluate their capability and limitations a field experiment was performed in the Bay of Bothnia in March 1975. Many different sensors, satellite and air borne, were tested, air photos taken and ground truth work carried out. The experiment was a cooperation between different institutions in Sweden, Finland and the Netherlands. The programme for the experiment is described in (1).

The Swedish Meteorological and Hydrological Institute (SMHI) is responsible for the ice information and ice forecasting service in Sweden. SMHI took an active part both in the organization and the management of the experiment and was responsible for the ground truth work performed. SMHI also carried out an ice dynamic experiment during the same period.

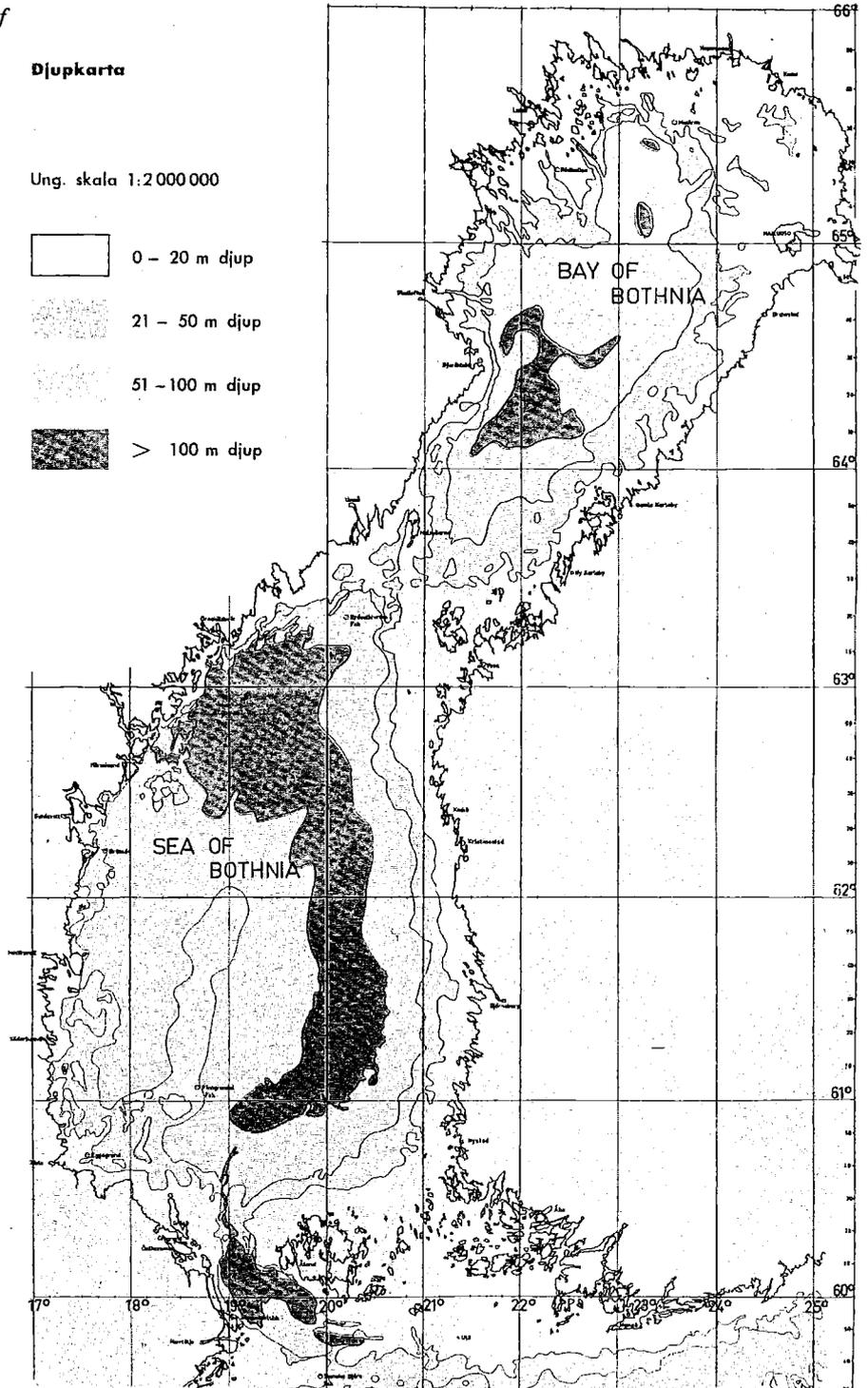
This report will describe the satellite and airphoto information available and the ground truth data from the Swedish test area. A report from a second ground truth area for which the Finnish Institute for Marine Research (FIMR) was responsible can be found in appendix B. The dynamical part of the experiment is documented in a separate report (2).

2 Background

2.1 Hydrography

The Bay and Sea of Bothnia, together called the Gulf of Bothnia is the northern extension of the Baltic (figure 1). Both basins are rather shallow (mean depth 42 and 69 m) and the water salinity low. Normal salinity values in the Bay of Bothnia are 3—3,5 ‰ and in the Sea of Bothnia 5—5,5 ‰ (2).

Figure 1. Map over the Gulf of Bothnia with depth.



2.2 Weather and Ice

The Gulf of Bothnia is situated between latitude N 60° and N 66° and consequently in the northern part of the westerlies. Normal air-temperatures from selected stations along the Swedish coast for the winter period (January—March) are shown in figure 2. The maximal ice extension during a normal winter is seen in the same figure. The ice normally starts to form in the northern skerries during November and grows then southward and towards the middle parts of the Bay and Sea of Bothnia. The maximal ice extension occurs usually during the first part of March, whereafter the melting starts. All the ice has normally disappeared at the beginning of June. Typical level ice thickness in the Bay of Bothnia is 50—70 cm and in the Sea of Bothnia 20—40 cm. Strong winds in connexion with the passages of low pressure systems force the ice to move and during the motion a deformation of the ice occurs. A considerable percentage of the area is therefore covered with rafted, ridged or hum-

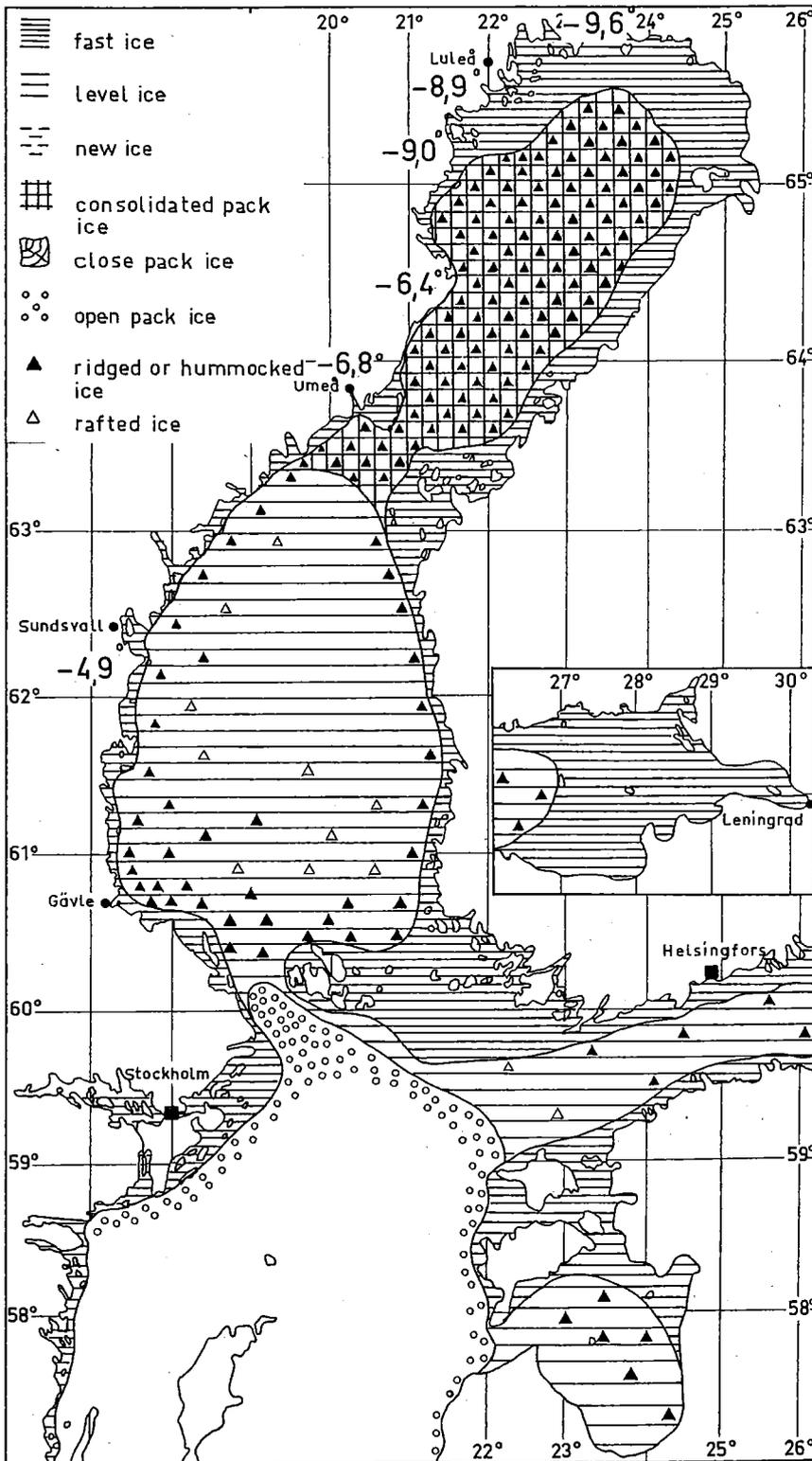
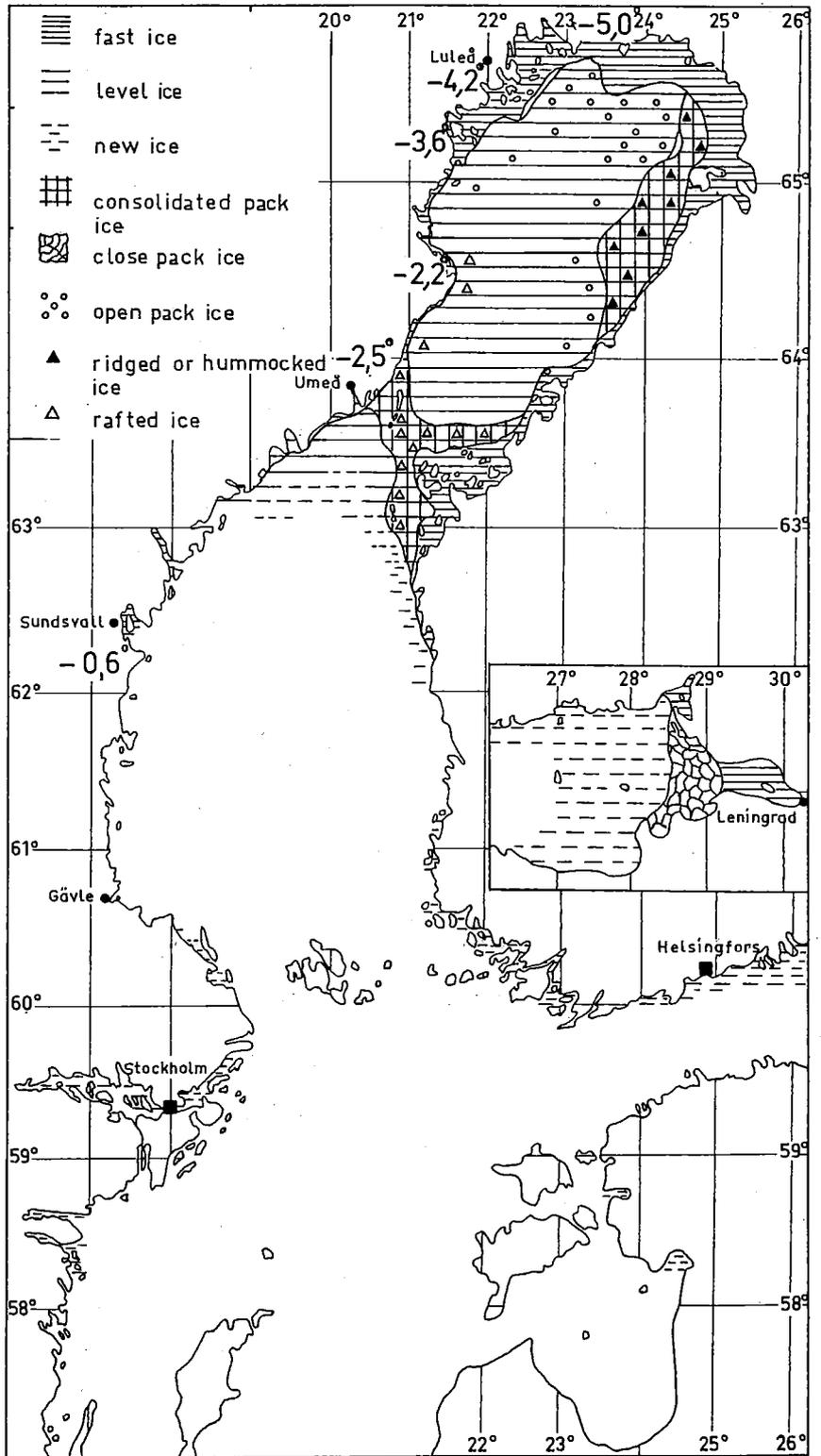


Figure 2. Map over the maximal ice extension and the ice types during a normal winter. The figures on the shores are climatic daily mean temperatures for the period January—March.

mocked ice. The ice ridges often penetrate down to 10 m below the surface and in the Bay of Bothnia pressure ridges down to 25—30 m have been investigated (3).

The winter 1975 was extremely mild as can be seen from figure 3. The mean air-temperatures for January—March were 4—5°C above normal in the Bay and Sea of Bothnia. The maximal ice extension was much less than normal and at the time of decision to carry out the field experiment, the ice extension was very critical. The level ice thickness was 20—40 cm while the fast ice in the skerries was a little thicker.

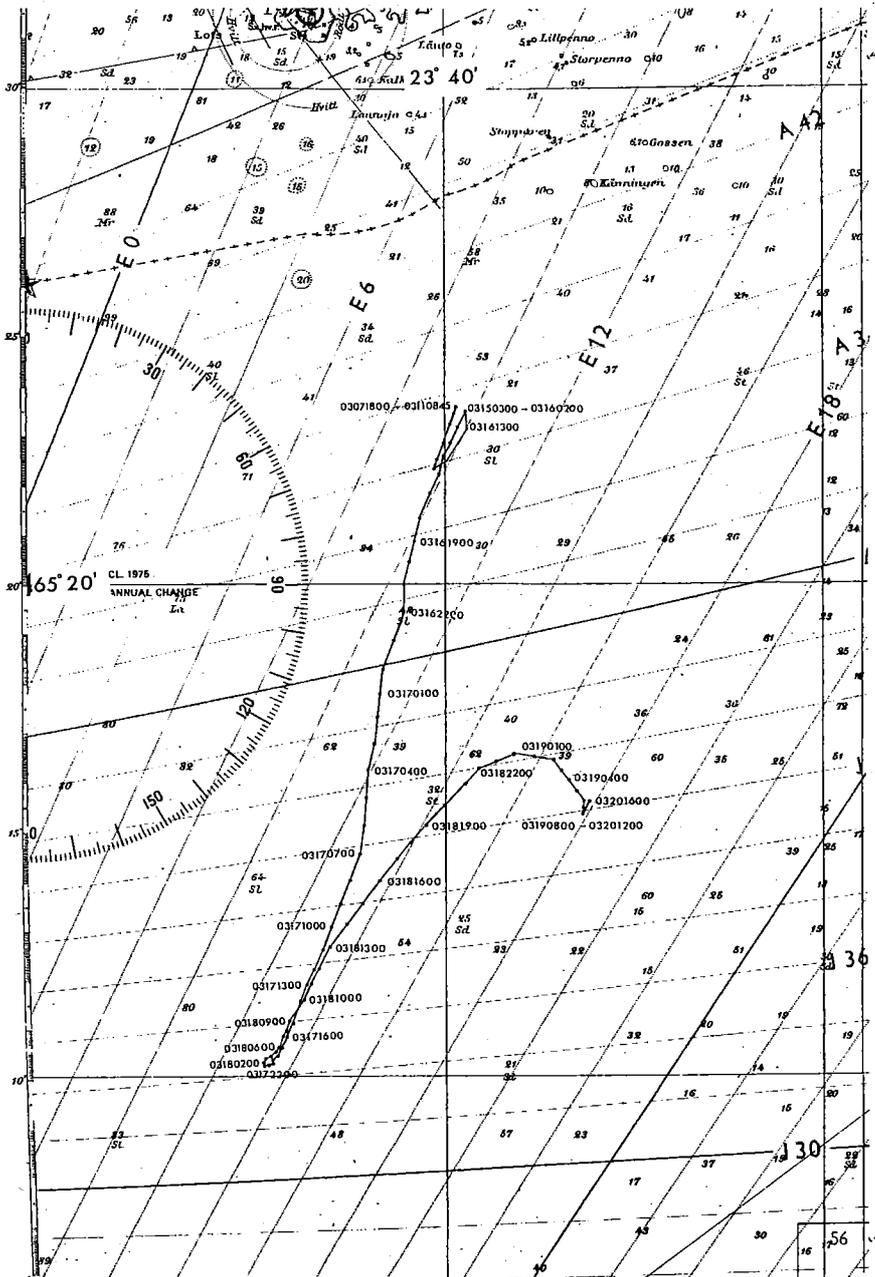
Figure 3. Map over the maximal ice extension and the ice types the winter 1975. The figures on the shores are daily mean temperatures for January—March 1975.



SMHI 3173 VBM 1974.06

The ice situation made it necessary to locate the experimental area to the northernmost part of the Bay of Bothnia, approximately 10 nm SSE of Malören (figure 4).

Figure 4. The drift of TOR with the ice during March 7—20. The figures on the trajectory refer to month, day and time of the day.



The weather during the period was very favourable for the experiment, the visibility was very good and the cloudiness very low. First the weather was dominated by a high pressure system, with almost clear sky and temperatures some degrees below 0°C. From March 15 some low pressure systems caused a more variable weather with a northerly gale which was followed by a southerly and later a westerly gale. At the end of the period again good weather with clear sky and good visibility prevailed.

During the period with strong winds a considerable ice drift occurred and the ground truth (GT) areas drifted a total distance of 45 km. The drift of the icebreaker TOR with the ice is shown in figure 4.

At the beginning no or negligible motion occurred and the ice in the test area was rather unchanged. During the time of considerable ice drift (March 16—20) also changes in the ice field occurred and they mainly affected the outer parts of the test areas.

3 Parameters of Interest

3.1 General

Several ice parameters affect the remote sensing signatures of sea ice. The primary parameters which should be evaluated from the remote sensing recordings and consequently be measured and observed by the ground truth team were

- ice or non-ice
- ice concentration (to which extent is the area covered by ice)
- ice roughness (to which degree is the ice deformed)
- ice thickness
- state of ice surface (melting ice, snow covered ice etc.)
- type of ice

Detailed information on these ice parameters within limited areas will give the icebreakers and navigation possibilities to choose the most economic route during the next few hours. Large scale information on the parameters above for the whole sea area will provide the initial data for forecasting the ice movement and development during the next 1—10 days.

Some environmental parameters also affect the remote sensing recording e.g.

- air temperature and temperature variations
- cloudiness
- wind speed
- sea state
- water temperature
- ice salinity
- time of day.

Those parameters should also be measured and observed.

3.2 Ice parameters

- Ice or non ice.** It is of definite interest for both navigation and forecasters to know if the area is **covered by ice or not**.
- Ice concentration.** A quantitative knowledge of the ice concentration (e.g. 70 % of the area is ice covered) is necessary for sea ice forecasts. For the shipping it is naturally of utmost interest to be aware of areas with low ice concentration in which the ship may travel with an acceptable speed.
- Ice roughness.** Rafted ice or ice with ridges is a serious obstacle for navigation in ice covered waters. Information on the **dimensions** as well as the **areal coverage** of the ridges is important when choosing the most suitable route. Also for the ice forecasters the roughness is of utmost interest. With a **quantitative** knowledge of the roughness the total ice mass in a chosen area can be estimated with a reasonable degree of accuracy. The forces acting upon the ice surface are also dependent on the roughness, the rougher surface the larger friction coefficient.
- Ice thickness.** The thicker the ice field is the harder it is to penetrate. Consequently it is an essential parameter for navigation. Studying the ice thickness one must be aware of the differences between level ice thickness and the total thickness of deformed ice. They differ very much, up to one order of magnitude or more. Of course it is of interest to measure both of them, but a knowledge of the level ice thickness together with a quantitative knowledge of the ice roughness may give the mean thickness of the deformed ice with an acceptable accuracy.
- State of ice surface.** A melting ice surface indicates that the ice resi-

stance is somewhat smaller and the ice therefore easier for ships to penetrate. It is also a valuable information for the forecaster.

If the ice surface is covered with snow the ice has a heat isolation causing the ice to grow slower. It is thus of interest for the ice forecaster to know both the snow covered area and the amount of the snow.

- **Type of ice.** Different types of ice are characterized by different thickness, roughness, flow size, concentration etc. A combination of the parameters above would give a good information on the type of ice.

3.3 Other parameters

The recordings from some remote sensors are affected by the atmosphere between the sensor and the ice and of course by different qualities in the ice. Registrations by satellite in the visual and infrared band are for instance obstructed by clouds, fog and rain. Registrations of the ice with infrared sensors are also influenced by the history of the temperature etc. Good knowledge of meteorological and oceanographical parameters are therefore necessary.

4 Ground Truth Programme

4.1 General

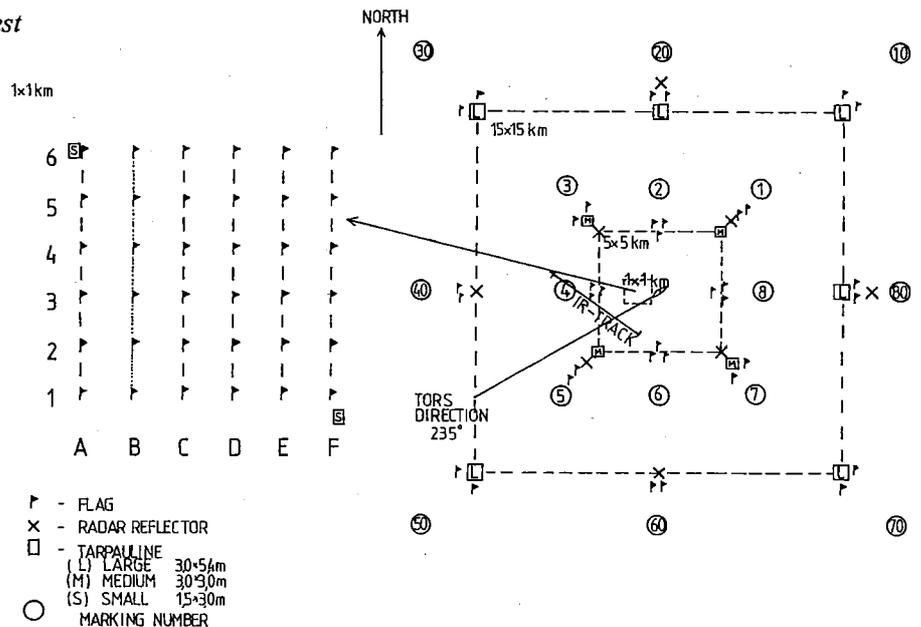
The ground truth comprised ice observations and measurements, weather observations, meteorological measurements and oceanographic measurements. In addition to the **real** ground truth data satellite information and aerial photography are also incorporated in this report. In attachment 1 a summary of the ground truth is presented and in table 1 the different ground truth methods are presented.

Table 1. Summary of ground truth information during Sea Ice-75.

TYPE OF INFORMATION	ALTITUDE	DATE	COVERAGE
NOAA SR * VHRR	1400 km	x x x x x x x x x x x x x	Scandinavia
Landsat-2 MSS	900 km	x x x	Northern part of Bay of Bothnia
High altitude photo (Swedish Air Force)	11 km	x x x	Tracks over the Bay of Bothnia (some covering parts of 15x15 km area)
Wild photo (Land survey of Sweden)	4.6 km	x x	15x15 km area
Hasselblad photo (Land survey of Sweden)	1.5 km	x x	5 x 5 km area
Ice reconnaissance with helicopter	10-100 m	x (x) (x)	15x15 km area
Ice observations and measurements. Meteorological and hydro- logical measurements	Ground	x x x x x x x x x x x x x	Around TOR in the 1x1 km and spotwise in the 5x5 km area
		10 11 12 13 14 15 16 17 18 19 20 Date	

The real ground truth work with observations and measurements of different parameters on the ice was carried out within special chosen and marked areas with various degrees of accuracy. Figure 5 shows a principle layout of the GT-areas.

Figure 5. Principle layout of the test area around TOR.



4.2 Special GT-areas

The test area was divided in one area 1x1 km, one 5x5 km and one 15x15 km.

The 1×1 km area (expanded to the left in figure 5) was located west of and near the icebreaker TOR. The area was marked with flags and two orange-coloured tarpaulins ($1,5 \times 3$ m). The distance between the flags was 200 m and the tarpaulins were placed in the northwest and southeast corner. The east-west rows were identified by numbers and the south-north rows by letters.

In the 1×1 km area the following GT work was carried out. Ice thickness measurements were made at each flag and at several other points in the area. In addition the ice thickness was measured at every 10th meter along the B-line. The snow thickness in the area was measured. The ice was classified and the width and height of ice ridges were measured. During the period March 10—20 no changes occurred in the 1×1 km area except for a very small increase in the ice thickness.

The 5×5 km area was marked with flags, tarpaulins and radar reflectors as shown in figure 5. In the mid point TOR was situated, equipped with a RACON as navigational aid for the aeroplanes. The radar reflectors were of net type with target areas of 2.150 resp 420 m² for 3 cm radar. They were mounted on aluminium pipes and stayed on the ice with wires (figure 6). The reflectors were put on the ice for two reasons, first to identify the area registered by the different radars and secondly to observe and measure the ice movement around TOR (2). Within the 5×5 km area detailed ice observations and measurements were made mainly in selected areas. These were chosen partly from the air photos and partly from the ice reconnaissance with helicopter for the reason that they contained ice of special interest. In the 5×5 km area the ice thickness was measured near the markings and in the selected areas. Also the snow cover was measured at those places. The changes in the ice in the 5×5 km area occurred mainly in the southern and southwestern parts where both cracks and ridges were formed after March 16. At the end of the period, March 19 and 20, cracks were formed in the whole area. They are not verified in the photo material.

Also the 15×15 km area, the outer area around TOR, was marked with flags, tarpaulins and radar reflectors (figure 5).

The ice and snow thickness near the markings were measured. A helicopter reconnaissance carried out over the area verified most details on the air photos. GT data over the 15×15 km are therefore of rather good quality for the days when Wild photos were taken (table 1). The changes in the 15×15 km area were considerable especially during the period March 16—20 when a pronounced ice drift occurred.

The meteorological and oceanographic observations and measurements were made in the mid point of the area, that is from and around TOR.

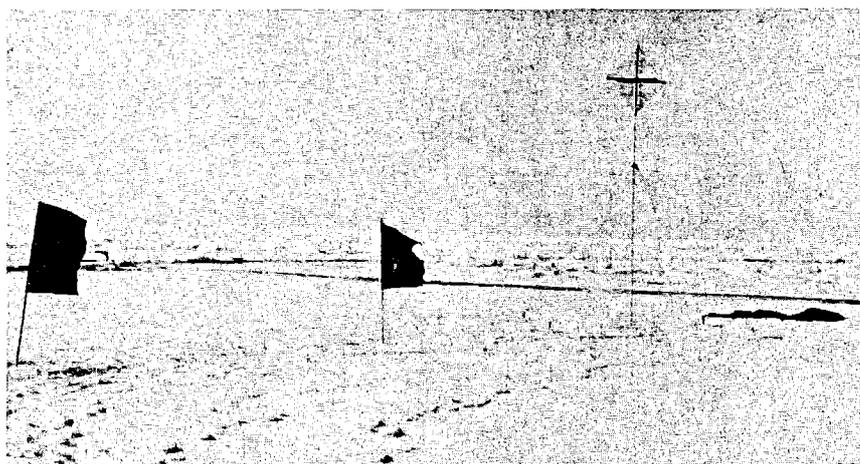


Figure 6. An example of a marking with a net reflector, flags and a tarpaulin.

4.3 Ground truth methods

The ground truth measurement were carried out in the following way.

- Ice thickness was measured with ice drill and measuring stick.
- Snow depth was measured with measuring stick.
- Ice ridges were located from air photos, the width and the height from sea level to the ridge top were measured with measuring stick.
- Ice surface temperatures were measured with resistance thermometers.
- Meteorological and oceanographic parameters were measured with standard instruments.
- Ice salinity was determined from samples analysed at laboratory.

5 Satellite Information

5.1 NOAA 4 Scanning radiometer

The weather satellite 64AA 4 is positioned in a sun synchronous orbit approximately 1400 km above the surface of the earth and passes over the same area twice a day, before noon and in the evening. The satellite is equipped with a scanning radiometer (SR) which is scanning the earth surface from horizon to horizon. The SR is measuring the radiation energy in the visual part of the spectra (0,5—0,7 μm) and in the infrared part (in the atmospheric "window") 10,5—12,5 μm . The visual channel gives a resolution of 4 km and the infrared channel 7,5 km just under the satellite. The resolution decreases towards the sides of the picture (4).

The information from the SR is in analogue form and is transmitted in real time. SMHI is equipped with a receiving station consisting of both a tape recorder and a picture unit.

Pictures from NOAA 4 SR have been collected for the period March 10—20. An example of a SR visual and infrared picture from NOAA 4 is seen in figure 7. In the middle and left part of the pictures Skandinavia is

Figure 7. An SR visual and infrared picture from NOAA 4 on March 17. It covers all Scandinavia.



seen and the open sea in Gulf of Bothnia shows up as black. In the northeastern part of the Bay of Bothnia white and grey tones show the sea ice with a lead in the northwestern part. From the IR picture land may, with some difficulty, be distinguished from sea and open sea from ice covered water.

The SR picture gives only a general view of the ice extension and details cannot be distinguished. Ice can normally be separated from open water but in many cases it is impossible to distinguish new ice from open water. The picture may give a qualitative information on the snow cover on the ice.

Some of the advantages with the SR information are:

- the data are transmitted in real time
- the receiving is simple and a receiving equipment is available at SMHI
- data are received twice a day
- the areal coverage is good (more than Scandinavia).

Some disadvantages are:

- the information (visual and IR) is weather dependent
- the visual part is light dependent
- the resolution is far from required
- the information is distorted.

5.2 NOAA 4 Very high resolution radiometer (VHRR)

The weather satellite NOAA 4 is also equipped with a VHRR. The radiometer is measuring the radiation energy in the visual part of the spectra (0,6—0,7 μm) and in the atmospheric "window", 10,5—12,5 μm . Both the visual and the IR data received from VHRR have a resolution of 0,93 km (4,5).

Analogue data are transmitted in real time but a small amount of data is stored and transmitted to special stations in the U.S. The equipment required for receiving VHRR data is more sophisticated and more expensive than the SR equipment. The nearest VHRR stations are situated in Tromsø, Norway and Bochum, West Germany.

Pictures on positive film for the period March 10—20 have been received from Bochum. From the pictures the Bay and the northern part of the Sea of Bothnia have been enlarged on paper copies. Analogue data tapes from March 16—18 have been received from Tromsø for analogue and digital processing. An example of a visual VHRR picture is seen in figure 8. The black part in the sea area is open water which is easily distinguished from land and ice. In the ice field leads and cracks are seen. The grey tones in the ice field indicate different ice concentration and snow cover.

In figure 9 the IR picture from the same time is shown. The IR picture contains less information than the visual (see for instance the grey tones in the ice cover) but an optimal information is received when using the two pictures simultaneously. Then, for instance, clouds may be separated from ice, as especially high and middle high clouds have a lower temperature and consequently are whiter than the ice in the IR picture.

From the VHRR pictures different ice parameters can be mapped. Ice can be distinguished from open water except in some occasions with new ice. Ice of different concentration may be distinguishable. The different ice types which can be mapped are fast ice, open, close, very close pack ice and new ice. A qualitative information on the snow cover can also be received.

As the human eye has a very limited capacity to distinguish different greytones in a picture, very much of the information disappears. The greytones in e.g. a VHRR picture can be enhanced by a density slicing technique either photographic or electronic. Figure 10 shows a photographic slicing of the VHRR pictures from figure 8 and 9. In the pictures the borders between ice and open water have been enhanced and also greytones within the ice in both the visual and the infrared picture have been intensified.

The resolution, the number of greytones and the quality of the VHRR data is good. A data processing of the taped information would therefore be valuable for several reasons. Correlation between the information from the satellite and ground truth on ice would probably give information on more ice parameters than the pictures do i.e. may it be possible to determine the ice concentration over an area with sufficient accuracy. If so, it would also be possible to analyse some ice parameters automatically with a computer.

Figure 8. 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.

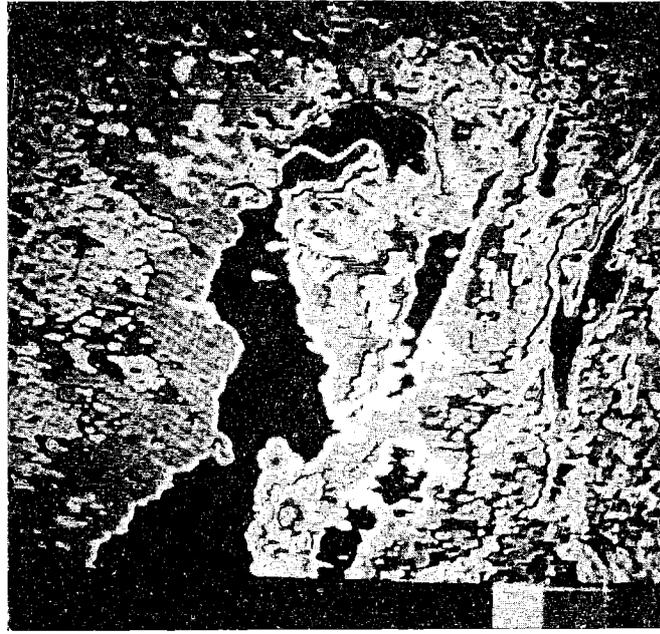


Figure 9. The infrared VHRR registration corresponding to figure 8.





Visual



Infrared

Some advantages with the VHRR information are:

- the data are transmitted in real time
- data are received twice a day
- the areal coverage is good (whole Scandinavia)
- the resolution is acceptable for more large scale mapping
- the taped information is of a quality which may make a data processing valuable.

Some disadvantages are:

- the information (visual and IR) are weather dependent
- the visual part is light dependent
- the information is distorted
- no receiving station is at present available in Sweden.

5.3 Landsat-2 Multispectral scanner (MSS)

The earth resources satellite LANDSAT-2 (earlier called ERTS) is positioned in an orbit approximately 900 km above the earth's surface. It passes over the same place every 18th day under the same sun elevation. The satellite has very good sensor systems. It is equipped with one multispectral scanner with four channels. The MSS measures the radiation energy. Every registration covers an area of 185×185 km and the resolution is as good as 70—100 m. The overlapping of the information is rather good at high latitudes and LANDSAT information can be received three days in succession for the Bay of Bothnia. The different sensors work in the following parts of the electromagnetic spectra,

Sensor	Band	Part of the spectra
MSS	4	0.5—0.6 μm
MSS	5	0.6—0.7 μm
MSS	6	0.7—0.8 μm
MSS	7	0.8—1.1 μm

The registrations are all made in the visual part of the spectra except for MSS 7 which registers in the near infrared (6).

Data from the satellite can be received in real time but a special equipment is required. Recently a receiving station which is said to have ability to get information from most of the Bay and Sea of Bothnia has been built in Italy. The satellite is also equipped with tape recorders on which data for selected areas can be stored. When the satellite passes over the U.S. the data are transmitted to ground stations. The tape recorder capacity is limited and it is therefore difficult to receive all wanted data. The data is in digital form (tapes) and in picture form (one picture for each channel).

Figure 10. Photographic density slicing of the VHRR pictures in figures 8 and 9. (Photo processing, H. Ödegård Vassdragsvesendet, Norge)

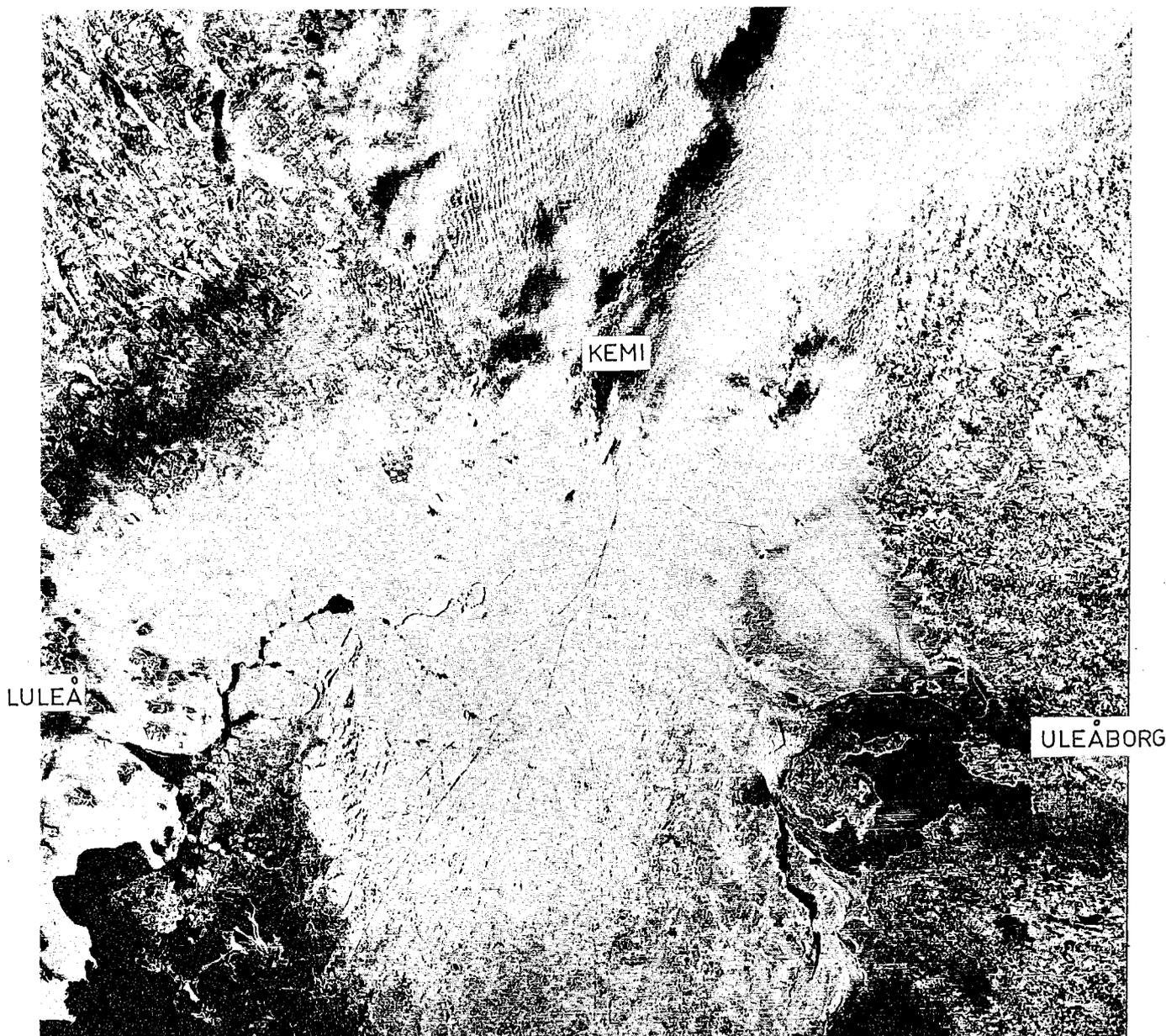


Figure 11. A registration made by the satellite LANDSAT-2 (MSS 7) on March 15. The picture covers the northern part of the Bay of Bothnia.

LANDSAT pictures (MSS 4—7) have been received from NASA, USA for three successive days, March 14, 15 and 16. The pictures cover parts of the Bay of Bothnia. Digital tapes for the days can be ordered from NASA. A picture from March 15 is shown in figure 11. The black parts in the picture is open water (or at some places new ice), the white unbroken areas are fast ice and the more greyish, sea ice of different types and concentration.

In figure 12 the LANDSAT picture in figure 11 is enlarged over Luleå—Malören. In the picture the icebreaker TOR can be seen.

For March 15 an enlarged colour composite has been made by the Swedish Land Survey and for all three days colour composites have been made with the Mini Add Col Viewer at the Institute of Geography at the University of Stockholm. They are available at SMHI.

The sensor systems onboard LANDSAT are of a very good quality and permit a number of different ice parameters to be identified. Ice can be distinguished from open water, in some cases however thin new ice may appear as open water. Single ice flows and openings in the ice larger than approximately 100 m can be identified. Line features like cracks can be even smaller (width 20—30 m) and still identified. This means that the ice concentration is rather easily estimated. From the LANDSAT data also deformed ice might be seen. Looking in detail at the enlarged pictures line structures show up which seem to coincide with the ridges mapped from the ground truth material. In order to find out if the resolution is sufficient for mapping the more pronounced deformed areas a further examination of both picture and tape data is required. Also differences in the state of the ice surface appear. The ice east of Marjanemi

has e.g. quite another grey tone than the ice west of the island in MSS 7 as can be seen in figure 11. The difference has been interpreted as melting snow surface or a snow cover mixed with water. The snow covered ice is very easily distinguished from ice without snow. Consequently the LANDSAT data are able to give a lot of, and possibly the most important ice parameters of interest and thus the following ice types: fast ice, pack ice, level ice, new ice, ridged ice etc.

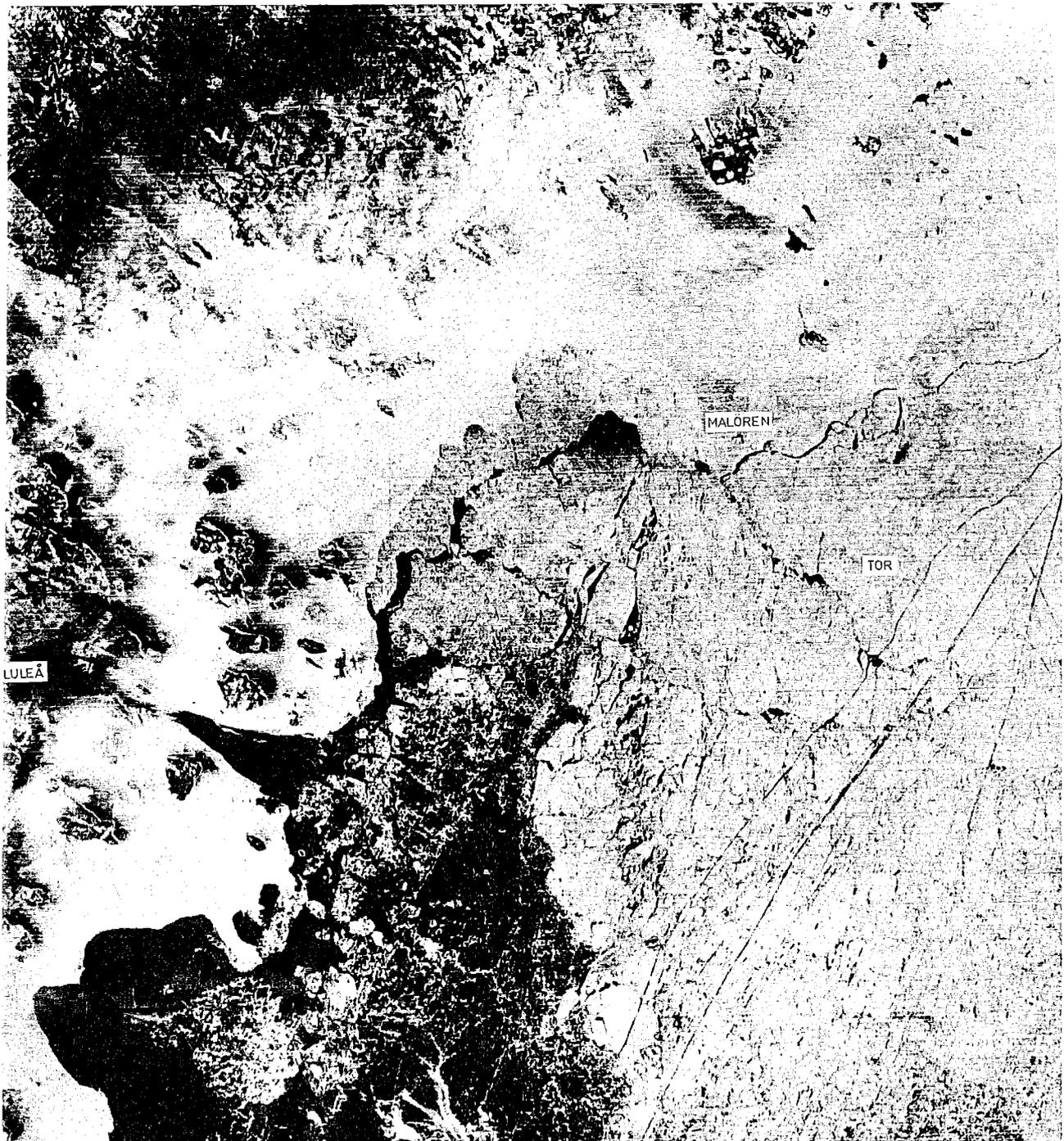
Advantages with the LANDSAT data are:

- the resolution permits a good large scale mapping for ice forecasting and to some extent small scale mapping for the navigation
- data from different parts of the spectra gives extra information
- the areal coverage is fairly good
- there is no distorsion in the pictures
- a digital processing might be valuable and give information on more ice parameters. Besides an automic data analysis might be possible.

Disadvantages are:

- data are available only 2—3 times every 18th day
- the information is dependent on weather and light
- no receiving station is available in Sweden

Figure 12. The area from Luleå to the icebreaker TOR, enlarged from figure 11.



6 Air Photo

Air photos from the experimental period are available from three different altitudes. The Swedish Air Force photographed from high altitude with a rather large covering and overlapping, the National Land Survey of Sweden photographed the 15×15 km area with a Wild RC 8 mapping camera and the 5×5 km area with a set of four Hasselblad cameras equipped with different lenses, filters and films.

6.1 High altitude photos

The Swedish Air Force was responsible for the high altitude photography. The photos were taken from an altitude of 9 and 12 km by the aeroplane Draken. The pictures are in black and white and have the original size 115×57 mm. The scale varies from 1:5000 to 1:200.000. The overlapping is good and permits stereo investigations.

The Draken flew different tracks in the Bay of Bothnia and some of them covered the area around TOR. Pictures are available from three days, March 10, 12 and 17. (For information on coverage, scale, and other data see attachment 1).

An example of the high altitude photos is shown in figure 13. The photo is from March 10 and is covering a 11.5×23 km area around TOR and has been enlarged so that the scale is 1:100.000. The photo is one from a serie covering a long track in the Bay of Bothnia.

Figure 13. Air photo taken by the Swedish Air Force on March 10 from 11.600 m. The 5×5 km area is shown on the photo. (Scale 1:100 000)

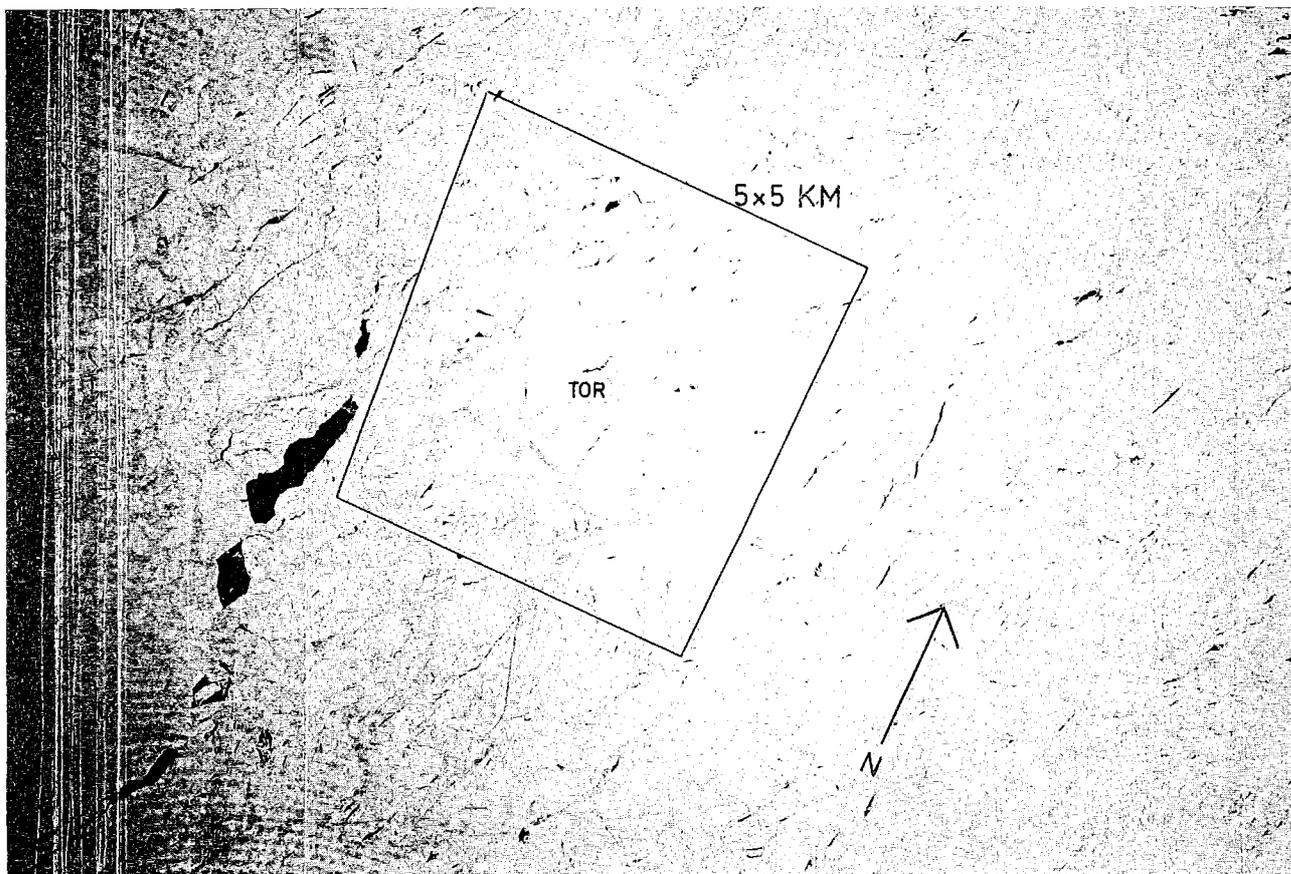




Figure 14. Air photo over TOR taken by the Swedish Air Force on March 10 from 11,600 m. (Scale 1:5,000)

An example of a 1:5000 scale picture is shown in figure 14. The picture is chosen from a series covering a 19 km long and 4 km wide track and parts of the 1 × 1 km area.

The photos taken by the Air Force covered fairly large areas in the Bay of Bothnia and show a considerable amount of details on the ice. The Air Force photos did not cover the 15 × 15 km area completely more than on March 10 due to navigational difficulties. Photos from some of the flights are difficult to locate geographically. The quality of the photos are good but not of the same quality as those taken by the National Land Survey.

6.2 Wild photos

The National Land Survey of Sweden was responsible for air photography with a Wild mapping camera. The carrier was an Aero Commander 680 SL aircraft.

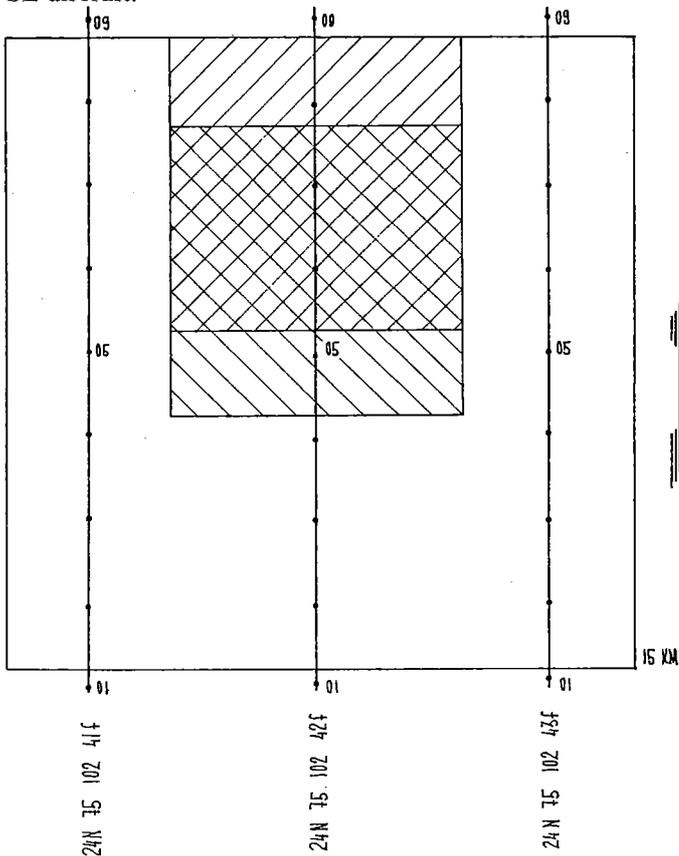
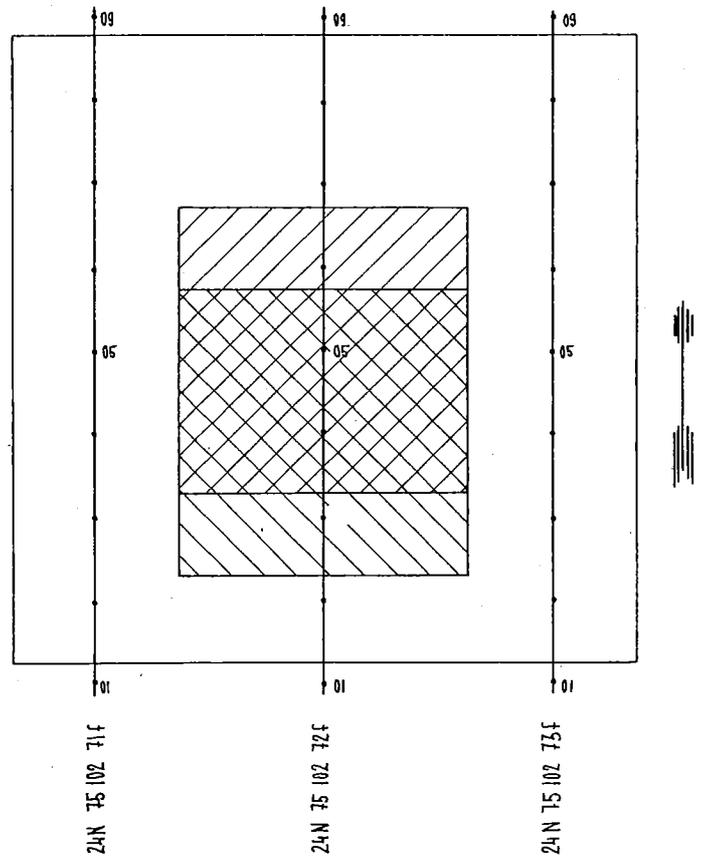


Figure 15. Idealized figure showing the coverage, overlapping, position and registration number for the photos taken by the Wild camera from 4,600 m on March 14.

The Wild photos are on 23×23 cm negative colour film. They were taken from an altitude of 4600 m on March 14 and 17 and covered the 15×15 km area (attachment 1). The photos were taken along three different tracks and with sufficient overlapping to permit stereo investigation. The position coverage, and registration number of the photos are seen in the idealized figures 15 and 16. Due to navigational problems (it was very difficult to find characteristic points or marks on the ice for the different tracks), small parts of the 15×15 km area are uncovered in spite of the planned overlapping.

Figure 16. Idealized figure showing the coverage, overlapping, position and registration number for the photos taken by the Wild camera from 4.600 m on March 17.



The Wild photos have an excellent quality and the resolution is utmost good. For instance the small tarpaulins (1.5×3.0 m) in the 1×1 km area are visible. Also ice ridges and other characteristic ice features are easily detected. An example of a Wild photo is seen in figure 17.

From the photos, mosaics or photomaps over the 15×15 km area have been constructed by the Land Survey. The markings on the ice have been located and marked on the photomaps. Examples of the photomaps are shown in chapter 8. Some colour enlargements covering the area around the icebreaker have also been made and are available. A short report from the Land Survey describing the air photo operation and the material available is given in appendix A.

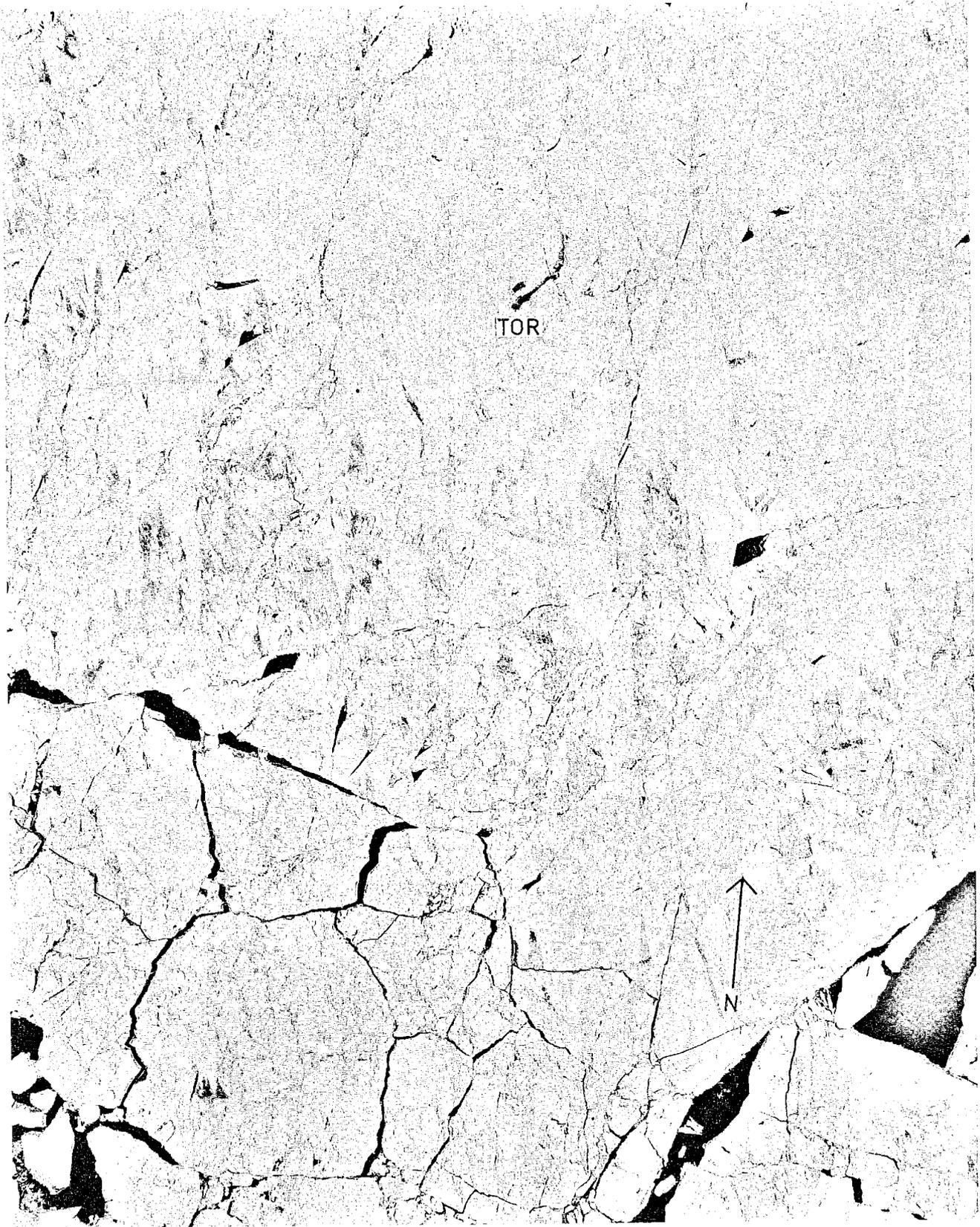
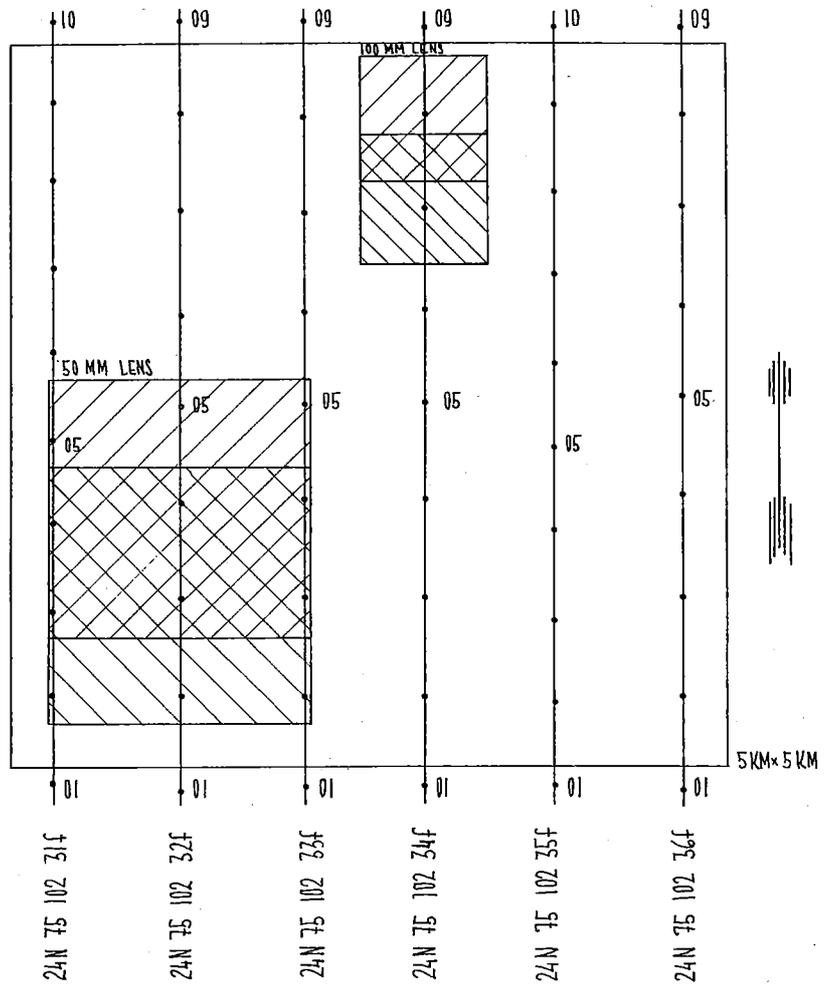


Figure 17. A Wild air photo taken
by the National Land Survey of
Sweden on March 17
(Scale 1:30,000)

Figure 18. Idealized figure showing the coverage, overlapping, position and registration number for the photos taken by the Hasselblad cameras from 1500 m on March 13.



6.3 Hasselblad photos

The National Land Survey of Sweden also photographed with a set of four Hasselblad cameras from an altitude of 1500 m. The carrier was the Aero Commander. The cameras were equipped with different lenses, filters and films and the exposures were simultaneous. The first camera had a 50 mm lens and a negative colour film, the second a 105 mm lens with a UV filter and black and white panchromatic film, the third a 100 mm lens and black and white infrared film and the fourth a 100 mm lens and colour infrared film. The size of the film is 6×6 cm. Pictures were taken on March 13 and 18 and covered the 5×5 km area (attachment 1). The photos were taken along six different tracks and the interval between the exposures permits stereo investigation on the photos taken with the camera equipped with the 50 mm lens. The position coverage and registration number of the photos are given in the idealized figures 18 and 19. Also small parts in the 5×5 km area are uncovered due to the navigational problems mentioned earlier.

The quality of the Hasselblad photos is very good. Most ice parameters are visible. The resolution is good and the small tarpaulins and even the shadows of the flags are detectable on the photos. Examples of Hasselblad photos are shown in chapter 8.

Photomaps covering the 5×5 km area have been made by the Land Survey for March 13 and 18. Also a photomap over the 1×1 km area for March 13 has been made. The position of the markings have been located and marked on the maps. On the 1×1 km photomap even the flags have been located and marked. Also black and white enlargements from the negative colour film have been made and are available (examples in chapter 8).

Some work has been initiated comparing the multispectral information with the different Hasselblad photos. Preliminary photographic colour mixing has been carried out, and from that one can conclude that there are differences between the different films. Variation in the snow cover are e.g. better visible in the UV photos and open water better in the IR photos. A further investigation ought to be carried out. In figure 20 a UV and a IR photo over the same area are shown.

Figure 19. Idealized figure showing the coverage, overlapping, position and registration number for the photos taken by the Hasselblad cameras from 1500 m on March 18.

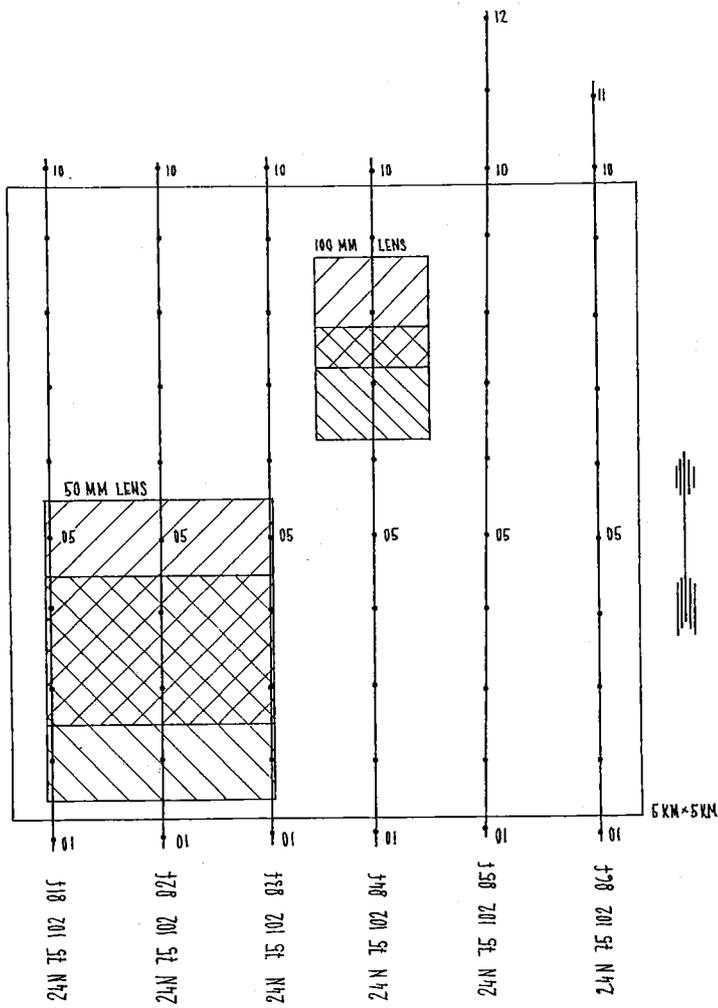
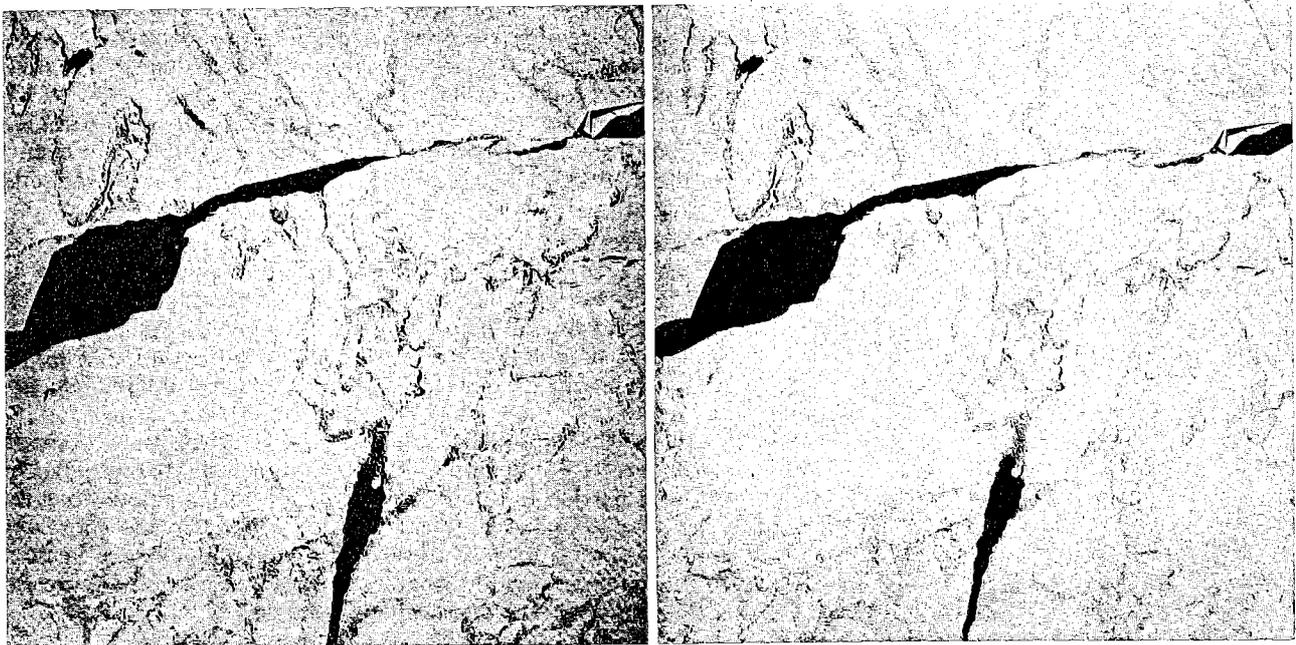


Figure 20. Air photos from the UV and IR cameras taken by the National Land Survey on March 13 from 1500 m showing an area southeast of TOR.



7 The Large Scale Ice Situation

Information on the ice was collected both on large and small scale. From the routine ice observations and ice charts, the NOAA VHRR pictures, the Landsat MSS pictures, the air photos and air reconnaissance carried out the large scale ice situation has been mapped. The analysis show the areas with open water, the ice concentration, the types of ice, some thickness values and areas with ridges. The maps are shown in figures 21—31.

As mentioned earlier the ice extension was much less than normal and mainly the northeastern part of the Bay of Bothnia was covered with pack ice with ridges. In the northwestern part mainly new ice or open water were present. Most of the changes in the ice occurred at the end of the period when a wide lead opened between the fast ice and the pack ice in the northern part of the Bay of Bothnia. Between March 16 and 20 also cracks and leads formed in the pack ice.

Figure 21—31. Ice charts showing coverage, concentration, ice thickness and type of ice.

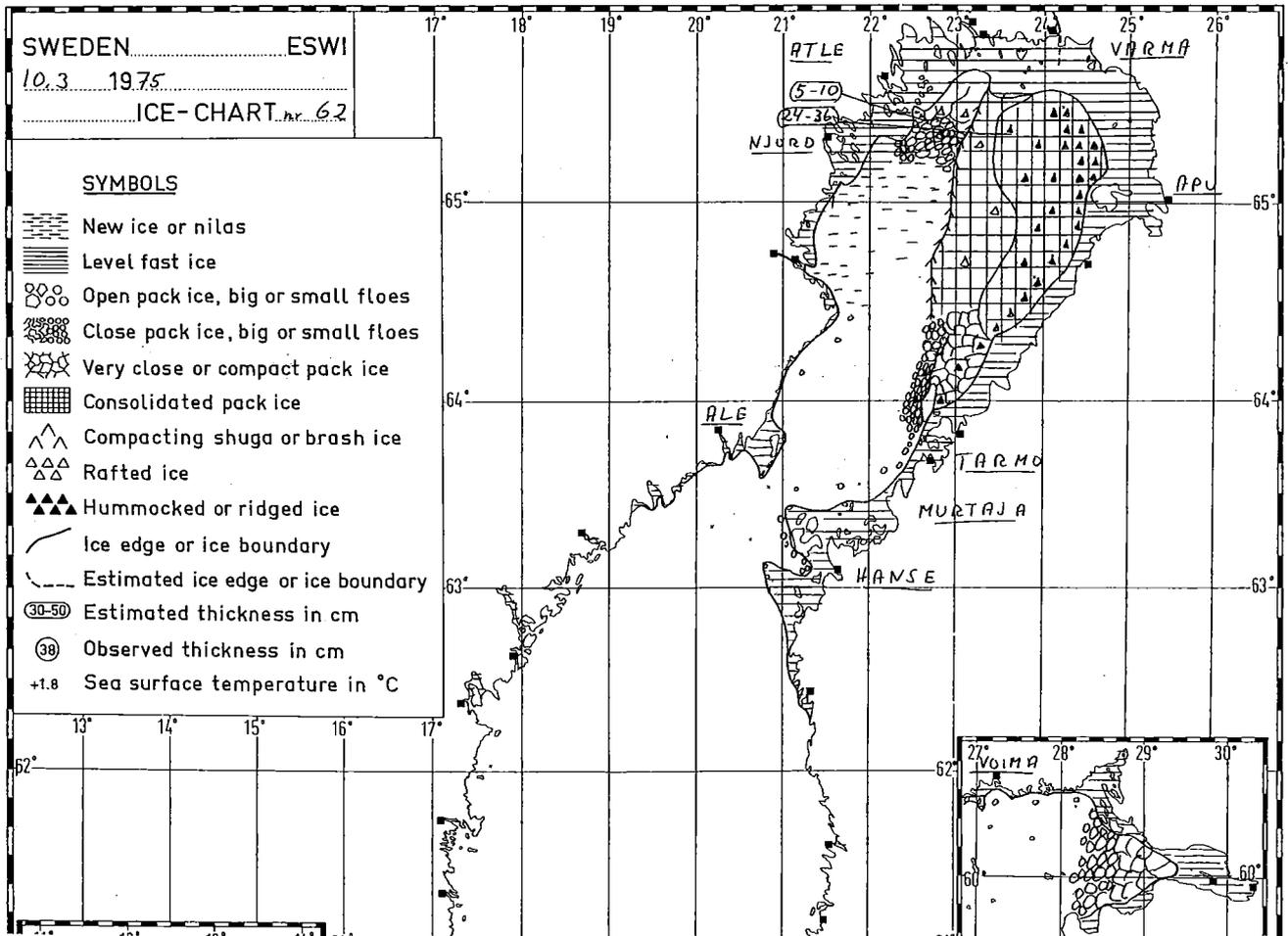


Figure 21. March 10.

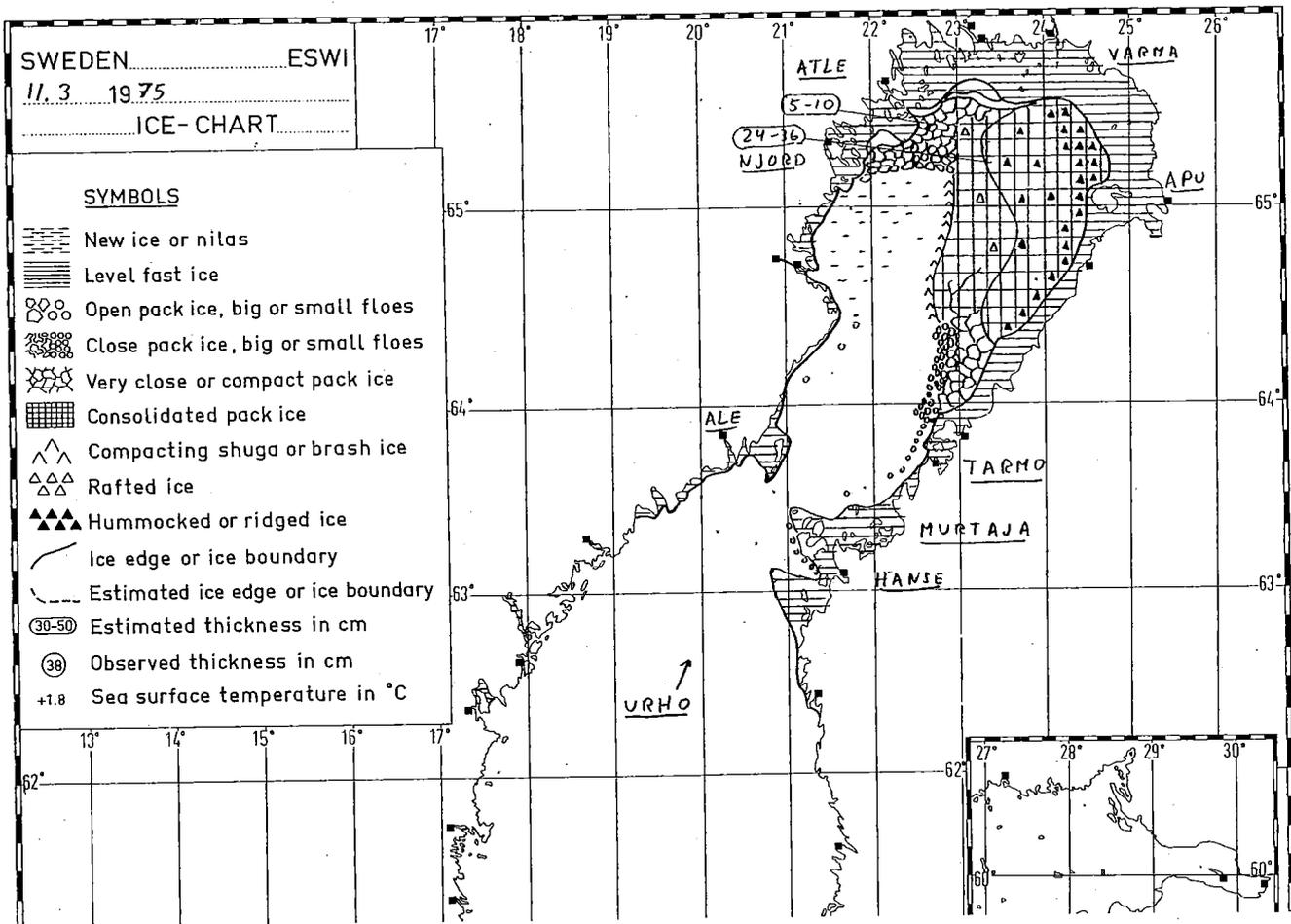


Figure 22. March 11.

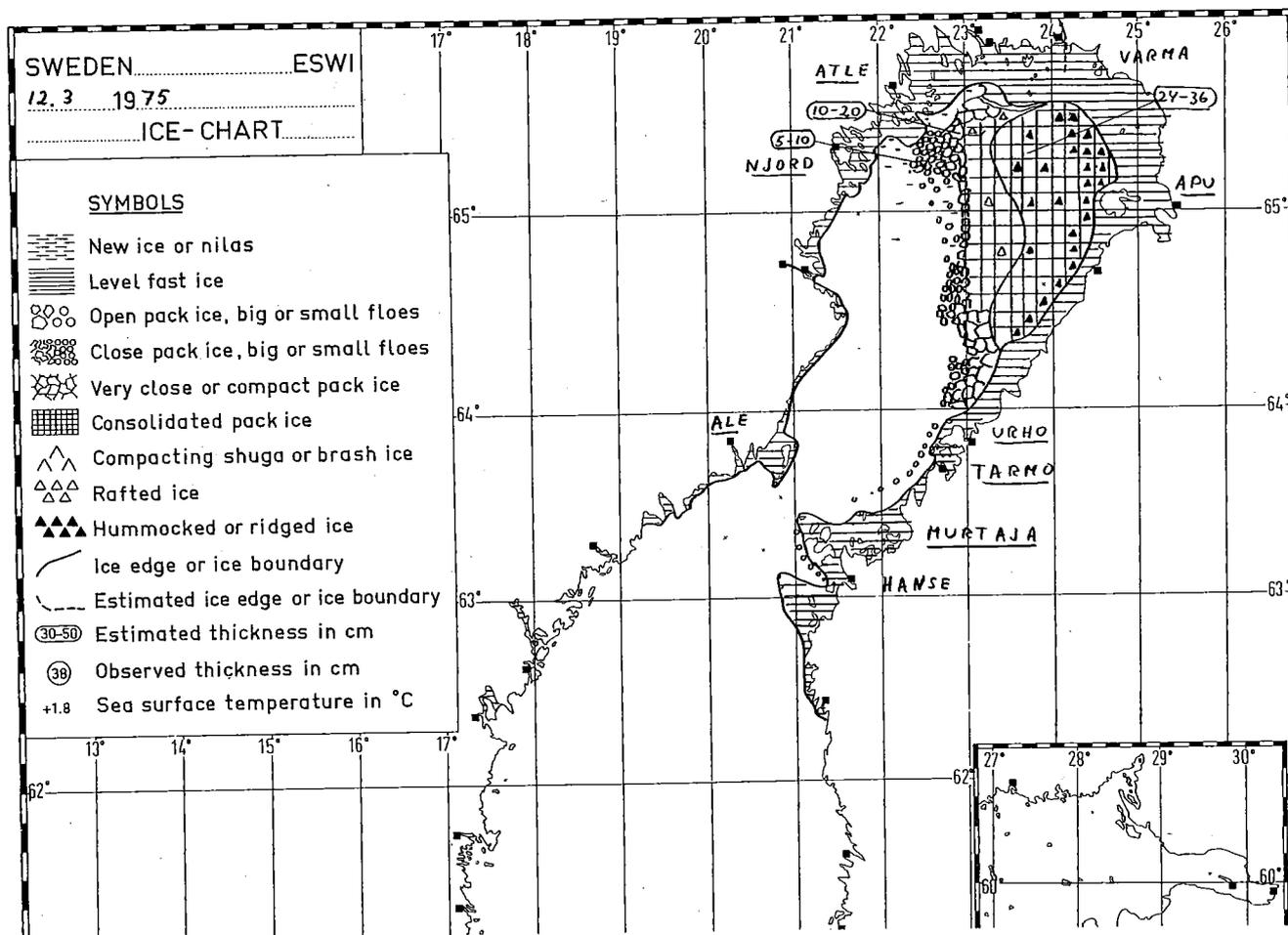


Figure 23. March 12.

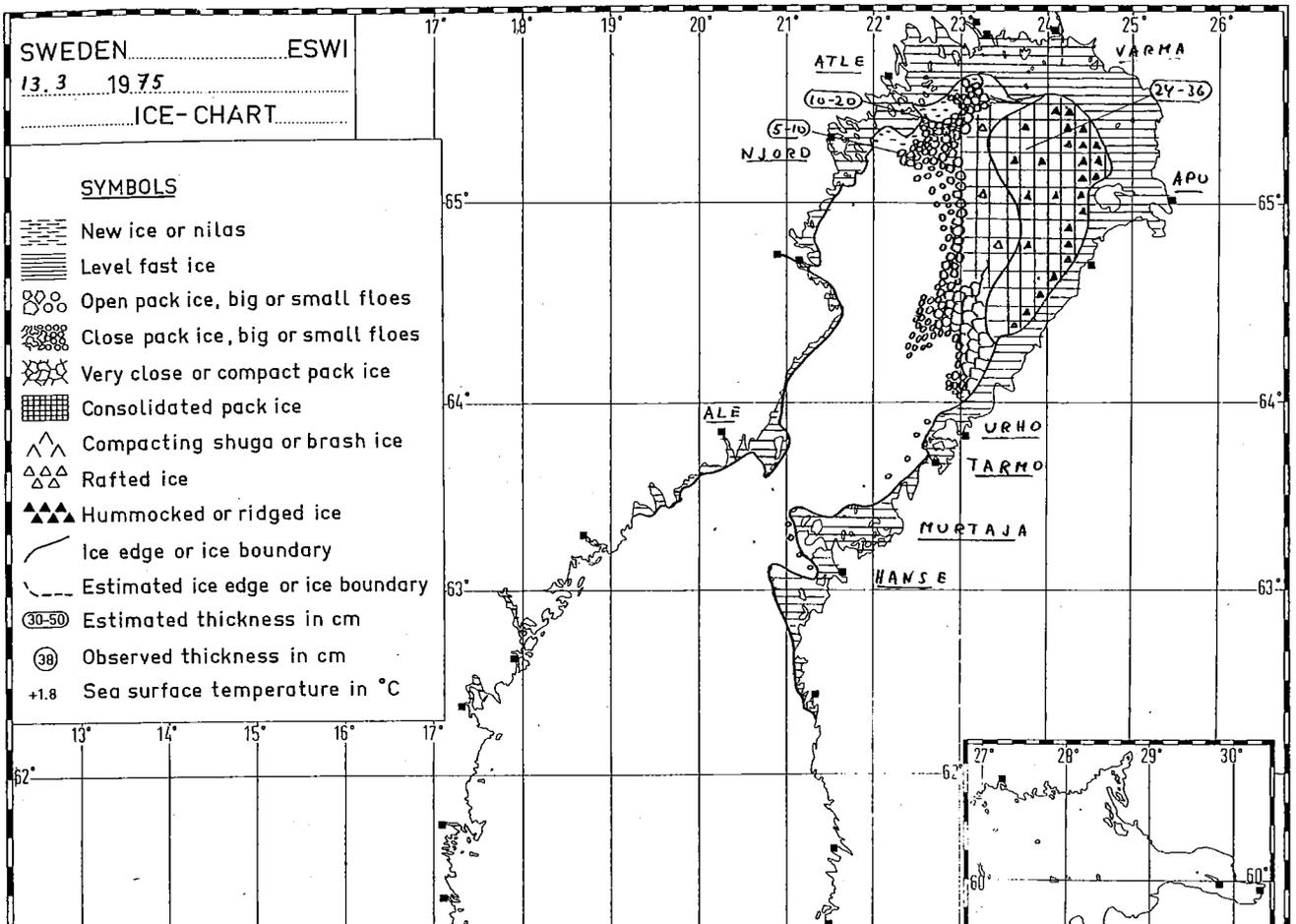


Figure 24. March 13.

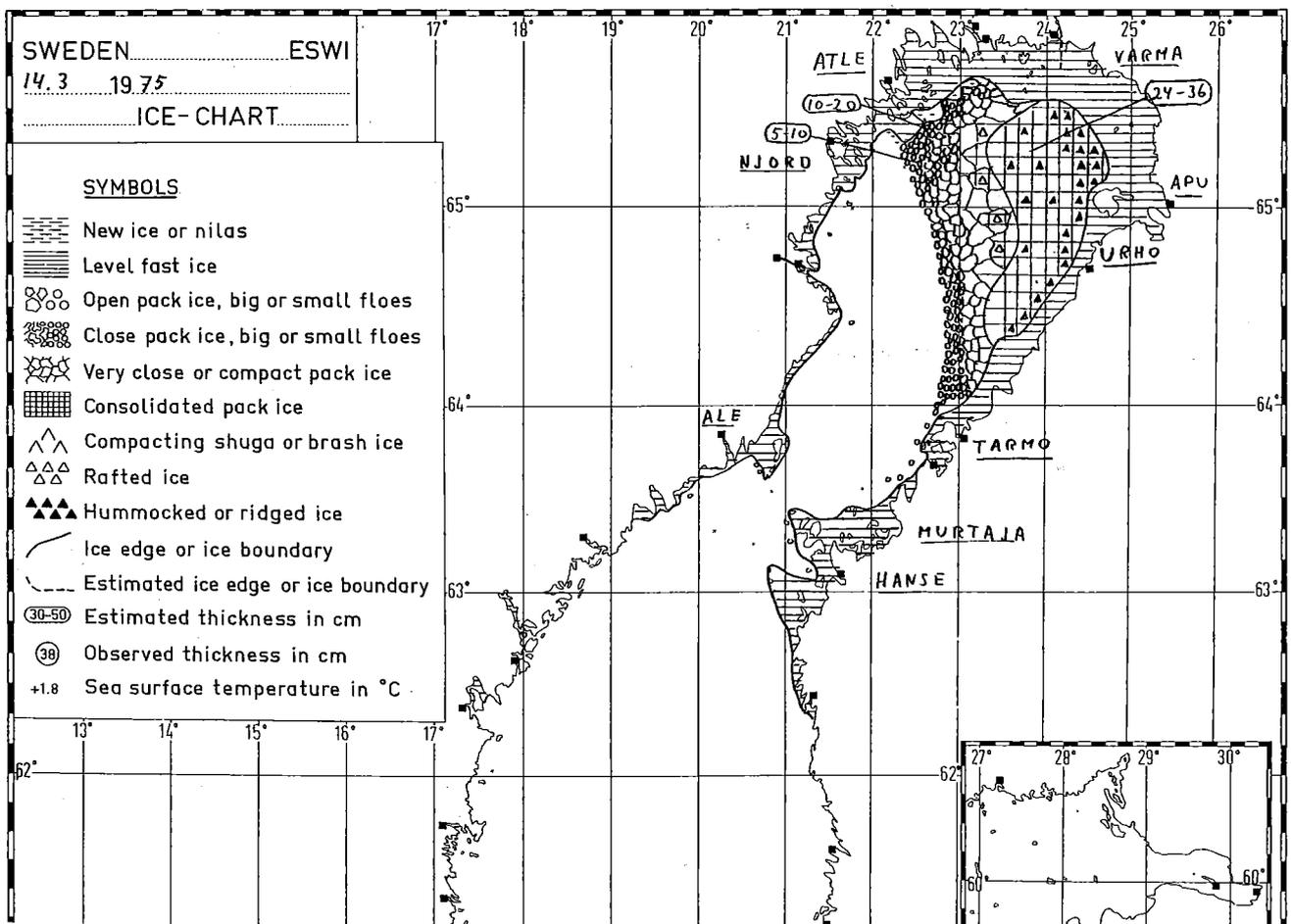


Figure 25. March 14.

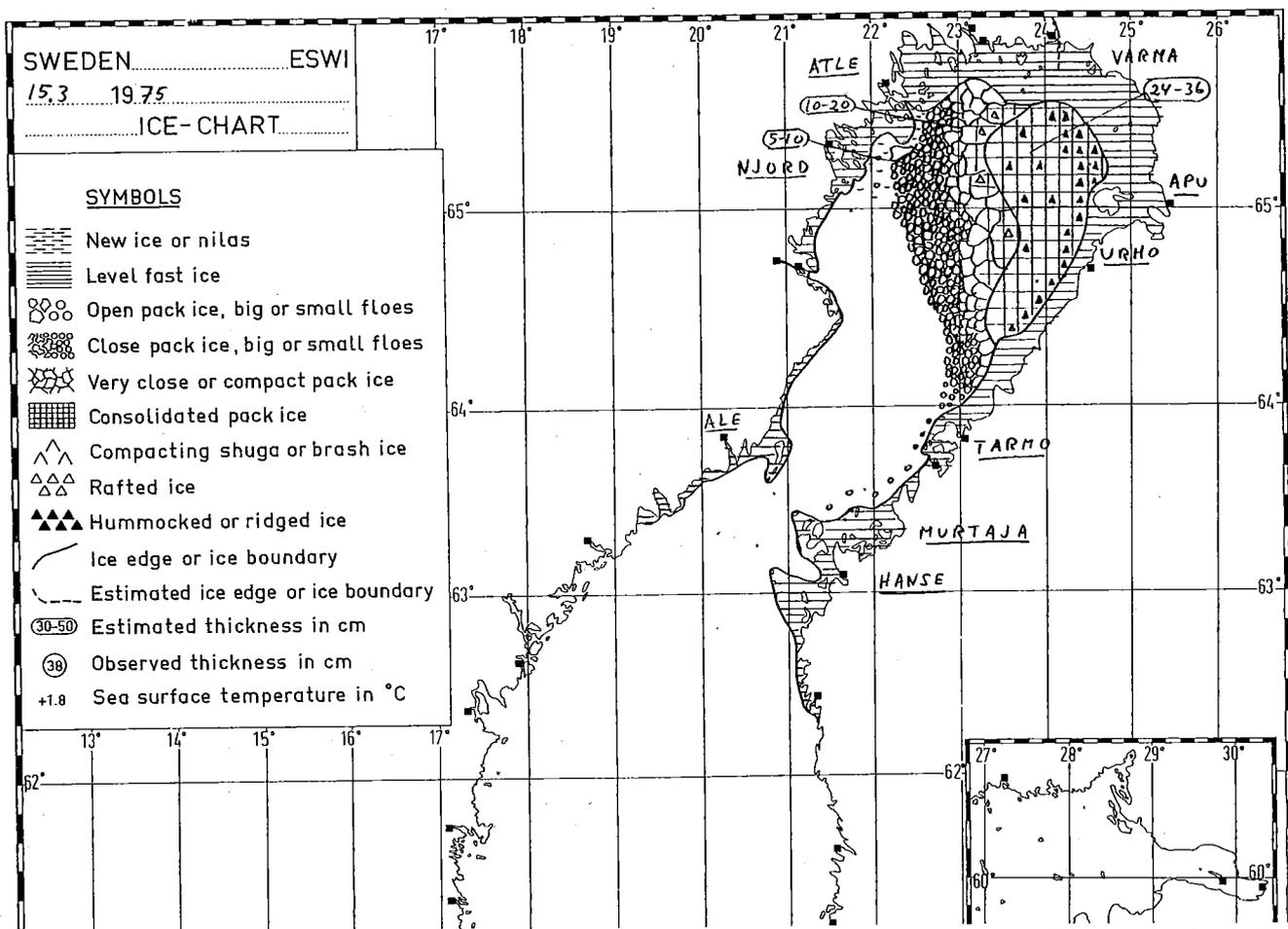


Figure 26. March 15.

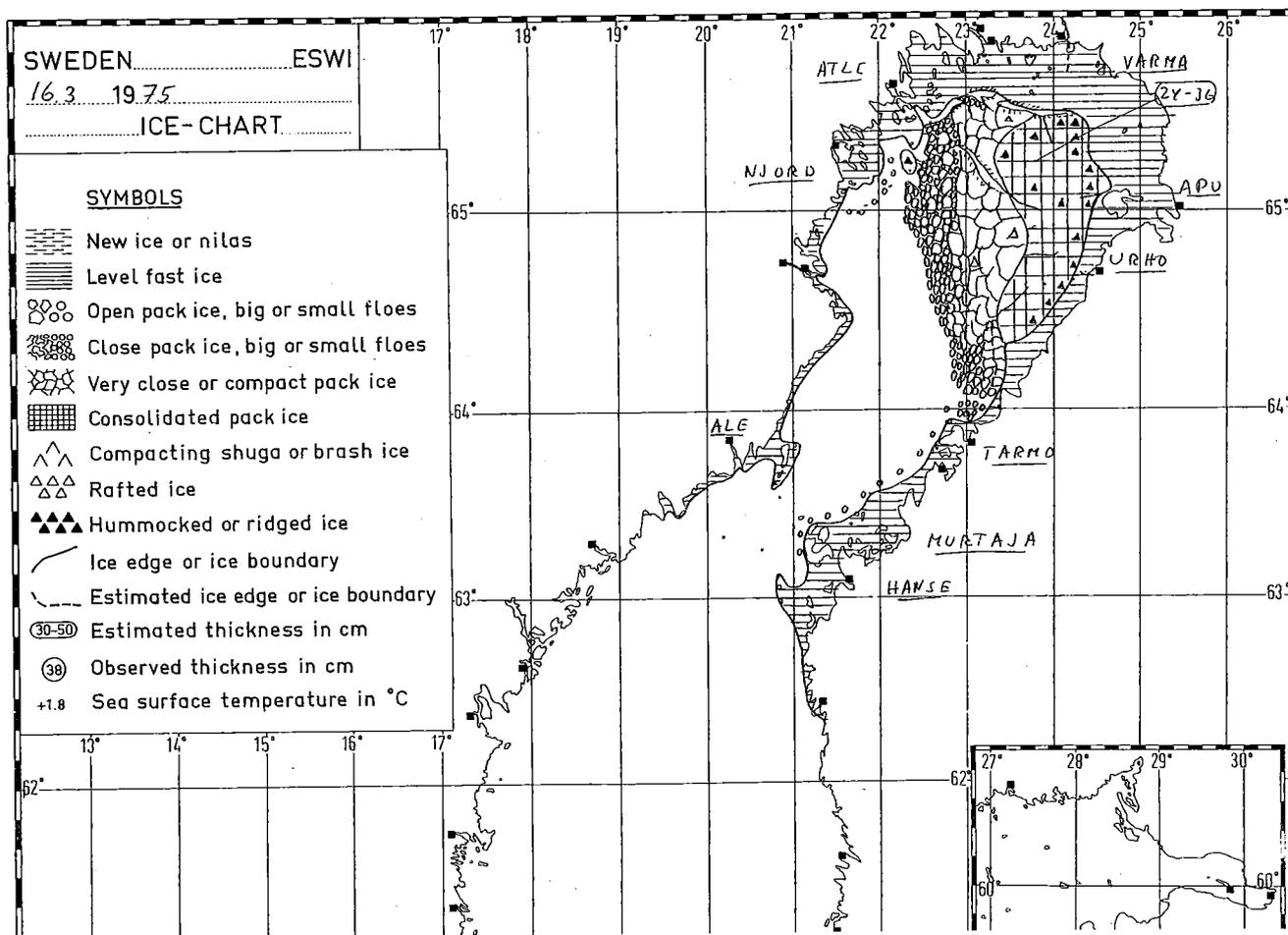


Figure 27. March 16.

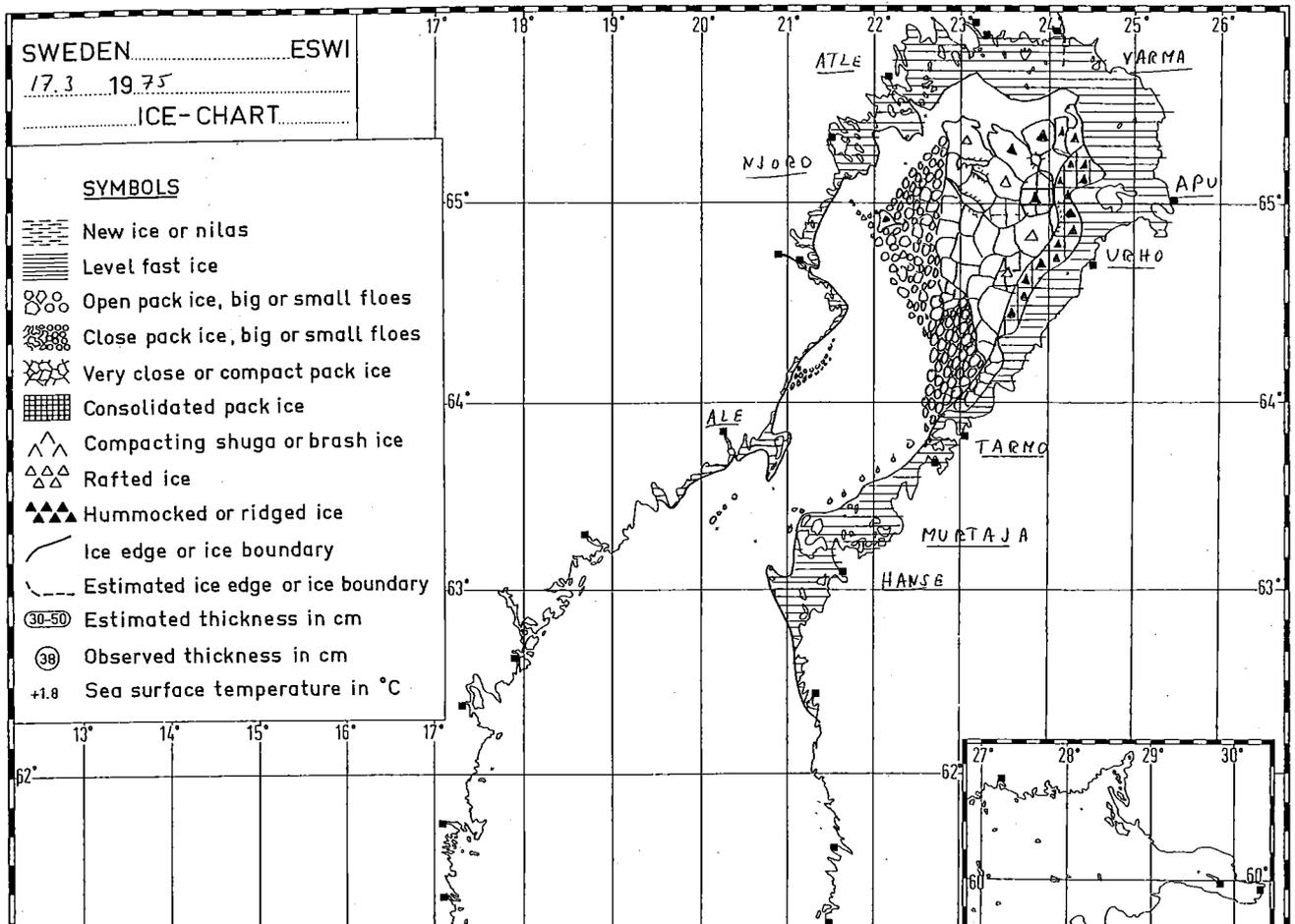


Figure 28. March 17.

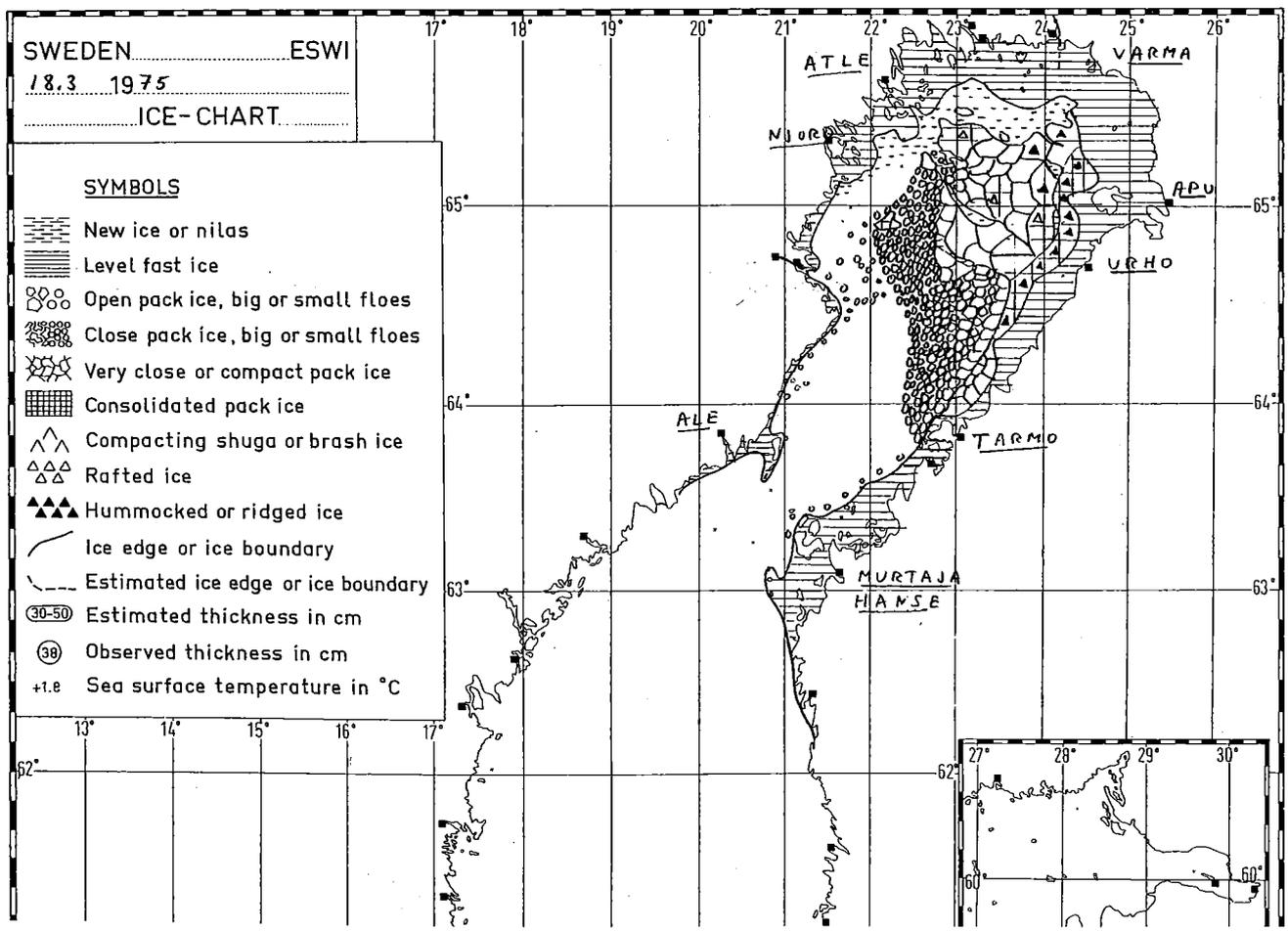


Figure 29. March 18.

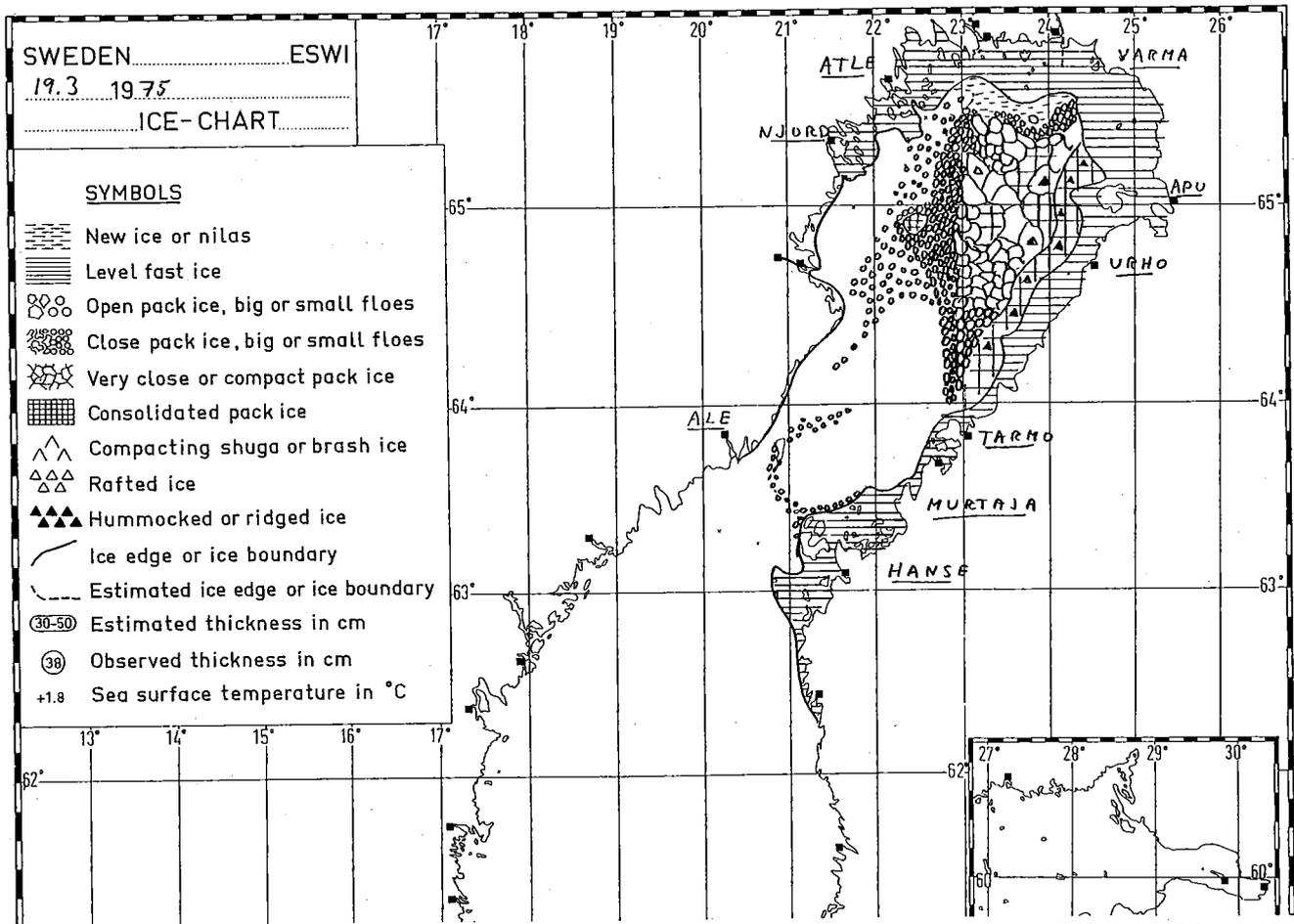


Figure 30. March 19.

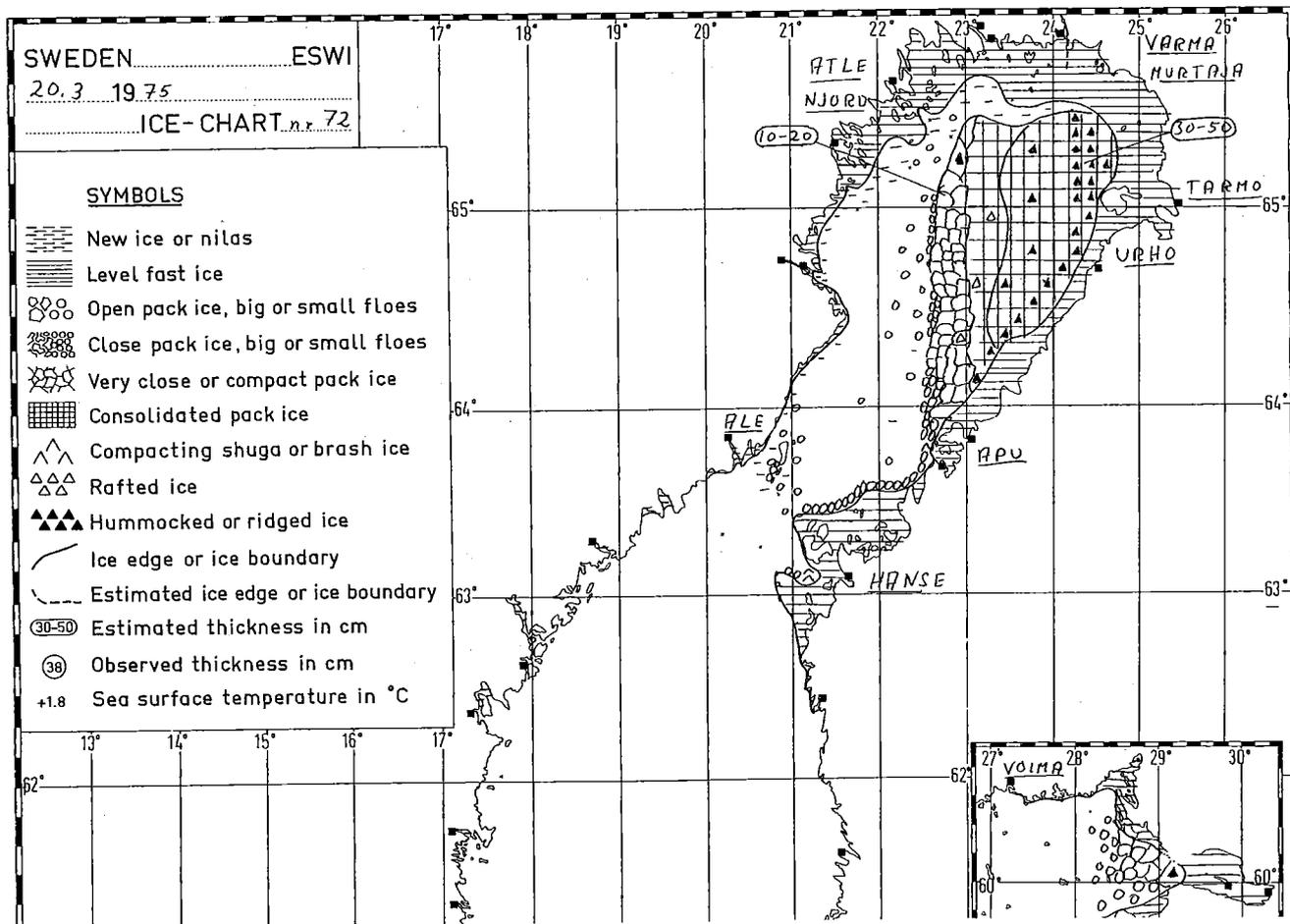


Figure 31. March 20.

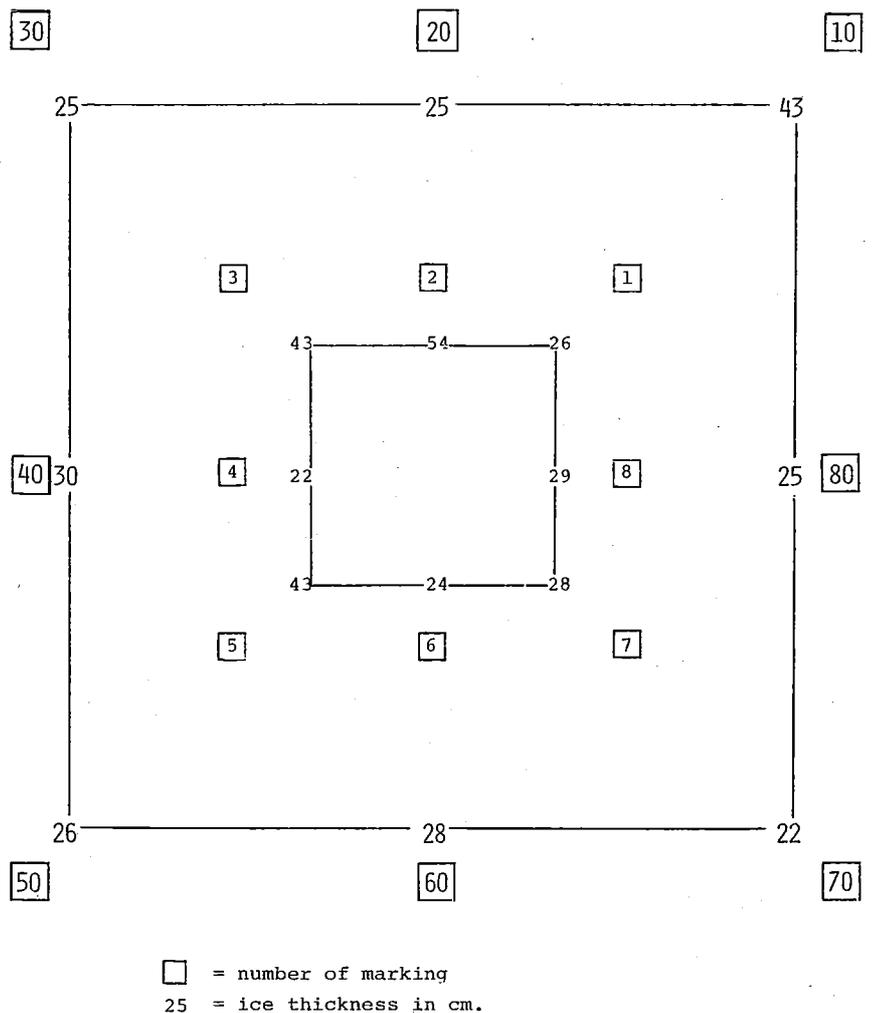
8 Small Scale Ice Observations

Visual ice observations were made from helicopter. The ice observations were plotted on sea charts and later on verified and supplemented with air photos information. Snow scooter trips were regularly made in the 5×5 km area to observe and measure interesting ice features visible on the air photos. Detailed visual observations and measurements were made on ground in the 1×1 km area and in specially selected areas where some air-borne sensors were tested.

8.1 The 15×15 km area

The markings in the 15×15 km area (figure 5) were placed on the ice on March 12. They were transported with the helicopter used during the experiment. The markings were placed on rather smooth ice so that they would be easily detectable. Ice thickness and snow depth measurements were made at those places. The snow depth was constant 2 cm on the level ice. The ice thicknesses are shown in figure 32.

Figure 32. Ice thickness and the markings in the 15×15 and 5×5 km areas.



An ice reconnaissance flight with the helicopter was made on March 13. The ice information was plotted on a sea chart. As no changes occurred between March 13 and 14 the data from the helicopter reconnaissance have been combined with the Wild photomap from March 14. The results are shown in figure 33 with overlay.

In order to present the data obtained in a way that will permit easy comparison with remote sensing data, the ice has been divided into different categories. They have been chosen in accordance with the ice parameters mentioned in chapter 3. The categories are given in table 2

Category	Type of ice
1	Open water
2	New ice (thickness less than 5 cm)
3	Level ice (thickness above 5 cm)
4	Rafted ice
5	Light to moderate ridged ice, areal coverage less than 50 %
6	Light to moderate ridged ice, areal coverage more than 50 %
7	Heavy ridged ice, areal coverage less than 50 %
8	Heavy ridged ice, areal coverage more than 50 %

The ice categories are exemplified with some photos in figures 34. In figure 34a an ice field with new ice and open water is seen (cat. 1, 2). Figure 34b shows level ice with raftings (cat. 3, 4) near the icebreaker TOR. Heavy and moderate ice ridges surrounded by level ice are present in figure 34c (cat. 7, 5, 3).

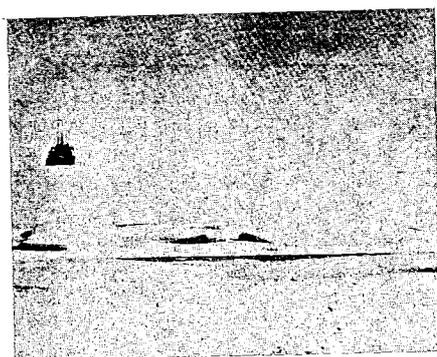
Figure 33. Mosaic from the Wild photos on March 14 over the 15 x 15 km area. On the overlay the ice categories and some typical ridges (-----) are presented.

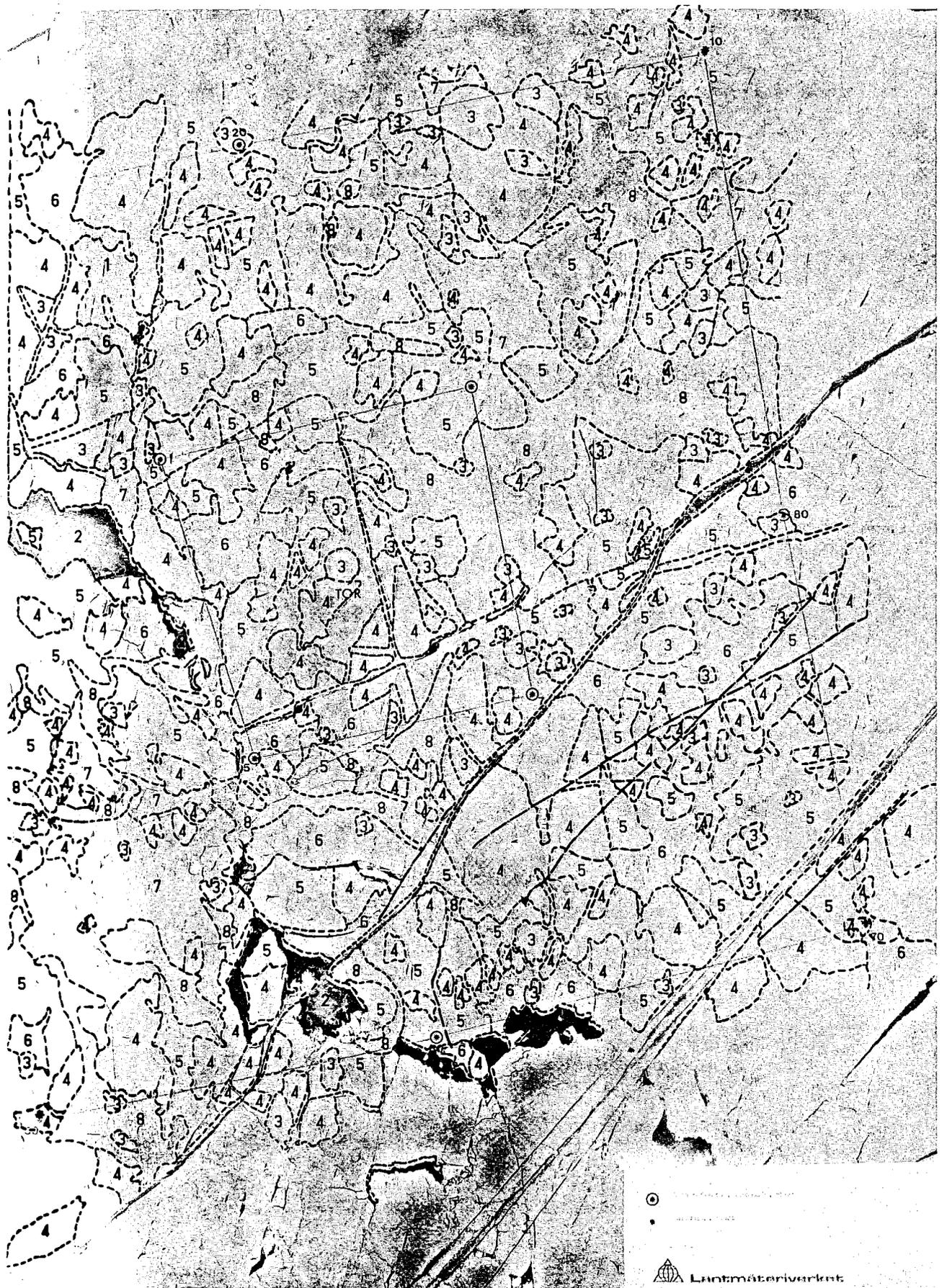
Table 2. Ice categories. The ice has been classified as heavy ridged if the ridges are more than 1,5 m above the ice surface.



Figure 34. Photos exemplifying the ice categories.

- a. open water and new ice
- b. level ice with raftings
- c. heavy and moderate ridges.





No further ice reconnaissance flight were made in the 15×15 km area but the Wild photos from March 17 and the high altitude photo from March 12 and 17 could be classified in the same way as March 14.

The ice situation in the 15×15 km area changed during the experiment. Between March 10 and 13 a fracture and two small 'lakes' were formed south of TOR. Until March 15 the fracture was deformed to an ice ridge but the 'lakes' were intact. From March 16 a considerable change occurred in connexion with a period with strong winds. Leads and fractures opened mainly outside the area. Within the area deformation occurred especially in the west and southwest parts. During March 19 and 20 several fractures opened in the whole area. The changes in the ice field is also seen when studying the area delineated by the radar reflectors (figure 35). The 15×15 km area increased 10 % from March 13 to 17 and decreased 10 % between 17 and 19. The shape of the area changed as well.

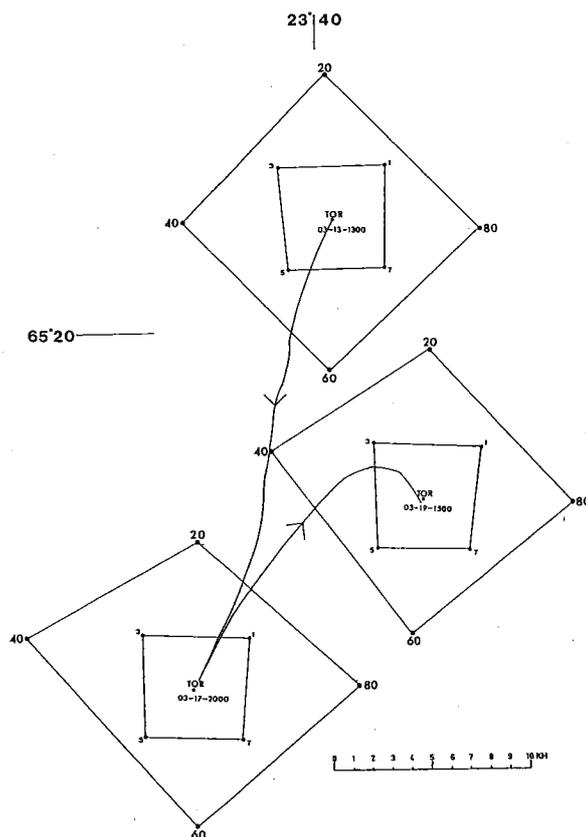


Figure 35. The deformation of the 5×5 km and the 15×15 km area during the ice drift. The arrowed line shows the drift of the TOR.

8.2 The 5×5 km area

The markings in the 5×5 km area (figure 5) were placed on the ice on March 11. The helicopter was used for the transportation. Also in this area the markings were placed on smooth ice. The ice thickness and snow depth were measured. The snow depth was 2 cm. The ice thickness values are shown on figure 32.

The ice in the area was mapped from the helicopter reconnaissance on March 13 mentioned under 8.1. The obtained data have been combined with the photomap from March 13 and classified in the same way as the Wild photomap from March 14. Also the photomap from the 18 th has been classified together with received ice information. The result from March 18 is shown in figure 36 with overlay.

No further air reconnaissance was carried out, but during a helicopter flight to some of the reflectors on March 19 it was observed that several new fractures had formed in the 5×5 km area. Except for this the changes in the area were very small during the experiment.

During the whole period snow scooter expeditions were made to selected areas within the 5×5 km area. The areas where chosen from air photos which were received from the Land Survey and the Air Force. Areas containing several interesting ice categories or ice parameters of special interest were examined in more detail and the ice photos were verified with ground truth. The selected areas are shown on overlay B in figure 36.

Figure 36. Mosaic from one of the Hasselblad cameras on March 18 over the 5×5 km area. Overlay A shows the ice categories and some significant ridges (—) and overlay B the selected areas.



No further ice reconnaissance flight were made in the 15×15 km area but the Wild photos from March 17 and the high altitude photo from March 12 and 17 could be classified in the same way as March 14.

The ice situation in the 15×15 km area changed during the experiment. Between March 10 and 13 a fracture and two small 'lakes' were formed south of TOR. Until March 15 the fracture was deformed to an ice ridge but the 'lakes' were intact. From March 16 a considerable change occurred in connexion with a period with strong winds. Leads and fractures opened mainly outside the area. Within the area deformation occurred especially in the west and southwest parts. During March 19 and 20 several fractures opened in the whole area. The changes in the ice field is also seen when studying the area delineated by the radar reflectors (figure 35). The 15×15 km area increased 10 % from March 13 to 17 and decreased 10 % between 17 and 19. The shape of the area changed as well.

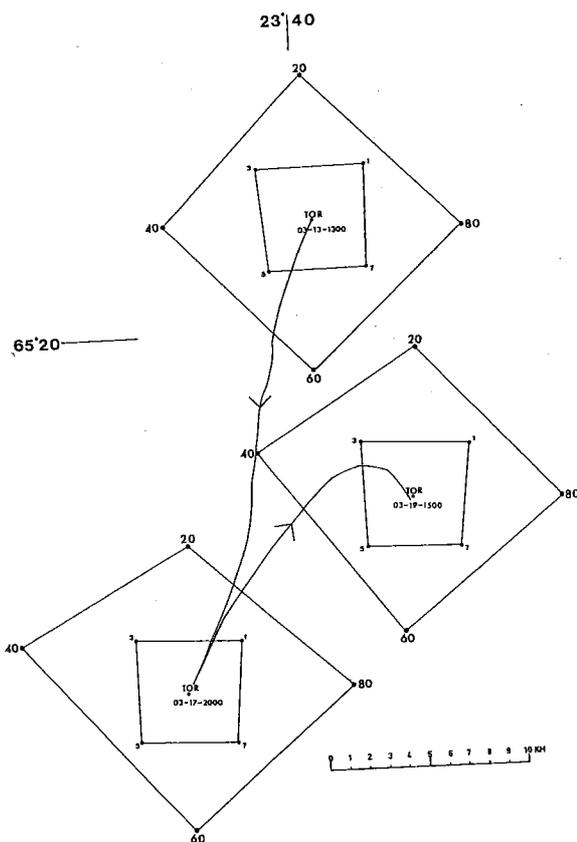


Figure 35. The deformation of the 5×5 km and the 15×15 km area during the ice drift. The arrowed line shows the drift of the TOR.

8.2 The 5×5 km area

The markings in the 5×5 km area (figure 5) were placed on the ice on March 11. The helicopter was used for the transportation. Also in this area the markings were placed on smooth ice. The ice thickness and snow depth were measured. The snow depth was 2 cm. The ice thickness values are shown on figure 32.

The ice in the area was mapped from the helicopter reconnaissance on March 13 mentioned under 8.1. The obtained data have been combined with the photomap from March 13 and classified in the same way as the Wild photomap from March 14. Also the photomap from the 18 th has been classified together with received ice information. The result from March 18 is shown in figure 36 with overlay.

No further air reconnaissance was carried out, but during a helicopter flight to some of the reflectors on March 19 it was observed that several new fractures had formed in the 5×5 km area. Except for this the changes in the area were very small during the experiment.

During the whole period snow scooter expeditions were made to selected areas within the 5×5 km area. The areas were chosen from air photos which were received from the Land Survey and the Air Force. Areas containing several interesting ice categories or ice parameters of special interest were examined in more detail and the ice photos were verified with ground truth. The selected areas are shown on overlay B in figure 36.

Figure 36. Mosaic from one of the Hasselblad cameras on March 18 over the 5×5 km area. Overlay A shows the ice categories and some significant ridges (—) and overlay B the selected areas.



SGA ICE -75
 Air photography covering 5 x 5 km area
 Date: 1975-03-18
 Flight altitudes 1500 m
 Camera: Hasselblad

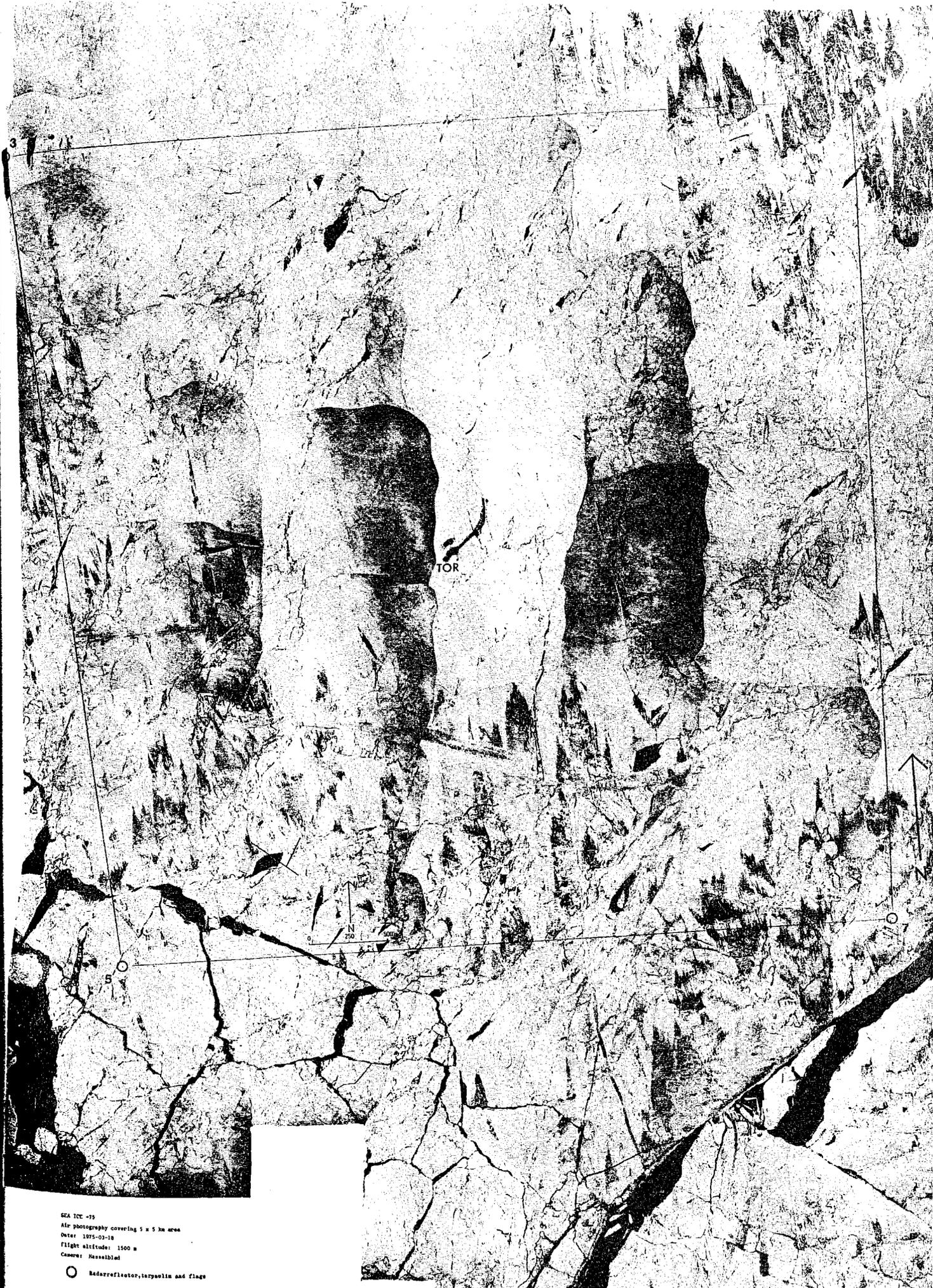
 Radarreflector, tarpaulin and flags

A. The 'lake' in SW and the IR-track

This area contained many different ice categories and was chosen as a special test area for the radar altimeter, the microwave radiometer and the IR-scanner. Flags were placed on the ice along two crossing tracks as shown in figure 37. In addition two radar reflectors were put on the ice at each end of the IR-track on March 18. Ice reconnaissance with hydrocopter and snow scooter was carried out both on March 15 and 18. The ice information from March 18 is presented in figure 37 with overlay. As can be seen from the figure all chosen ice categories are present, the lake with new ice, areas with level and rafted ice, areas with both heavy and light ridges and open water near the very heavy ridges in the northwest part of the IR-track. The IR-scanner did not participate in the project before March 19 and unfortunately many changes occurred in the ice field between March 18 and 19. Several fractures with open water formed in the middle part of the IR-track, the lead in the western part disappeared and an ice ridge formed along the old ice edge. Hummocking and ice pressure occurred and the radar reflector in the northwestern part of the IR-track was lost.

Figure 37. Hasselblad photos over the lake in SW and the IR-track from March 18. The two crossing lines were marked with flags. The overlay shows the ice categories the height of ridges ($\frac{\text{MAX}}{\text{MEAN}}$) ice thickness values (0) and flight track (—|—|—).

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SCA 100 -75
Air photography covering 5 x 5 km area
Date: 1975-03-18
Flight altitude: 1500 m
Camera: Hasselblad

○ Radarreflector, tarpaulin and flag

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A
18
1d

A. The 'lake' in SW and the IR-track

This area contained many different ice categories and was chosen as a special test area for the radar altimeter, the microwave radiometer and the IR-scanner. Flags were placed on the ice along two crossing tracks as shown in figure 37. In addition two radar reflectors were put on the ice at each end of the IR-track on March 18. Ice reconnaissance with hydrocopter and snow scooter was carried out both on March 15 and 18. The ice information from March 18 is presented in figure 37 with overlay. As can be seen from the figure all chosen ice categories are present, the lake with new ice, areas with level and rafted ice, areas with both heavy and light ridges and open water near the very heavy ridges in the northwest part of the IR-track. The IR-scanner did not participate in the project before March 19 and unfortunately many changes occurred in the ice field between March 18 and 19. Several fractures with open water formed in the middle part of the IR-track, the lead in the western part disappeared and an ice ridge formed along the old ice edge. Hummocking and ice pressure occurred and the radar reflector in the northwestern part of the IR-track was lost.

Figure 37. Hasselblad photos over the lake in SW and the IR-track from March 18. The two crossing lines were marked with flags. The overlay shows the ice categories the height of ridges ($\begin{matrix} \text{MAX} \\ \text{MEAN} \end{matrix}$) ice thickness values (0) and flight track (—|—|—).



B. The 'lake' in SE

Another area of special interest was another 'lake' situated southeast of TOR. Also in this area several of the ice classes were present with both new ice and open water. The multispectral air photos also showed variations which can be related to hardly detectable differences in the snow cover. Also parts of an old, frozen track from an icebreaker was noticed in the area. Ice data for the area from March 15 are presented in figure 38 and on the overlay.

Figure 38. Hasselblad photo over 'the lake in SE' from March 13. The overlay shows the ice categories, the height of ridges ($\frac{\text{MAX}}{\text{MEAN}}$) and ice thickness values (0) from March 15.



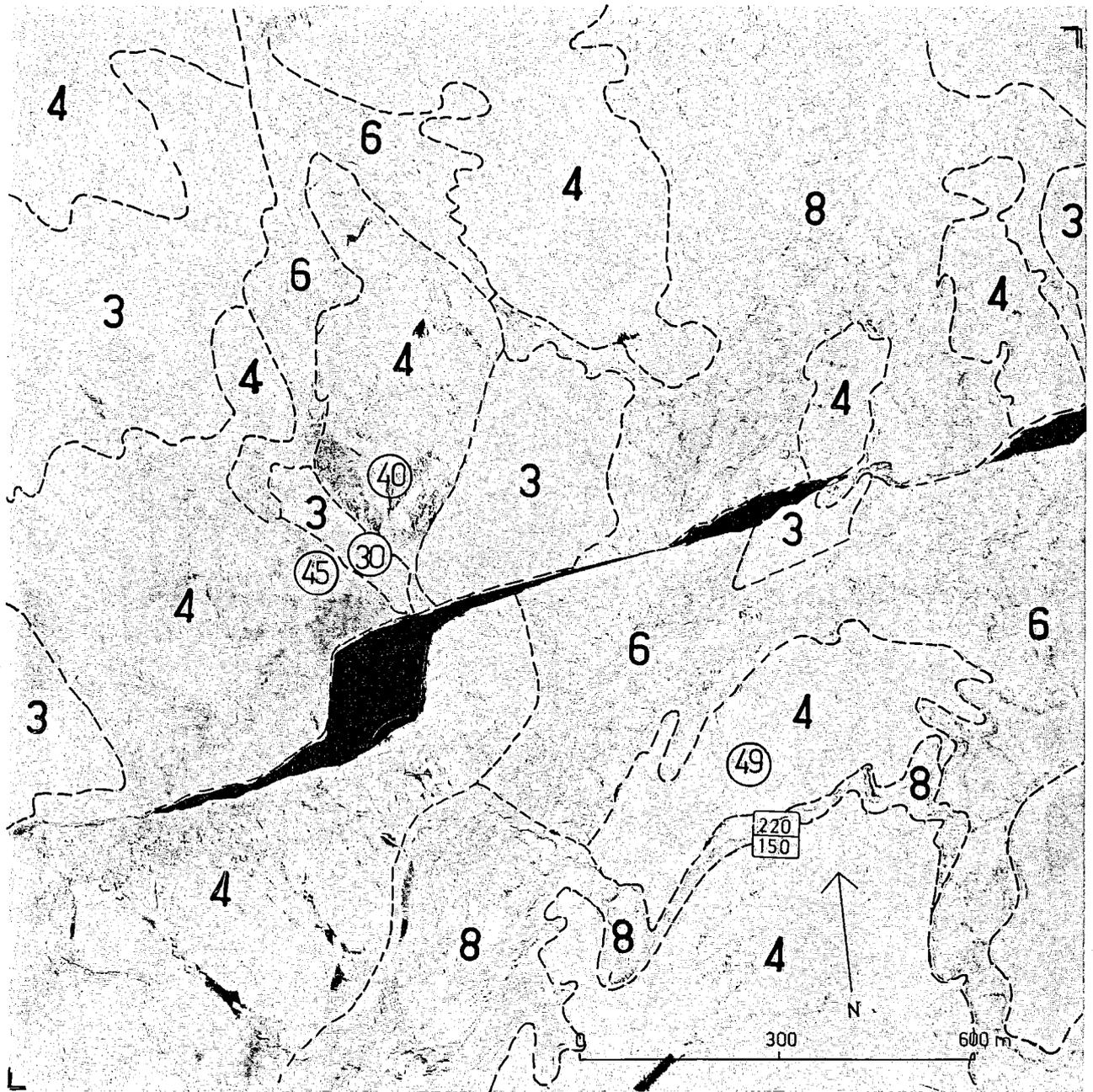
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B. The 'lake' in SE

Another area of special interest was another 'lake' situated southeast of TOR. Also in this area several of the ice classes were present with both new ice and open water. The multispectral air photos also showed variations which can be related to hardly detectable differences in the snow cover. Also parts of an old, frozen track from an icebreaker was noticed in the area. Ice data for the area from March 15 are presented in figure 38 and on the overlay.

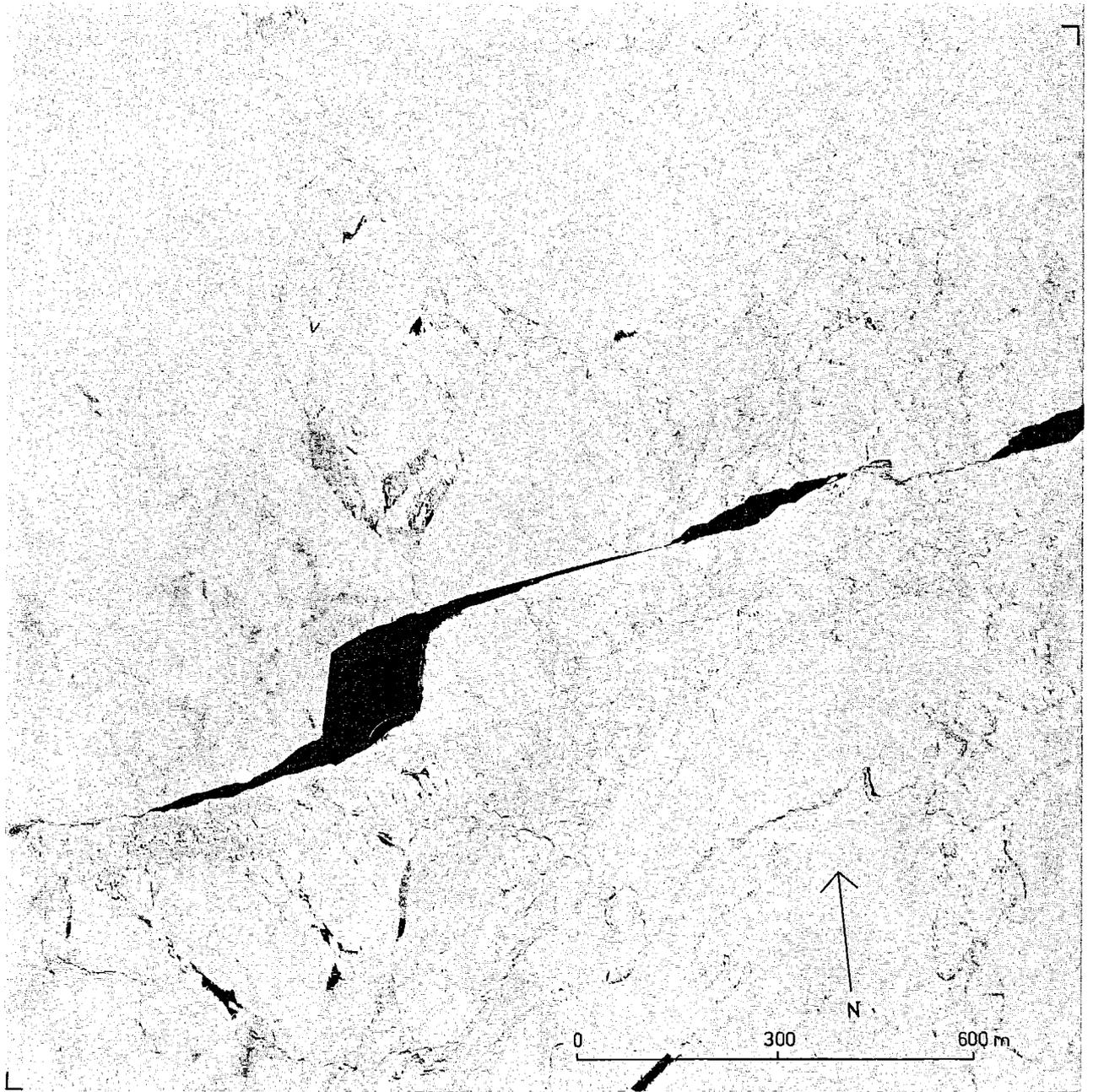
Figure 38. Hasselblad photo over 'the lake in SE' from March 13. The overlay shows the ice categories, the height of ridges ($\frac{\text{MAX}}{\text{MEAN}}$) and ice thickness values (0) from March 15.



C. The 'pyramids'

East of TOR there was a large area with a high coverage of heavy ridges. To the west of this area two pyramidal ridges which were more than 2.5 m above the ice surface were present. The 'pyramids' were chosen as a test area for the radar altimeter. Ice information on the area is seen on the Hasselblad photo and on the overlay in figure 39. The snow thickness was homogeneous and about 2 cm.

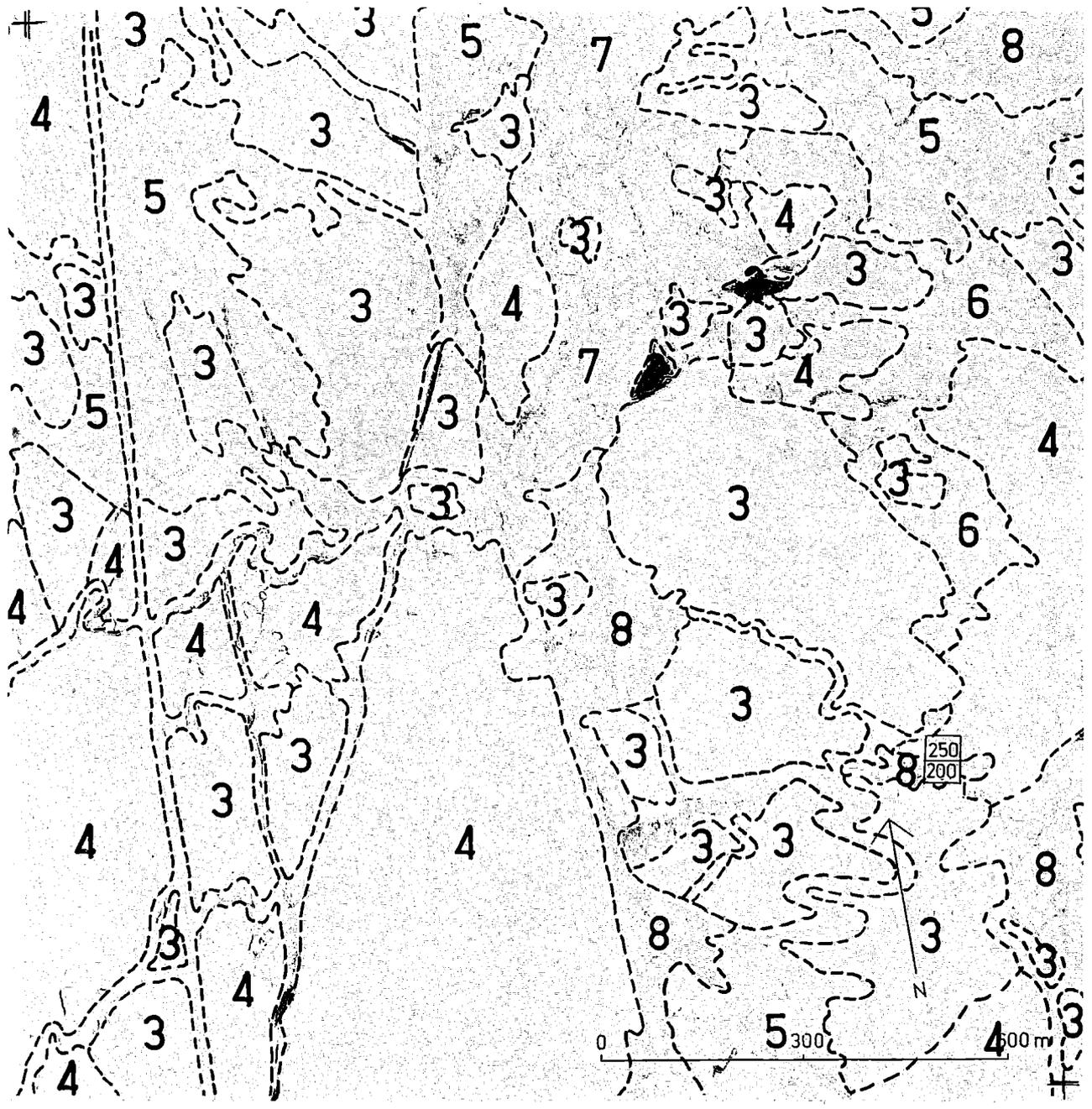
Figure 39. Hasselblad photo over the area around 'the pyramids' from March 13. On the overlay the ice categories, the height of the 'pyramids' (^{MAX} / _{MEAN}) are presented.



C. The 'pyramids'

East of TOR there was a large area with a high coverage of heavy ridges. To the west of this area two pyramidal ridges which were more than 2.5 m above the ice surface were present. The 'pyramids' were chosen as a test area for the radar altimeter. Ice information on the area is seen on the Hasselblad photo and on the overlay in figure 39. The snow thickness was homogeneous and about 2 cm.

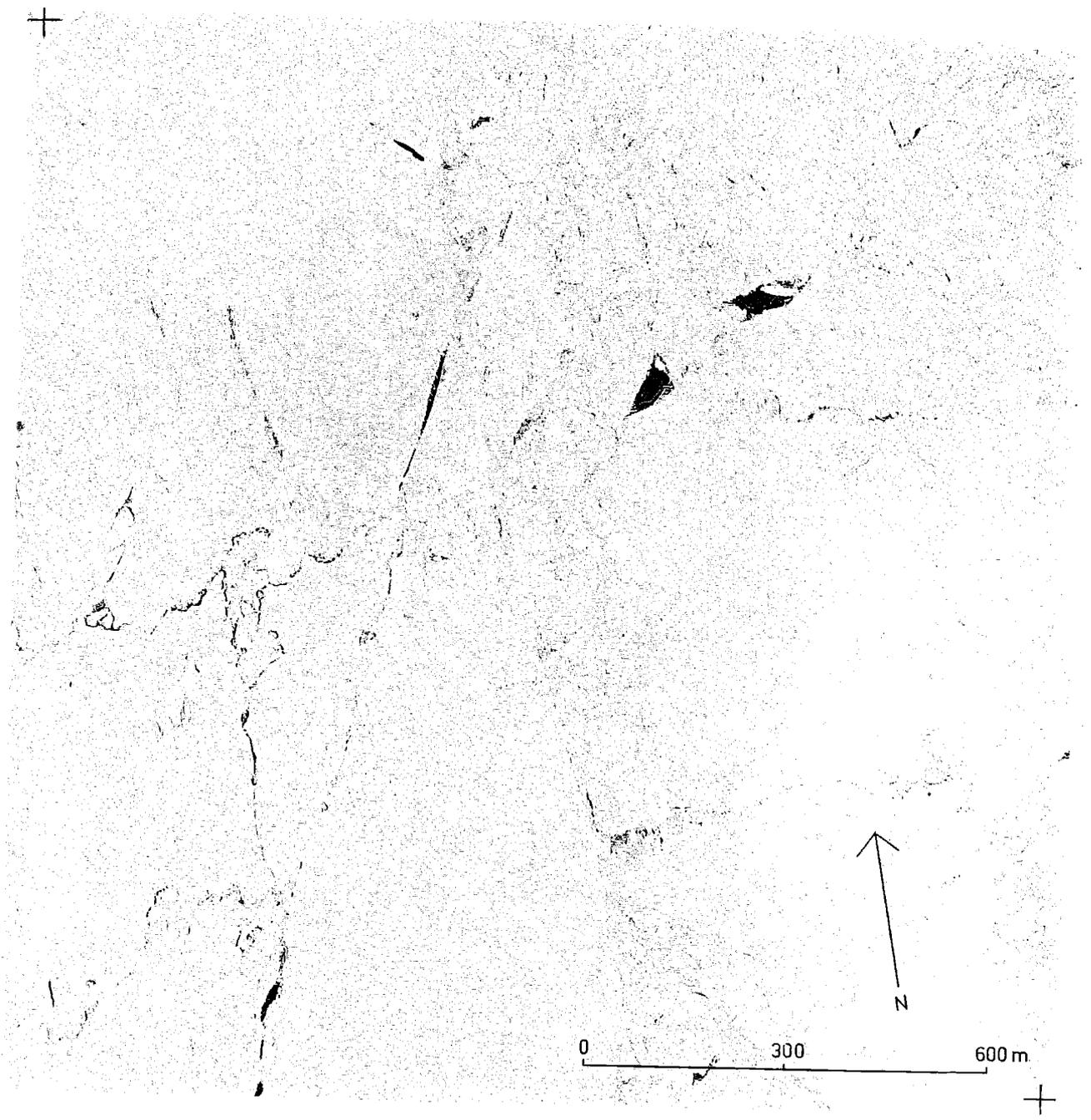
Figure 39. Hasselblad photo over the area around 'the pyramids' from March 13. On the overlay the ice categories, the height of the 'pyramids' ($\begin{matrix} \text{MAX} \\ \text{MEAN} \end{matrix}$) are presented.



8.3 The 1 × 1 km area

The flags and the tarpaulins in the 1 × 1 km area were placed on the ice during March 8 to 10. Thereafter a detailed ground truth work was carried out. Ice thickness and snow depth were measured, heights and widths of ice ridges measured, ice types determined etc. The information was plotted on a chart and is presented on overlay A together with the photomap of the 1 × 1 km area (figure 40). The photomap is from March 13 but no changes occurred in the area during the period except for a small (3—4 %) increase in the level ice thickness. The increase was verified from control measurements made in several places within the area. The ice has also been classified according to table 2 and the results are seen on overlay B in figure 40. The ice in the area was rather smooth but both raftings and ridges occurred. Especially in the northeastern part of the area heavy ridges up to almost 2 m were observed. The snow depth was 2 cm.

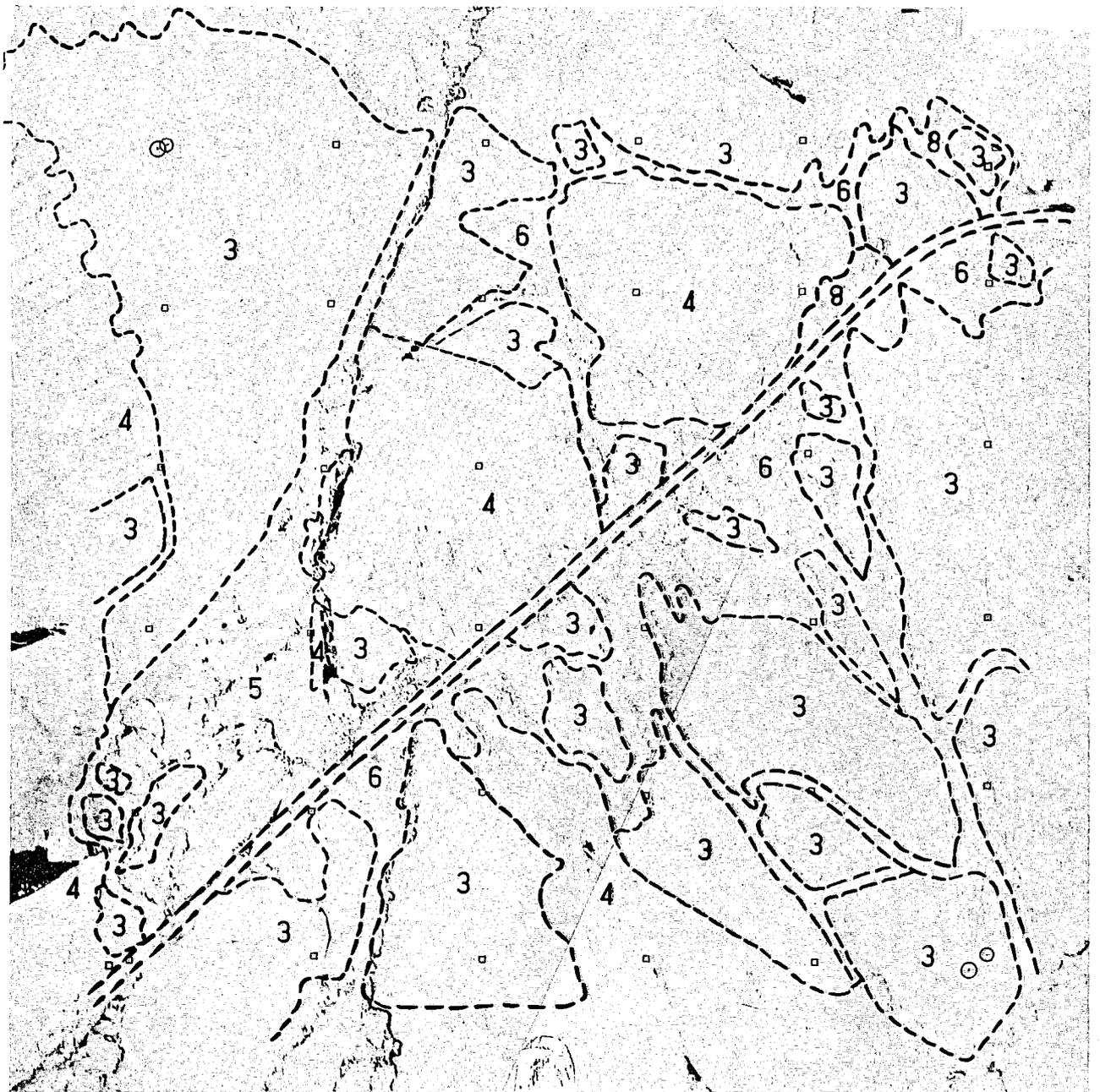
Figure 40. Mosaic from one of the Hasselblad cameras on March 13 covering the 1 × 1 km area. Results from a detailed ice mapping from the ground are shown on overlay A. The ice categories are shown on overlay B.



8.3 The 1 × 1 km area

The flags and the tarpaulins in the 1 × 1 km area were placed on the ice during March 8 to 10. Thereafter a detailed ground truth work was carried out. Ice thickness and snow depth were measured, heights and widths of ice ridges measured, ice types determined etc. The information was plotted on a chart and is presented on overlay A together with the photomap of the 1 × 1 km area (figure 40). The photomap is from March 13 but no changes occurred in the area during the period except for a small (3—4 %) increase in the level ice thickness. The increase was verified from control measurements made in several places within the area. The ice has also been classified according to table 2 and the results are seen on overlay B in figure 40. The ice in the area was rather smooth but both raftings and ridges occurred. Especially in the northeastern part of the area heavy ridges up to almost 2 m were observed. The snow depth was 2 cm.

Figure 40. Mosaic from one of the Hasselblad cameras on March 13 covering the 1 × 1 km area. Results from a detailed ice mapping from the ground are shown on overlay A. The ice categories are shown on overlay B.



Along the B-line (figure 5) detailed ice thickness measurements were made. Holes were drilled every ten meters and the ice thickness measured. The variations were considerable, from some centimeters to more than 1 m. The results are shown in figure 41. The drillings were made mainly for the tests with the microwave radiometer and radar altimeter.

On March 19 four pots with burning oil were placed in the corners of the area as identification points for the IR-scanner registrations.

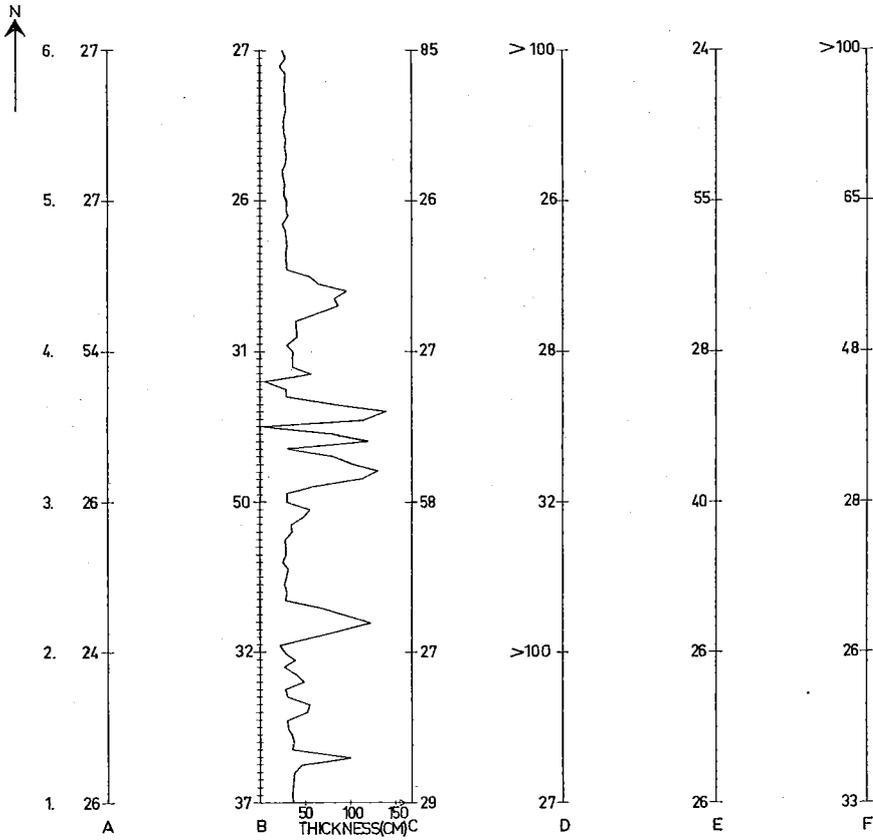
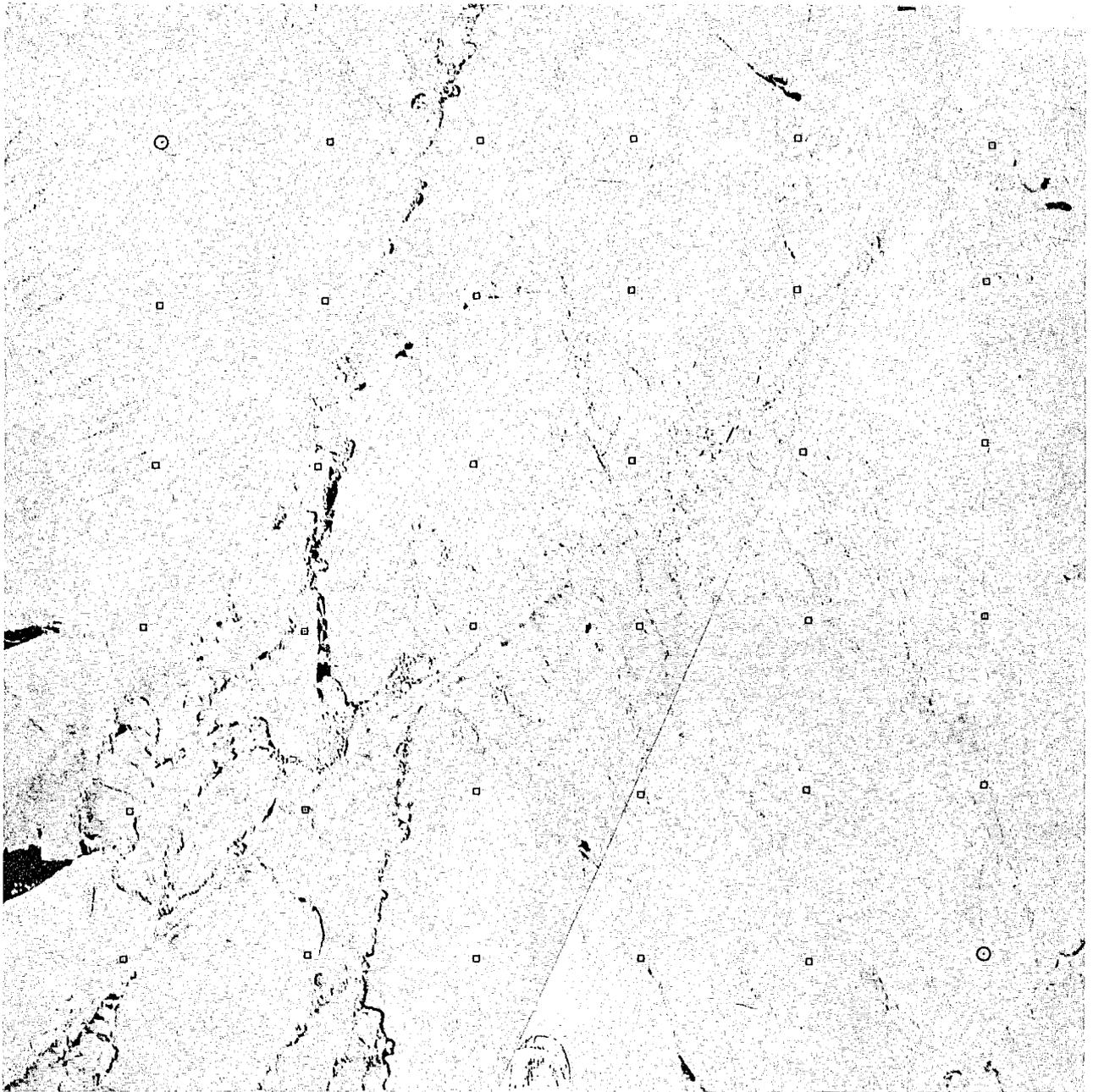


Figure 41. Ice thickness measurements at the flags and along the B-line in the 1 × 1 km area.



Along the B-line (figure 5) detailed ice thickness measurements were made. Holes were drilled every ten meters and the ice thickness measured. The variations were considerable, from some centimeters to more than 1 m. The results are shown in figure 41. The drillings were made mainly for the tests with the microwave radiometer and radar altimeter.

On March 19 four pots with burning oil were placed in the corners of the area as identification points for the IR-scanner registrations.

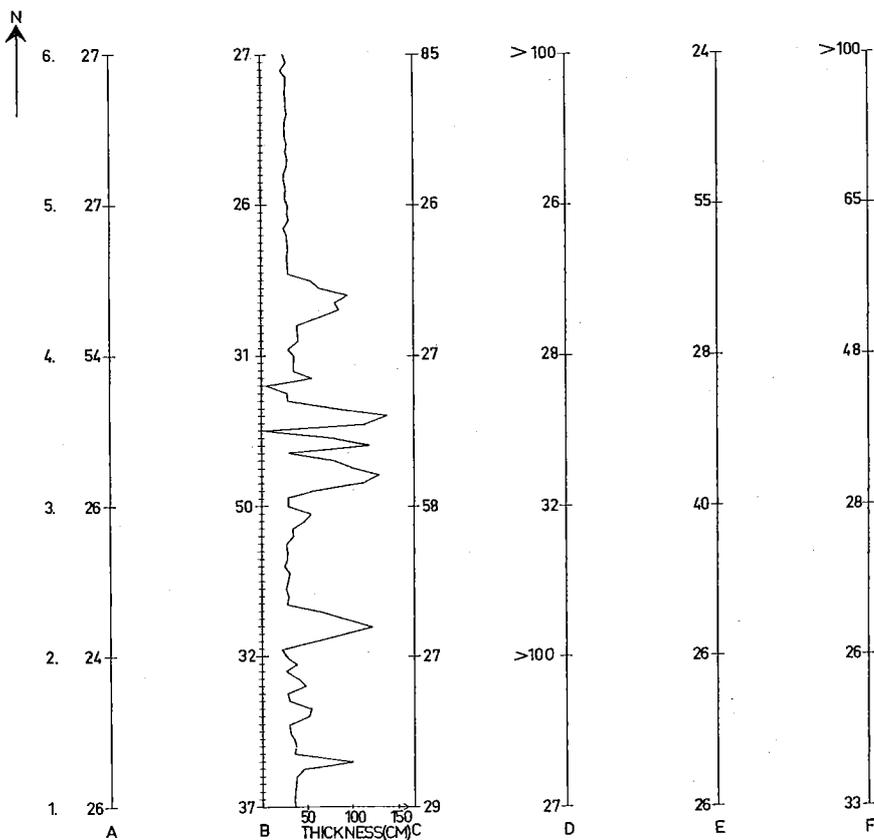


Figure 41. Ice thickness measurements at the flags and along the B-line in the 1 x 1 km area.

9 Environmental Data

9.1 Meteorological measurements and observations

From TOR routine weather messages were made and transmitted to shore. From those observations a table containing cloud amount, visibility and relative humidity have been compiled (attachment 2). The crew that normally makes the observations had during the experiment a lot of extra duties, and weather observations from some periods are therefore missing. The wind and temperature at TOR and at the coast station Bjuröklubb as well as the air pressure at the latter, are given in attachment 3.

9.2 Oceanographic measurements

The temperature and salinity at different depths in the water were measured with an electric thermometer and salinometer, type MC 5 from Electric Switzgear. The temperatures from the surface down to 40 m varied slightly just below 0°C. The salinity values were constant 3.4 ‰. (Attachment 4).

Currents under the ice were measured both continuously at one level and intermittently at different levels. Data and analysis concerning the ice dynamics are presented in more detail in a separate report (2).

9.3 Ice salinity and temperature

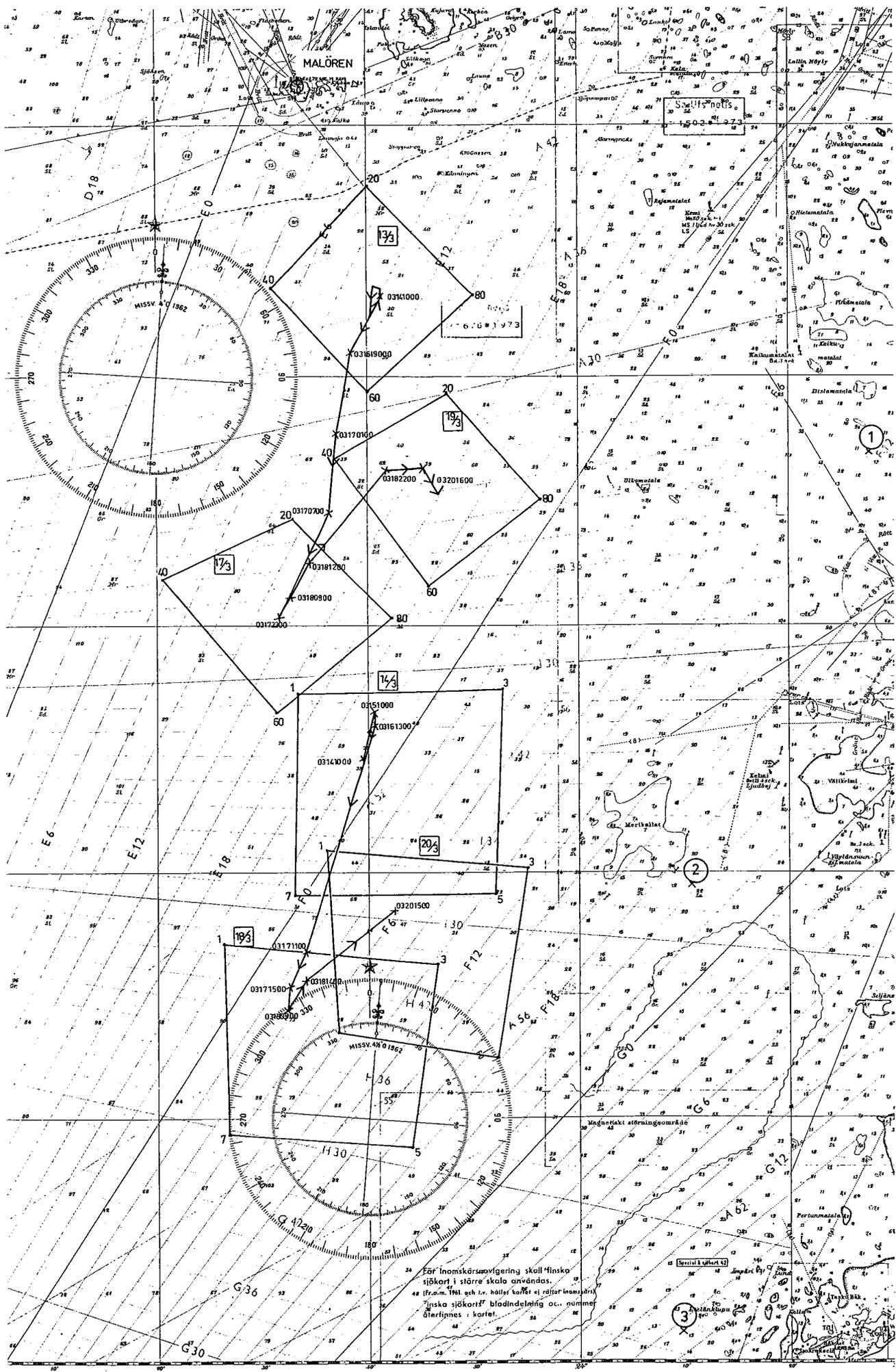
The salinity of the ice was measured in the following way. Two areas, with level ice thickness of 27 cm, were chosen.

In the area samples were taken. They were cleaned at top and bottom and 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 determined in laboratory with an accuracy of ±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 see that the ice salinity varies with depth in the ice.

The ice temperature was measured at five different points with Pt 100 transducers, coupled to an electric temperature meter. Measurements were made continuously between March 8 and March 19 with some drift stops. 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 available 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 different. The changes and lags seem, however, not to be systematic.

Table 3. Ice salinity in different layers from two areas in the northern part of the Bay of Bothnia.

LEVEL (counted from top)	AREA 1, S(‰)		AREA 2, (‰)	
	analyse 1	analyse 2	analyse 1	analyse 2
1 (2— 7 cm)	0.432	0.438	0.451	0.453
2 (8—13 cm)	0.295	0.289	0.196	0.195
3 (14—19 cm)	0.440	0.440	0.363	0.366
4 (20—25 cm)	0.252	0.250	0.273	0.273



För inomskärsmätning skall finska
 sjökort i större skala användas.
 (Fr.o.m. 1941) och tv. höjter kan ej rejjas inom åren
 finska sjökort i blanddelning oc. nummer
 återfinnes i kortet.

10 Data from the Finnish Area

As was mentioned above two ground truth areas were selected. One main area with TOR in the centre for which SMHI was responsible and another area south of TOR for which the FIMR was responsible. The location of the Finnish area is seen in figure 42 and the observations made during the experiment are given in appendix B. The drift and the changes in the ice are very much the same as those in the Swedish area, as is evident from figure 42.

Figure 42. *The drift of the outer Finnish and Swedish GT-areas during the period 13/3—20/3. The circled markings along the Finnish coast are current meter positions.*

11 Discussions and Conclusions

A large amount of data was collected during the experiment. Thanks to very favourable weather conditions with few clouds and good visibility most of the satellite registrations are usable and of good quality. Also the planned air photography was carried through successfully and with excellent results. The ice reconnaissance with helicopter and the ground truth on the ice were very much facilitated and the accuracy of the results was improved because of the weather.

The satellite pictures from NOAA SR, NOAA VHRR and LANDSAT MSS all give large scale information on the ice but with different resolution. The routine ice service is today using data from NOAA SR which has a resolution that gives insufficient information to the ice forecasters and naturally also to the winter navigation. The resolution of NOAA VHRR is better and during favourable weather conditions the VHRR gives a better information on the ice borders and the ice concentration than the routine ice charts do today. The resolution of the LANDSAT data is still better and probably sufficient for mapping most of the ice parameters of interest except for the ice thickness and detailed ice roughness. The VHRR and MSS data have potentials to give further and automatized ice information when using the taped registrations directly. Further studies should be carried out in order to investigate the advantages using the digital satellite data.

Air photography was possible during most of the days and consequently the selected ground truth areas are very well mapped. The air photos were vital for the quality and coverage of the ground truth information. One experience from the work is that it is extremely difficult to collect a detailed ice information on an area as big as 15×15 km by visual observation technique and even on an area as small as 5×5 km. It is also very difficult to try to optically integrate the information to a desired scale during an ice reconnaissance flight. This experience gives a further reason for objective mapping techniques.

The ground truth work on the ice was very much facilitated due to the excellent service provided by the Land Survey as well as by the Air Force. Air photos of the ice were sent by air from the laboratories and were received onboard the icebreaker the day after the photography. The photos could thus be used as maps (during the days of no ice changes) and specific ice characteristics observed and measured.

When mapping the ice in the Baltic information are required on two scales, one small scale (resolution tens of meters) covering areas of the order 5000 km^2 for short term navigation purposes and one larger scale (resolution hundreds of meters) for large scale mapping and forecasting purposes. However some parameters required on the larger scale have to be measured on the smaller scale. Probably all measurements should be performed with better resolution with a subsequent data integration and reduction for the large scale mapping and forecasting.

The markings on the ice were sufficient for the ice dynamic studies but insufficient for the air photography. The large tarpaulins on the ice were too small to be visually located by the aircraft navigators, although they could later be identified on the photos. Even the icebreaker was sometimes difficult to locate from the air. The difficulties could be divided in

- finding the right area on the ice
- flying along the right track once the area was discovered.

Orange coloured safety smoke signals gave the most clearly detectable markings for the navigators and should be placed in both end points of a photo track. The difficulties should be kept in mind when planning a future experiment.

If a detailed ground truth work is to be carried out it is necessary for the investigators to be based in or close to the experimental area. Helicopter resources are necessary. The most favourable base is certainly an

icebreaker where radio facilities, helicopter, hydrocopter, snow scooter etc. could be available. Grönvall (appendix B) has mentioned the difficulties during the Finnish ground truth work where such a base was not available. A further advantage during this experiment was the availability of the many volunteers from the crew of the icebreaker to assist in the work.

The ground truth programme was mainly planned on the basis of parameters required for navigational and ice forecasting purposes. The evaluations of various sensor registrations may well require different resolution or information on other ground truth parameters. Very few specifications on the ground truth have however been presented by the different sensor groups neither before nor after the experiment. It is consequently difficult to decide whether the ground truth data are sufficient for the users or if some of the data are unnecessary in a future experiment.

In the report different analyses of the ice situation have been presented. Further specialized analyses with emphasis on different ice characteristics could be made, meeting the requirements of various sensor groups. The comparison of the sensor registrations and the ground truth should be made in close cooperation between sensor and ground truth groups. With a specification of the required ground truth information and a better planned data analysis, already before the experiment, it would be possible to optimize the ground truth work and analysis in a future project.

References

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5. Mc Clain, E.P., 1973: Earth Satellite measurements as applied to sea ice problems. COSPAR, Approaches to earth survey problems through use of space techniques. Proc. Constance 23—25 May 1973. Academic-Verlag, Berlin 1974.
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Attachment 1

Summary of ground truth data.

Method	Date	Time	Scale	Altitude	Cloud %	Covered area
<u>Satellites</u>						
SR (NOAA 4) (Vis+IR)	10	0921		1473 km	10-20	Scandinavia
"	11	0822		"	70	"
"	12	0917		"	10-20	"
"	13	0817		"	20	"
"	"	1012		"	70	"
"	14	0918		"	10	"
"	15	0811		"	60	"
"	16	0907		"	50-60	"
"	17	0807		"	0	"
"	"	1001		"	0	"
"	18	0902		"	10-20	"
"	19	0802		"	0	"
"	"	0957		"	0	"
"	20	0957		"	80	"
"	"	1050		"	50-60	"
VHRR (NOAA 4)	Cf SR NOAA 4)					
MSS (Landsat 2)	14/3			900 km		Northern part of the Bay of Bothnia. Middle and Finnish side.
	15/3			"		Swedish and Finnish side.
	16/3			"		Middle and Swedish side.
<u>Aeroplanes</u>						
High altitude camera	10/3	1330	1:200 000	11.600 m	0	Luleå Malären TOR KF 0310 Rödkallen Luleå Covers Finnish and Swedish 15 x 15 km areas
High altitude camera	10/3	1330	1:52.000	11.600 m	0	Luleå Malären TOR Covers great parts of the Swedish 5x5 km area
"	"	1330	1:5.000	"	0	Track over TOR direction 160° Width 1.5 km, Length 1.5 km, Covers half of the Swedish 1x1 km area
"	12/3	1100	1:160.000	9.000 m	0	Track from Malären direction 200° Width 1.5 km, Length 1.5 km, Covers half of the Swedish 15x15 km area
"	"	1100	1:15.000	"	0	Three tracks over unidenti- fied areas
"	17/3	0930	1:200.000	11.600 m	0	Luleå Malären south- wards TOR (in a corner), Luleå southwards Parts difficult to identify. Covers half of the Swedish 15x15 km area
Wild camera	14/3	14.30-15.10	1:30.000	4.600 m	0	Swedish 5x5 km area
"	17/3	14.20-15.40	1:30.000	4.600 m	0	Swedish 5x5 km area
MS-camera	13/3	11.40-12.30	1:15.000 1:30.000	1.500 m	0	Swedish 5x5 km area
"	18/3	11.20-12.10	1:15.000 1:30.000	1.500 m		Swedish 5x5 km area

<u>Method</u>	<u>Date</u>	<u>Time</u>	<u>Scale</u>	<u>Altitude</u>	<u>Cloud %</u>	<u>Covered area</u>
<u>Measurements and observations.</u>						
Meteorological parameters						
Wind	10-20/3	Every 15 min				Around TOR
Temperature	"	" "	and continuously			"
Air pressure	"	Every 15 min				"
Humidity	"	Every 3 hours				"
Visibility	"	" "				"
Clouds	"	" "				"
Weather	"	" "				"
Oceanographic parameters						
Current	10-20/3	Continuously + occasionally				Around TOR
Watertemp.	"	Occasionally				"
Salinity	"	"				"
Ice parameters (Swedish area)						
Concentration	10-19/3	Regularly				Northern Bay of Bothnia
Thickness	"	"				1x1, 5x5 and 15x15 km areas
Pressure ridges (height-width)	"	"				"
Roughness	"	"				"
Snow cover	"	"				"
Ice-open water	"					Northern Bay of Bothnia
Floes size	"					1x1, 5x5 and 15x15 km areas
Ice drift	10-20/3	Every 15 min				Position of TOR
Ice deformation	"	" "				5x5 and 15x15 km areas
Ice temperature	10-19/3	Continuously				Around TOR
Ice salinity	19/3					"

Attachment 2

Selected weather parameters at TOR during SEA ICE-75.

Month	Day	Time (GMT)	Cloud Amount eighths	Visibility (in km)	Relative Humidity U %
03	10	00	9	200 - 500 m	100
		03	9	200 - 500 "	100
		06	9	50 - 200 "	70
		09	0	20 - 50 km	65
		12	0	20 - 50 "	80
		15	0	20 - 50 "	75
		18	2	20 - 50 "	100
		21	1	750 "	85
		11	00	6	20 - 50 "
	03		9	200 - 500 m	100
	06		9	50 - 200 "	100
	18		2	50 km	80
	21		2	50 "	95
	12	00	0	50 "	60
		03	0	50 "	95
		06	2	50 "	85
		09	1	50 "	85
	13	00	0	50 "	80
		03	0	50 "	95
		06	3	50 "	85
		15	4	50 "	70
		18	2	50 "	95
	14	00	0	50 "	85
		03	0	50 "	85
		06	1	50 "	85
		18	7	50 "	90
		21	7	20 - 50 "	85
	15	00	8	20 - 50 "	95
		03	8	20 - 50 "	95
		06	8	20 - 50 "	95
		09	0	20 - 50 "	70
		15	2	20 - 50 "	95
	16	00	8	750 "	65
		06	3	750 "	75
		18	7	20 - 50 "	65
		21	1	50 "	75
	17	00	0	50 "	65
		03	0	50 "	75
	18	12	7	20 - 50 "	80
		15	4	20 - 50 "	80
		18	3	20 - 50 "	80
		21	3	20 - 50 "	80
19	00	8	20 - 50 "		
	06	1	20 - 50 "		
	21	2	20 - 50 "		

Attachment 3

WIND VELOCITY, AIRTEMPERATURE AND AIRPRESSURE BETWEEN 75-03-10 - 75-03-20.

Month	Day	Time (GMT)	Icebreaker TOR	Rödkaullen	Bjuröklubb	Bjuröklubb
			Dir(360)/Speed(m/s) temp	Dir(360)/Speed(m/s) temp	Dir(360)/Speed(m/s)temp	Pressure(mb)
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
	11	00	070/00 -3	-	210/06 -3	1010.4
		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
	12	00	280/10 -3	-	300/08 -3	1023.4
		03	250/08 -4	320/08 -1	300/08 -4	1023.0
		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

Month	Day	Time (GMT)	Icebreaker TOR	Rödkaullen	Bjuröklubb	Bjuröklubb
			Dir(360)/Speed(m/s) temp	Dir(360)/Speed(m/s)temp	Dir(360)/Speed(m/s)temp	Pressure(mb)
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, AIRTEMPERATURE AND AIRPRESSURE BETWEEN 1975-03-10 - 1975-03-20

Month	Day	Time (GMT)	Icebreaker TOR	Föskallen	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	350/12 0	995.6	
		15	353/15 -2	020/12 -1	020/16 0	995.6	
		18	340/16 -3	360/11 -3	350/17 -1	1002.2	
		21	345/18 -5	-	350/18 -3	1005.3	
		17	00	342/17 -6	-	350/18 -4	1003.3
			03	341/17 -6	340/07 -8	350/18 -4	1010.5
	06		350/16 -6	340/07 -8	350/16 -4	1013.3	
	09		350/13 -5	340/05 -6	360/13 -4	1015.1	
	12		353/10 -3	340/05 -4	340/11 -2	1013.3	
	15		340/07 -3	020/12 -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

Month	Day	Time (GMT)	Icebreaker TOR	Föskallen	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	210/08 -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	1025.6
			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 4

HYDROGRAPHIC OBSERVATIONS

DATE: 75-03-04 TIME: 1000

DEPTH (m)	TEMPERATURE (°C)	SALINITY (S ⁰ /∞)
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 ⁰ /∞)
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 ⁰ /∞)
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 ⁰ /∞)
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 ⁰ /∞)
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

NATIONAL LAND SURVEY OF SWEDEN

Anders Bergman

The Land Survey of Sweden carried out photography within the "Sea Ice-75" programme on the 13, 14, 17 and 18 March, 1975. A Wild 23×23 cm format camera loaded with negative colour film was used on two of the days and four Hasselblad cameras loaded with black and white panchromatic film together with a UV filter, with black and white infra film, with negative colour film and with colour infrafilm which was developed in negative form respectively, on the other two days. Programme details have been described in an earlier report.

For the latter purpose a limited number of photographs have been processed and evaluated as part of SMHI's contribution to the programme.

The Land Survey of Sweden's principal task following the carrying out of the photography has been the production of material for projects carried out by other participating institutions. Photographic products have thus partly been prepared from our own photography and partly using photographs from Landsat, NOAA, SLAR and Swedish Air Force negative material.

The making of contact copies from our own photography as well as the covering of the production costs for the preparation of photomaps over the different test surfaces have been comprised the Survey of Sweden's main contribution to the project. Otherwise work has been carried out on a normal repayment service bases for space research purposes.

All negative material from our own photography as well as that developed by the Land Survey of Sweden from Landsat and NOAA photography is stored in our archives. Material can be supplied on order from us.

The range of the material prepared is shown in the table below

Photomaps over	1 × 1 km area	1975-03-13
"	" 5 × 5 km "	03-13
"	" 5 × 5 km "	03-18
"	" 15 × 15 km "	03-14
"	" 15 × 15 km "	03-17
B/W enlargement from Hasselblad negative colour film		03-13
B/W enlargement from Hasselblad negative colour film		03-18
Colour enlargement from Wild negative colour film		03-14
Colour enlargement from Wild negative colour film		03-17
Colour coded Landsat-picture		03-15
B/W Landsat negative + enlargement		03-14
B/W Landsat negative + enlargement		03-15
B/W Landsat negative + enlargement		03-16
B/W enlargement from Air Forces negative		03-10
B/W enlargement from Air Forces negative		03-12
B/W enlargement from Air Forces negative		03-17
Enlargment from NOAA-VHRR from eleven days		
SLAR negative & enlargement		
Colour picture of icebreaker "TOR"		

Sea-ice is an unusual airphotography object for Land Surveys flying team. The airphotographer, Bertil Sandström has made the following comments:

From a flight-operation point of view the participation in "SEA ICE -75" resulted in many positive impressions. The efficiency of the project coordinators, who were always able to give necessary information without any delay either by telephone via Härnösand Radio or, during the flights, by radio from icebreaker TOR, is particularly worth to mention.

Considerable navigation problems arose in connection with the aerial photography. The signals put out on the ice were extremely difficult to identify from the air and consequently the demarcations of the two areas, 5×5 and 15×15 km, utmost difficult to detect. Different ways were tested to lead the photo aircraft to the right area and along the photo track. Smoke signals from burning oil were placed on the ice and also orange smoke distress signals. Even the helicopter which was equipped with a Decca Navigator system was used to lead the photo aircraft to the start point of the photo tracks. The orange smoke distress signals used to locate the start point on each photo strip were of great help. Similar signals at the end of each strip should be used in a future experiment to attain the required navigational accuracy.

No technical problems arose with the aircraft or the camera equipments during the experiment.

Appendix B

Institute of Marine Research

Hannu Grönvall

(Remote sensing of sea ice in the Gulf of Bothnia March 1975)

When investigating within the bounds of the Finnish-Swedish cooperation the applicability of various remote sensing methods for the observation of the ice situation, the field work to be done in praxis on the ice was concentrated to two areas (programme), one of which areas the Institute of Marine Research was put in charge of. The area, of which SMHI was in charge, was the foremost one when making observations, because the icebreaker TOR was stationarily situated in the area, and it was located towards south-southeast of Malören, the area of the Institute of Marine Research being on the western side of Merikallat.

In addition to the ice situation the aerial route of aeroplanes and helicopters equipped with various devices for remote sensing had an influence upon the choice of the location of the areas.

In regard to the Institute the original programme had to be to some extent forsaken, in the first place by restricting the work planned, as there was no stationary base nearby, and all the operations had to be carried out by helicopter from remote bases.

In this report all the observations made through the initiative of the Institute of Marine Research will be presented.

Flow recording

The Institute of Marine Research installed in three places on the fast-ice area current meter of the Alekseyev type. An additional meter was situated in the area, of which SMHI was in charge, close to the icebreaker TOR.

The current meters were suspended from the ice to a depth of approximately 5 meters, whereby the influence of the roughness of the lower surface of the ice was at least for the most part eliminated.

All the gauges recorded at 10 minutes intervals. Of the fast-ice gauges (figure 43) there area records available from the place No 1 for the period 4.3—20.3, from the place No 2 for the period 3.3—20.3. and from place No 3 for the period 4.3—12.3 1975. The gauge close to the icebreaker TOR was in action during the period 11.3—20.3.1975. There are no flow recording values attached to this report. They are available at the Institute of Marine Research. The recordings obtained from the fast-ice area show no flow at all.

The location of the radar reflectors and the marking flags

In the tables 1—9 the sites of the radar reflectors and the marking flags during the various times for observation are given. The Institute of Marine Research chose on the western side of Merikallat two areas of only 5×5 km and 15×15 km so that in the points 2, 4, 6 and 8 of the outer area and in the points A, C, E and G of the inner area one radar reflector and two marking flags were installed. In the other points (1, 3, 5, 7, B, D, F and H) three marking flags were introduced. The most noticeable movement of the ice occurred on 16—17.3. when the ice moved approximately 10 nautical miles in the south-southwestern direction. To a large extent, the areas maintained their form during the whole of the observation time 14.3—20.3. Some small internal alterations, however, did occur. On the figure 43 the sites of the reflectors and the flags are shown during the various observation times. Within the period of research the marks in the places 6 and H were lost.

Other observations in the research area

The great distance between the base and the area of observation caused much inconvenience to the other observation work (the thickness of the ice, ice ridging, the leads in the ice etc.) Only on 15.3 satisfactory information could be obtained about the area. Even then the sensing of the inner area was of primary concern. In the following some other observation material is presented, mainly in a tabular form.

Place	At o'clock	The thickness of the level ice	Open water	Pressure ridges
1	9.15	53-64 cm (rafted)	1/10	1/10
8	9.30	45-50 cm (rafted)	1-2/10	3/10
7	9.50	27 cm	1/10	3/10
6	10.00	25-28 cm	0/10	1/10
5	10.05	29 cm	0-1/10	1/10
4	10.15	48-53 cm (rafted)	0/10	4-5/10
3	10.30	41-53 cm (rafted)	0-1/10	3-4/10
2	10.40	26-28 cm	2/10	1/10
B	10.45	52 cm (rafted)	1/10	1/10
C	10.50	29 cm	1-2/10	1/10
D	10.55	52-54 cm (rafted)	0/10	1/10
E	11.00	27 cm	0-1/10	1-2/10
F	11.05	45-50 cm (rafted)	0-1/10	1-3/10
G	11.10	27-29 cm	0-1/10	1-2/10
H	11.15	26 cm	0/10	1/10
A	11.17	27-29 cm	0-1/10	3/10

Place	At o'clock	Decca		Thickness		Pressure ridges		Open water	Lead		
		Red	Green	cm	Amount	Height	Direction		Width	Direction	
A	13.34	E 20.95	I 46.0		1/10	30-50 cm		2/10	2-3 m	195°	
1	13.40	E 22.20	I 45.6	28	4/10	50-60 cm		1/10			
		E 22.25	I 45.73					10/10			
B	13.43	E 22.20	I 45.60		4/10	0.5-1 m		1/10			
2	13.45	F 0.30	I 45.5	29	2/10			1/10			
C	13.48	F 1.00	I 45.60		2/10			1/10	1-2 m	210°	
		F 1.70	I 44.2					10/10			
3	13.51	F 1.50	I 44.2	52	1/10			0/10			
4	13.53	F 0.75	I 44.35	30	4/10	0.5-1 m		0/10			
		F 0.55	I 44.45		10/10	1-2 m					
5	13.55	E 23.80	I 44.35	45	3/10	0.5-1.5 m		0/10	1-2 m	230°	
		E 20.50	I 44.50		10/10	1-1.5 m		210°			
		E 23.00	I 44.55					10/10			240°
		E 22.60	I 44.70		10/10	0.5-1.5		10/10			5.5 m
		E 22.45	I 44.00								
6	14.00	E 22.45	I 44.30	28	4/10			1/10	1-2 m	240°	
7	14.03	F 22.00	I 44.50	27	1/10			1/10			
H	14.05	E 22.10	I 44.90		2/10	0.5-1 m		1/10			
		E 22.65	I 43.85					10/10			

Place	At o'clock	Decca		Thickness	Amount	Pressure ridges		Direction	Open water	Lead	
		Red	Green			Height	Direction			Width	Direction
S	14.07	E 23.15	I 43.75	23	2/10	0.5-1 m			0/10		
9	14.9	F 0.10	I 43.70	33	3/10				0/10		
10	14.14	F 1.10	I 43.45	29	6/10	0.5-1.4 m					
D	14.14	F 1.90	I 43.45		3/10				1/10	5-20 m	210°
		F 2.05	I 43.00					10/10			
11	14.16	F 2.30	I 42.10	30	1/10				0/10		
12	14.17	F 1.50	I 42.40	50	5/10	0.5-1.5 m			0/10		
13	14.19	F 0.65	I 42.75	26	0/10						
14	14.22	E 23.70	I 42.95	23	3/10	0.5 m			0/10		
15	14.23	E 22.80	I 42.75	31	1/10				0/10		
G	14.26	E 23.40	I 41.60		0/10				0/10	1-2 m	240°
16	14.28	F 0.10	I 41.45	29	2/10				0/10		
F	14.30	F 1.35	I 41.20		3/10				2/10		
17	14.32	F 2.50	I 41.20	30	6/10				1/10	1-2 m	210°
		F 3.75	I 40.50					10/10			
E	14.36	F 3.75	I 40.0		0/10				0/10	2-5 m	210°
		F 2.80	I 42.1		6/10			2/10			
		F 0.95	I 45.85					10/10			
		F 0.20	I 46.15					10/10			

The general ice situation in the observation area 14—20.3 1975

At the beginning of the observation period there was comparatively little open water (0—2/10), however, after the ice had moved on 16—17.3. in the south-southeastern direction a great number of leads had opened in the ice field. Particularly in the central Bothnian Bay to the west of the observation area there was much open water. The leads closed mostly because of the south-eastern wind blowing in the evening of 18.3.

Finally

In the report many matters have been only mentioned or an accurate description is missing. This is due to the fact that they have probably been accurately described in the SMHI report from the observation area. Such are for instance the describing of the observation devices and -marks as well as the results obtained by the flow recording device close to the ice-breaker TOR.

Table 1.

Radarreflectors and flags		Decca	
Place	Red	Green	Decca
1	E 16.3	I 47.0	I
2	E 21.8	I 47.0	I
3	F 3.0	I 46.25	I
4	F 6.40	I 40.0	I
5	F 10.25	I 32.4	I
6	F 5.5	I 31.5	I
7	E 23.6	I 31.4	I
8	E 19.2	I 39.7	I
A	E 22.0	I 42.0	I
B	F 0.1	I 42.0	I
C	F 1.9	I 42.28	I
D	F 2.9	I 39.75	I
E	F 4.8	I 36.3	I
F	F 2.55	I 36.8	I
G	F 0.56	I 36.9	I
H	E 23.2	I 39.35	I

Table 2.

Radarreflectors and flags		Decca	
Place	Red	Green	Decca
1	E 15.55	J 32.2	J
2	E 21.2	J 31.85	J
3	F 2.45	J 30.8	J
4	F 5.60	I 42.80	I
5	F 9.25	I 35.65	I
6	F 4.3	I 35.35	I
7	F 22.4	I 35.8	I
8	E 18.25	I 43.55	I
A	E 21.1	I 45.65	I
B	E 23.35	I 45.15	I
C	F 1.15	I 45.4	I
D	F 2.0	I 43.0	I
E	F 3.85	I 39.7	I
F	F 1.50	I 40.55	I
G	E 23.55	I 40.60	I
H	E 22.2	I 43.4	I

Table 3.

Radarreflectors and flags		Decca	
Time	Place	Red	Green
March 14 at 10 o'clock	1	E 16.05	I 31.7
	2	E 21.65	I 31.2
	3	F 2.8	I 30.3
	4	F 6.0	I 42.5
	5	F 9.6	I 35.4
	6	F 4.6	I 33.5
	7	F 22.7	I 35.8
	8	E 18.55	I 43.4
March 16 at 13 o'clock	A	F 21.6	I 45.2
	B	E 23.75	I 44.85
	C	F 1.6	I 44.8
	D	F 2.45	I 42.6
	E	F 4.25	I 39.2
	F	F 1.8	I 40.25
	G	E 23.85	I 40.65
	H	E 22.6	I 43.0

Table 4.

Radarreflectors and flags		Decca	
Time	Place	Red	Green
March 17 at 11 o'clock	1	E 20.9	I 31.0
	2	F 2.5	I 31.1
	3	F 9.0	I 31.25
	4	F 11.75	II 43.45
	5	F 15.7	II 36.1
	6	F 9.9	II 34.55
	7	F 3.0	II 33.9
	8	E 22.0	II 41.75
March 17 at 11 o'clock	A	F 2.2	II 45.2
	B	F 4.45	II 45.7
	C	F 6.7	II 45.6
	D	F 7.55	II 42.3
	E	F 9.55	II 39.8
	F	F 6.8	II 40.25
	G	F 4.6	II 40.25
	H	Lost	

Table 5. Radarreflectors and flags

Time	Radarreflectors and flags		
	Place	Red	Green
March 17 at 15 o'clock	1	F 20.5	H 45.65
	2	F 2.95	H 46.45
	3	F 9.8	H 46.0
	4	F 12.6	H 40.25
	5	F 16.55	H 32.95
	6	F 10.7	H 31.65
	7	F 3.95	H 31.0
	8	F 22.0	H 39.55
	A	F 2.75	H 42.1
	B	F 5.1	H 42.45
C	F 7.3	H 42.8	
D	F 8.2	H 40.4	
E	F 10.25	H 36.75	
F	F 7.5	H 37.2	
G	F 5.3	H 37.0	

Table 6.

Time	Radarreflectors and flags		
	Place	Red	Green
March 18 at 9 o'clock	1	F 20.75	H 44.50
	2	F 3.15	H 45.65
	3	F 10.15	H 45.2
	4	F 12.95	H 39.35
	5	F 17.05	H 31.75
	6	F 11.6	H 30.85
	7	F 5.20	G 47.4
	8	E 22.4	H 38.85
	A	F 3.15	H 40.65
	B	F 5.55	H 40.8
	C	F 7.75	H 41.4
	D	F 8.7	H 39.0
	E	F 10.75	H 35.50
	F	F 7.0	H 35.8
	G	F 5.7	H 35.7
	H	-	-

Table 7. Radarreflectors and flags

Time	Radarreflectors and flags		
	Place	Red	Green
March 18 at 14 o'clock	1	F 20.6	H 46.9
	2	F 2.05	H 47.65
	3	F 9.9	H 47.0
	4	F 12.75	H 41.2
	5	F 16.9	H 33.25
	6	F 11.4	H 32.2
	7	F 5.15	H 32.0
	8	E 22.1	H 41.5
	A	F 2.85	H 42.9
	B	F 5.45	H 42.5
C	F 7.7	H 43.3	
D	F 8.7	H 41.0	
E	F 10.75	H 37.50	
F	F 7.9	H 37.7	
G	F 5.6	H 37.85	

Table 8.

Time	Radarreflectors and flags		
	Place	Red	Green
March 19 at 15 o'clock	1	F 23.55	I 35.0
	2	F 4.95	I 35.6
	7	F 7.60	H 39.0
	8	F 0.60	I 30.7
	A	F 5.55	I 31.05
	B	F 7.65	I 30.6
	C	F 9.45	I 30.9
	D	F 10.4	H 46.75
	E	F 12.3	H 43.4
	F	F 9.7	H 44.15
	G	F 7.85	H 44.4

Table 9.

Radarreflectors and flags

Time	Place	Green	
		Red	Green
March 20 at 15 o'clock	1	E 23.6	I 35.1
	2	F 5.0	I 35.65
	3	F 10.95	I 34.45
	4	F 14.05	H 47.0
	5	F 17.7	H 39.25
	7	F 7.7	H 39.05
	8	F 0.7	I 30.75
	A	F 5.55	I 31.1
	B	F 7.65	I 30.6
	C	F 9.45	I 30.95
	D	F 10.4	H 46.75
	E	F 12.3	H 43.45
	F	F 9.95	H 44.2
	G	F 7.85	H 44.45

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