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IMSI REPORT NO. 2: THE BALTIC SEA ICE FIELD CAMPAIGN 17-24 March 1997
Data report

Hannu Grönvall, Martti Hallikainen, Pekka Kosloff, Marko Mäkynen, Mikael Nizovsky, Tero Purokoski, Ari Seinä and Markku Similä

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Report on activities in the winter of 1997

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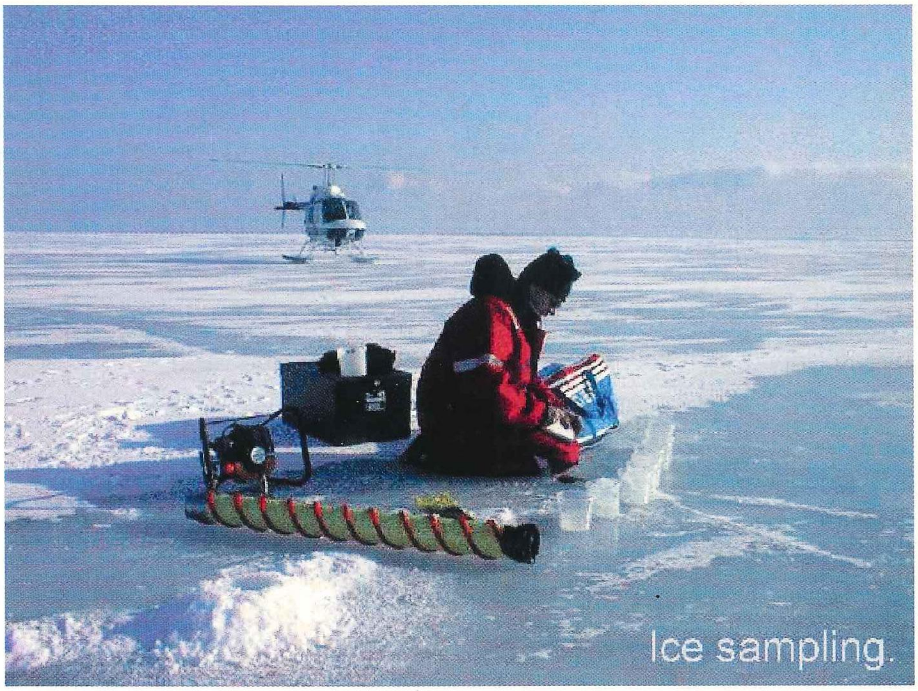

Ice sampling.

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ABSTRACT

The IMSI Baltic Sea ice field campaign took place in the period 17 - 24 March 1997. The participating institutes were the Finnish Institute of Marine Research (FIMR) and the Laboratory of Space Technology from the Helsinki University of Technology (HUT). The field experiment consisted of two Ice Stations in the Bothnian Sea. The main objective of the field campaign was to carry out field measurements to enable the geophysical validation of the RADARSAT data. In addition to the field measurements directly related to this goal, some other measurements were also carried out, i.e. the scatterometer measurements performed are intended to increase our understanding of the dependence of backscatter behaviour on incidence angle. The airborne radiometer measurements conducted provided an opportunity for an investigation into the integrated use of passive and active microwave sensors.

1. INTRODUCTION

The Finnish Ice Service has used ERS SAR data routinely during the last few years. The launching of the RADARSAT satellite meant a major step forward in microwave-based sea ice mapping because of the fully operational properties of the satellite. Hence it was considered of great importance to examine the characteristics of RADARSAT ScanSAR Wide mode data. A suitable opportunity to realise this field campaign came about in connection with the IMSI project. The acronym IMSI refers to the project "Integrated Use of New Microwave Satellite Data for Improved Sea Ice Observations", which is part of the European Commission Environment and Climate Program.

The IMSI Baltic Sea ice field campaign took place in the period 17 - 24 March 1997. The participating institutes were the Finnish Institute of Marine Research (FIMR) and the Laboratory of Space Technology from the Helsinki University of Technology (HUT).

The main objective of the field campaign was to perform field measurements to enable the geophysical validation of the RADARSAT data. Especially useful was regarded an overall view of the ice conditions in the Bothnian Bay. To this end, a relatively extensive aerial photography programme was carried out both manually and automatically (see section 3.1). To quantify this knowledge, an ice sample set was collected, which was spatially distributed over a large area (see section 2.3). A large set of remote sensing data from NOAA and ERS-2 SAR are also available for the RADARSAT image validation (see section 4). This data was acquired for the project's use by the Finnish Ice Service.

The aim relating to the overall view of ice conditions in the whole Bothnian Bay was also reflected in the locations of the two Ice Stations, which represented different kinds of ice fields.

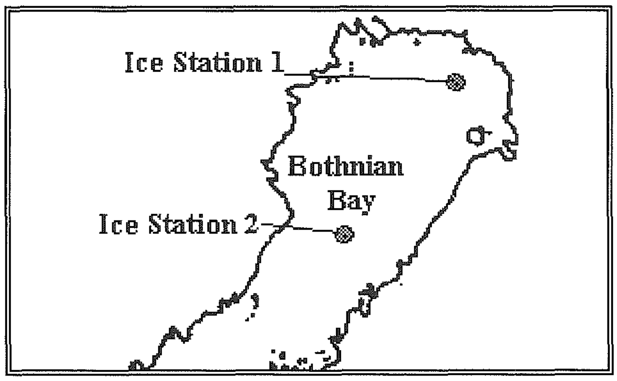


Fig. 1. Intensive ice stations for the IMSI field campaign in the Bothnian Bay.

The scatterometer and radiometer measurements can also be connected to RADARSAT data. Detailed information about the effect of incidence angle on the backscatter behaviour can be derived from the HUTSCAT measurements (see section 3.2). As is well known, the large variation in the incidence angles is one of the main problems with RADARSAT images. Imaging and non-imaging airborne radiometer measurements, which coincided in time with the RADARSAT data acquisition, were conducted by HUT. These measurement flights provided an opportunity to investigate the integrated use of passive and active microwave sensors (see section 3.2).

The expedition was realised with the research vessel Aranda, which offered excellent working conditions. Many thanks are due to the captain and crew of R/V Aranda and all the participants in the IMSI field experiment in the air, on the sea, on the ice and on the land.

2. GROUND TRUTH

2.1. Weather data

2.1.1. Weather stations

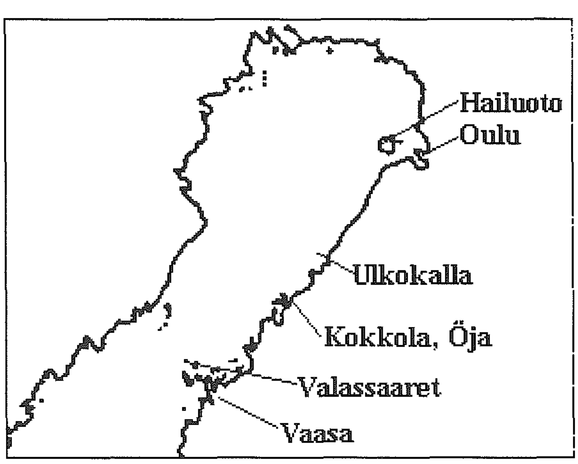


Fig. 2. The weather stations.

The weather stations used are shown in Figure 2. These stations were selected as being representative of the area. Hailuoto and Ulkokalla were the nearest stations to the R/V Aranda's measurement points.

Air Temperature

In March the air temperatures in the northern Bothian Bay were , except for the period 7-13 March, below zero. In the southern Bothnian Sea, air temperatures were below zero from the 14th March onwards. March in general was some 2-3 °C warmer than normal (Fig. 3).

During the field experiment, air temperatures were on average ~ -8 °C in the northern Bothnian Bay, ~ -6 °C in the middle part, and ~ -5 °C in the southern part. Maximum temperatures were - 2 °C in the northern part, 0 - -1 °C in the middle part and +1 °C in the southern part. Minimum temperatures were respectively -17 - -18 °C, -14 °C and -11 °C (Figs. 4-9) (FMI 1997).

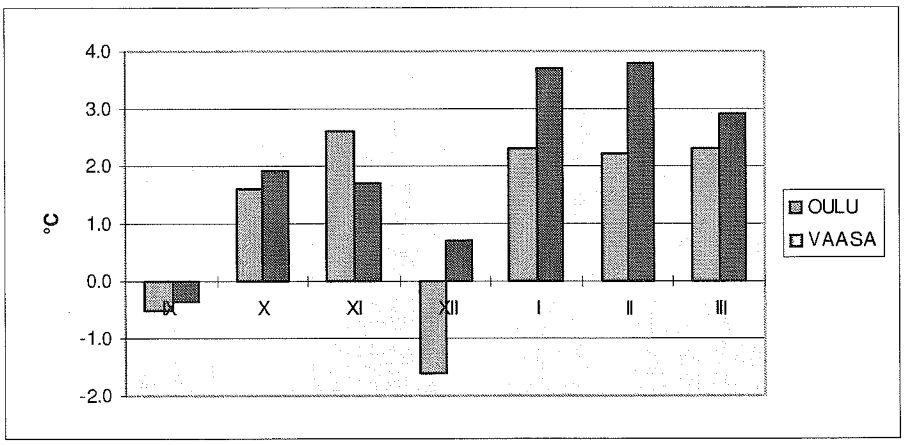


Fig. 3. Monthly average air temperature anomalies at Oulu and Vaasa November 1996 - March 1997.

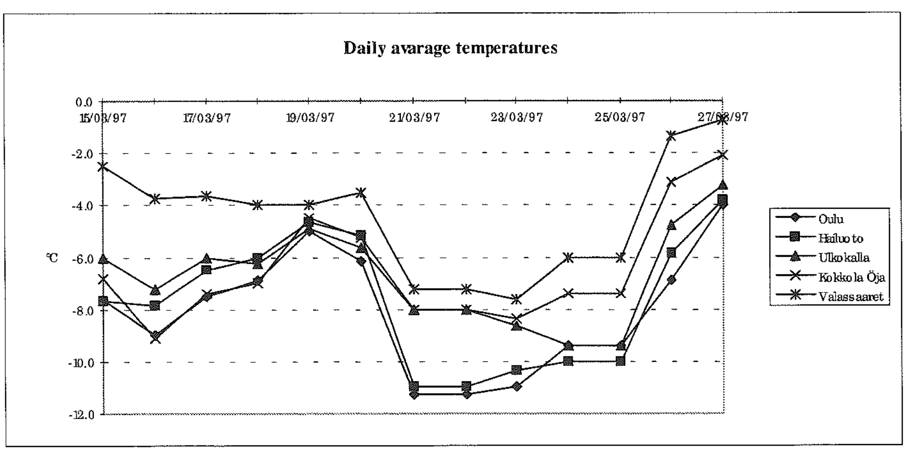


Fig. 4. Daily average temperatures in the Bothnian Bay 15-27 March 1997.

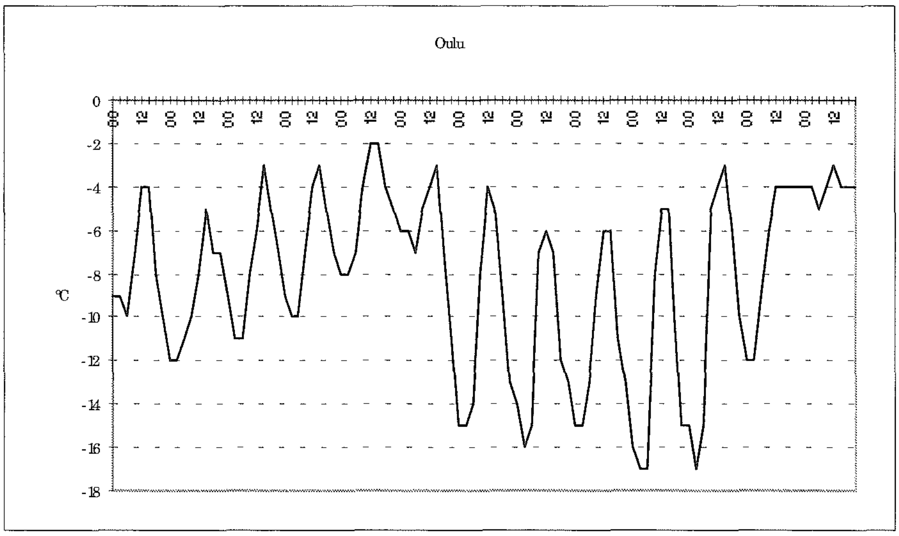


Fig. 5. Air temperature at Oulu airport 15-27 March 1997 at 3-hourly intervals.

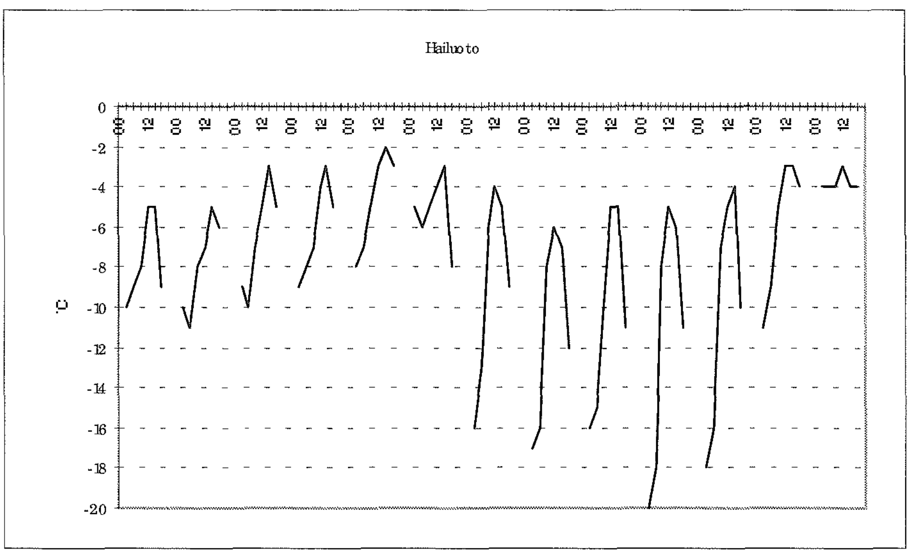


Fig. 6. Air temperature at Hailuoto 15-27 March 1997 at 3-hourly intervals.

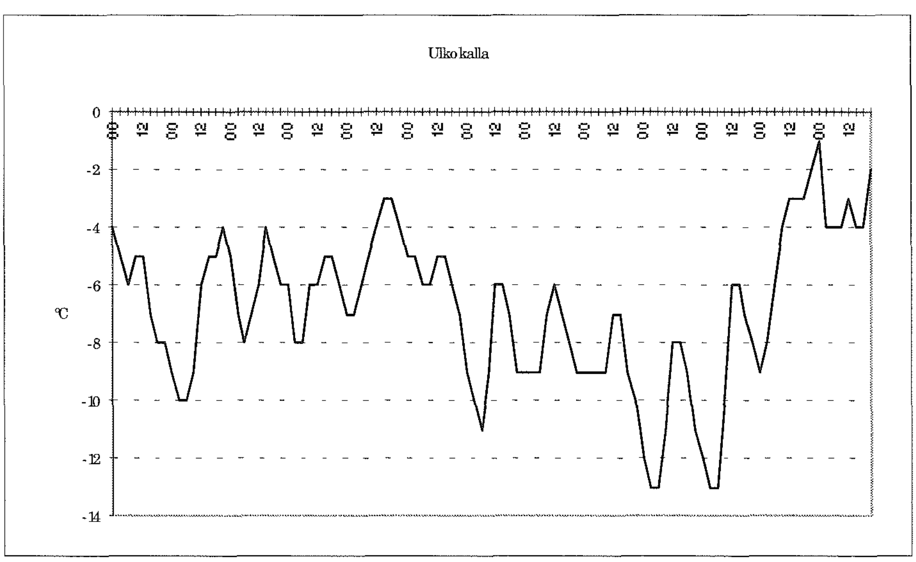


Fig. 7. Air temperature at Ulkokalla 15-27 March 1997 at 3-hourly intervals.

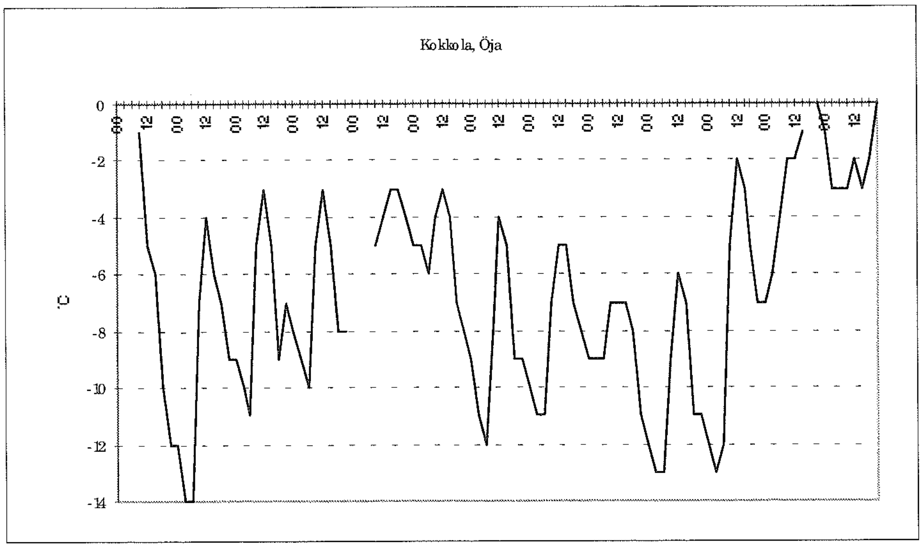


Fig. 8. Air temperature at Kokkola, Öja 15-27 March 1997 at 3-hourly intervals.

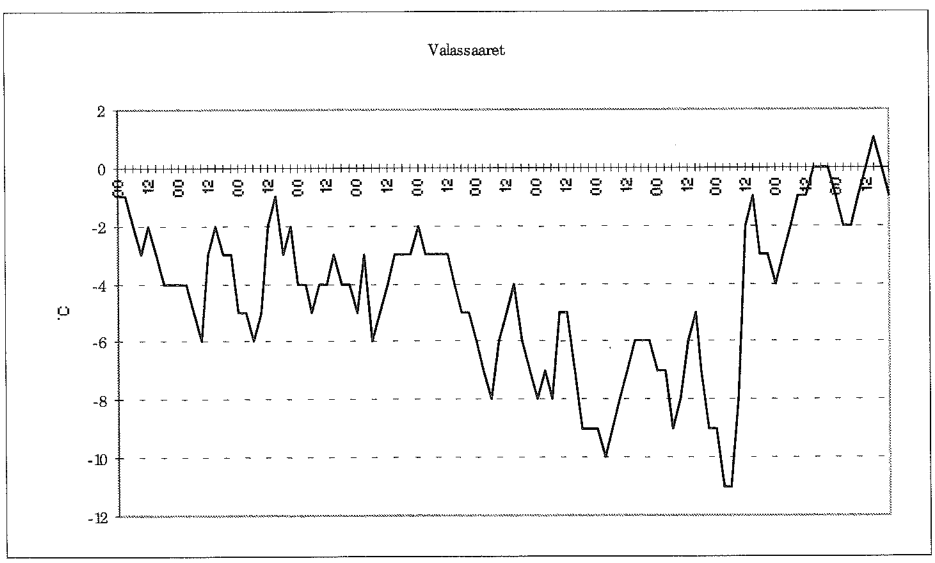


Fig. 9. Air temperature at Valassaaret 15-27 March 1997 at 3-hourly intervals.

Air pressure

The air pressure at the weather stations was quite similar, as can be seen from figure 10, varying from a daily average value of 976 hPa to 1027 hPa. The maximum daily average value was reached at Hailuoto on 24 March and the minimum at Valassaaret on 27 March. The absolute maximum of 1027 hPa was reached at Hailuoto on 24 March and absolute minimum of 972 hPa at Valassaaret on 27 March.(Fig. 10) (FMI 1997).

Wind

The wind speed daily averages varied from approximately 0.7 to 13.9 m/s, as shown in Figure 11. The maximum daily average was reached at Ulkokalla on 27 March and minimum at Hailuoto on 24 March. The absolute maximum of 16 m/s was observed at Ulkokalla on 27 March (FMI 1997).

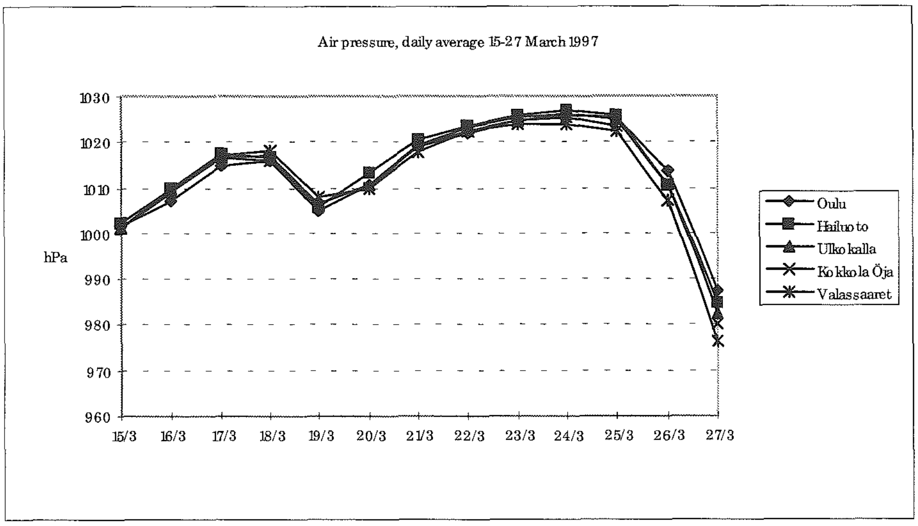


Fig. 10. Daily average air pressure values in the Bothnian Bay area , 15-27 March 1997.

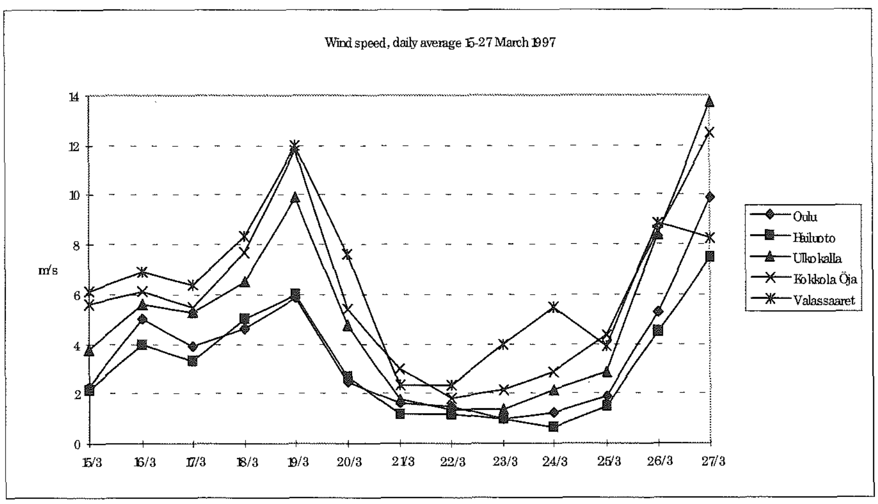


Fig. 11. Daily average wind speeds in the Bothnian Bay area, 15-27 March 1997.

The daily average direction (Fig. 12) was mainly from the north and north-west at the beginning (15 March), turning towards the south at the end of the month (27 March).

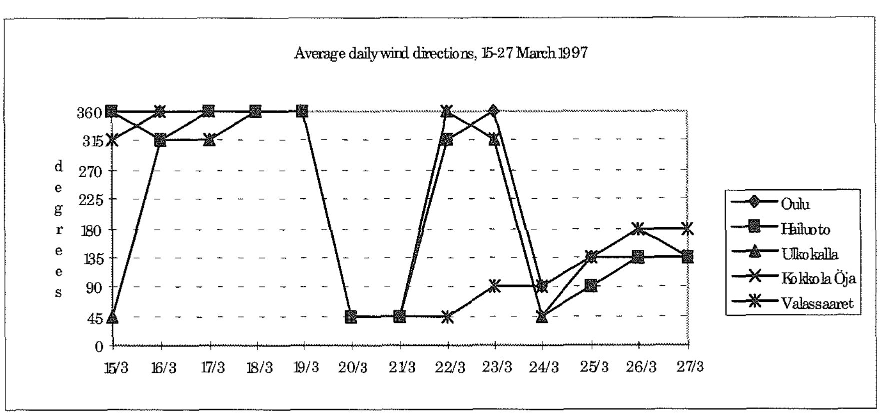


Fig. 12. Daily average wind directions in the Bothnian Bay area, 15-27 March 1997. 360 = North, 45 = North-East, 90 = East, 135 = South-East, 180 = South, 225 = South-West, 270 = West, 315 = North-West.

Humidity

The daily average humidity varied from 55 to 95 %, reaching its maximum of 95 % at Kokkola on 27 March and minimum of 55 % also at Kokkola on 25 March (Fig. 13). The absolute maximum of 98 % was observed at Kokkola on 27 March and absolute minimum of 38 % at Oulu on 25 March (FMI 1997).

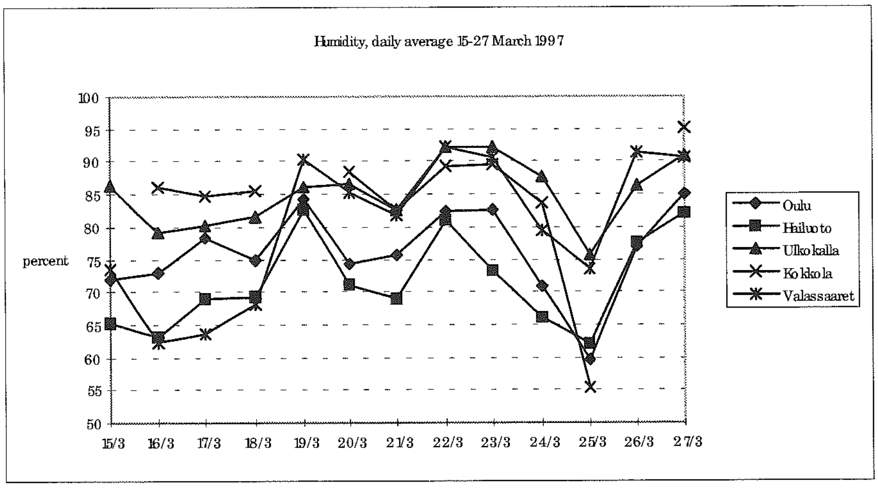


Fig. 13. Daily average humidity values in the Bothnian Bay area, 15-27 March 1997.

Cloudiness

The cloud cover over the Bothnian Bay varied frequently, as can be seen from Figure 14. According to the daily average interpretation the sky was totally cloud-covered at Oulu on 27 March, at Hailuoto on 19, 26, and 27 March, at Kokkola on 26 and 27 March, and at Valassaaret on 19, 26, and 27 March. The sky was totally clear at Hailuoto on 17 and 25 March (FMI 1997).

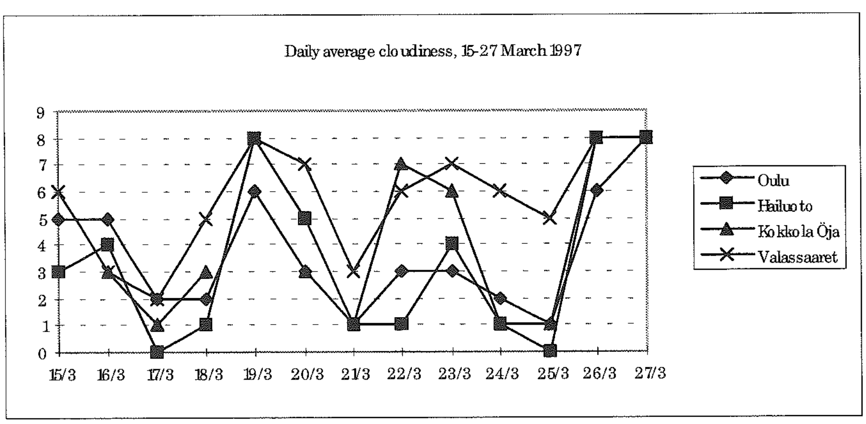


Fig. 14. Daily average cloudiness in the Bothnian Bay area, 15-27 March 1997. 0=clear, 1=1/8 or less of the sky covered by clouds, 2=2/8 of the sky covered by clouds, 3=3/8 of the sky covered by clouds, 4=4/8 of the sky covered by clouds, 5=5/8 of the sky covered by clouds, 6= 6/8 of the sky covered by clouds, 7=7/8 of the sky covered by clouds, 8=the sky totally covered by clouds.

Visibility

The daily average visibility varied from approximately 1,200 to 50,000 metres as shown in Figure 15. The daily average maxima were observed at Oulu on 15, 16, and 18 March. The daily average minimum was observed at Hailuoto on 27 March 1997. The absolute maximum 50,000 m, was observed at Oulu during several occasions, and the absolute minimum, <100 m, at Oulu on 26 March 1997 (FMI 1997).

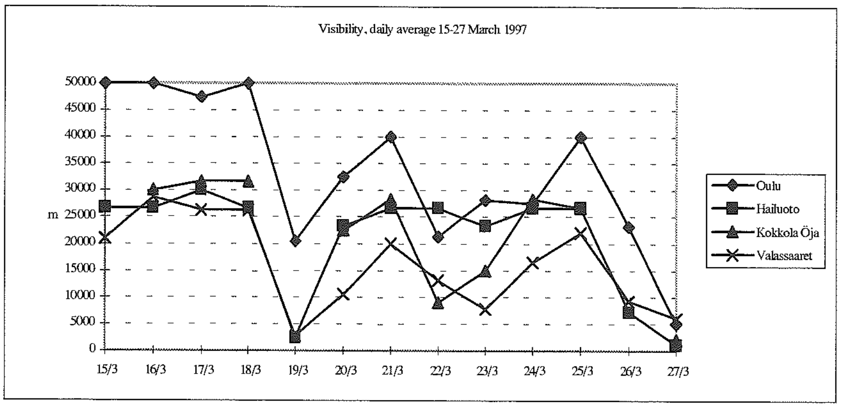


Fig. 15. Daily average visibility values in the Bothnian Bay area, 15-27 March 1997.

2.1.2. R/V Aranda Weather Station

Weather data was logged at 20-minute intervals. The observation series of air temperature, atmospheric pressure, wind speed and wind direction are shown in Figure 16. The same raw weather data is also listed in *appendix 2*.

Temperature and air pressure are given as 1-h averages, whereas wind speed and direction are 10-minute averages.

From 18th to 21st March, R/V Aranda was at Ice Station 1. On the 21st at 11.40 (UTC), R/V Aranda started to navigate towards the Ice Station 2, where it arrived the next day (22nd) at 09.20 (UTC). R/V Aranda remained at Ice Station 2 till the end of the logged weather data set (the last logged observation was on the 24th at 05.00 (UTC)).

Unfortunately there is quite a lot of data missing, which can be seen as gaps in the series plots. This is due to R/V Aranda's new weather software, which was not functioning properly at the time of the expedition. Because of the faulty software, one should use caution when interpreting the weather data. Even though in general the data quality is good, some sudden changes may have been due to the software.

2.2. Snow data

2.2.1. The snow thickness at the fixed stations

The snow thicknesses at the beginning of March were < 15 cm except in the most northern parts of the Bothnian Bay (the locations of the fixed stations are shown in Figure 21). The snow thickness was measured once a week, on Thursdays (Fig. 17). However, at Röyttä the measurements were done on a daily basis (Fig. 18). At least three measurements were taken at the same place at 2-3 m intervals and the average thickness was calculated. During the field campaign no radical changes occurred in snow thickness (FIMR 1997).

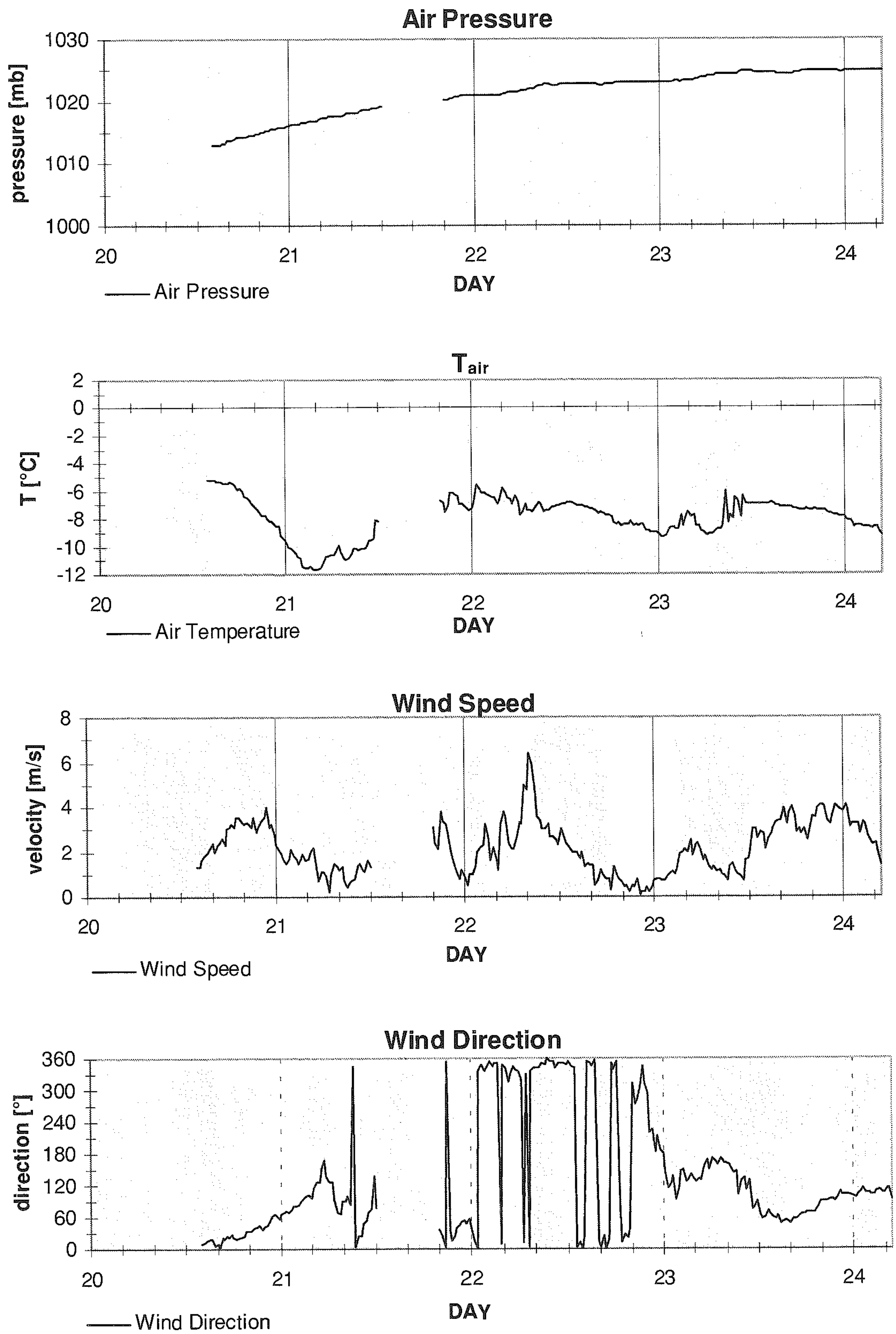


Fig. 16. The observation series of air pressure, air temperature, wind speed and wind direction during the IMSI field expedition (17-24 March). Observations were made at the R/V Aranda weather station. There is no usable logged weather data from 17th to 20th March.

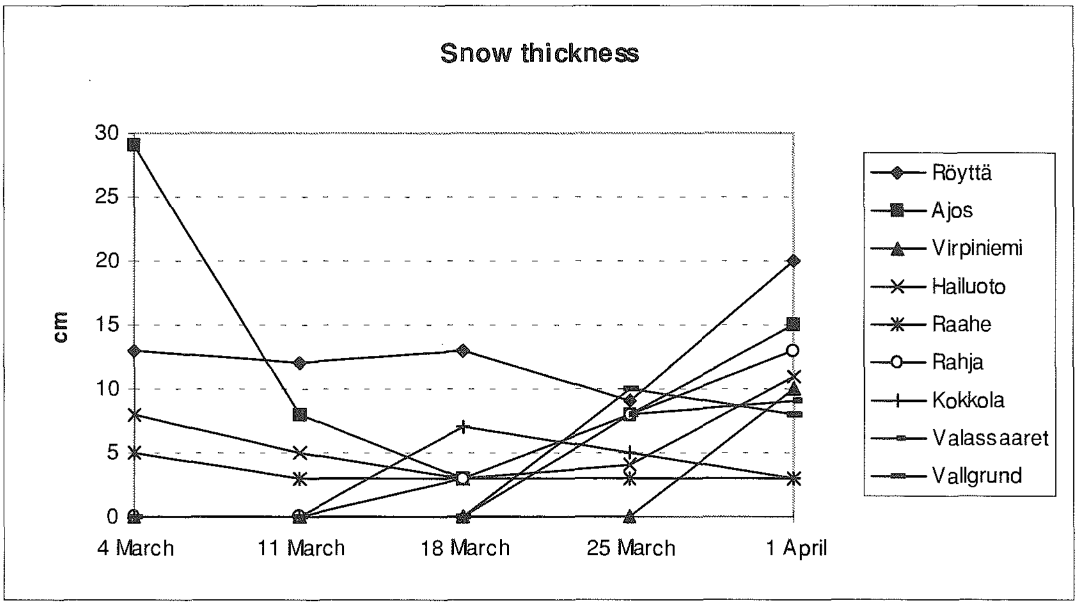


Fig. 17. Snow thickness at the fixed stations in March. Measurements were made once a week.

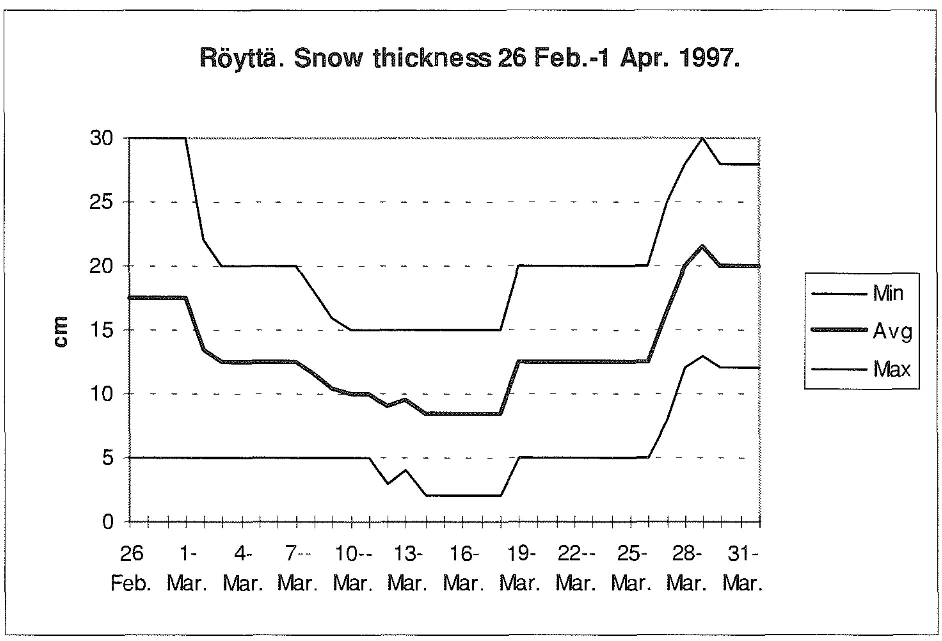


Fig. 18. Daily snow thickness at Röyttä. Minimum, average and maximum thickness are shown.

2.2.2. R/V Aranda measurements

Three scientists from the Laboratory of Space Technology (LST) participated in the field campaign on board the R/V Aranda and conducted ground truth measurements. The ground truth measurements by the LST consisted of snow characteristics and of photographs with hand-held cameras. Snow characteristics measurements included the snow thickness, density, volumetric wetness, temperature and crystal size. Photographs include close-ups of ice and snow structure, as well as surface and overall views of the ice and snow conditions. The snow measurements and photography were conducted along flag lines. At Ice Station 1 the length of the flag line was about 1 km and was to the east of R/V Aranda. At Ice Station 2 the length was a little less than 1 km and as direction was towards the west.

Methods

The density and wetness profiles of the snow cover were measured with the snow fork instrument (Sihvola & Tiuri 1986). The density was also measured by taking a sample with a precisely-known volume. The snow fork determines the density and wetness of snow by measuring the dielectric properties of the snow below 1 GHz. The snow fork is based on a parallel-wire transmission line microwave resonator. When the fork is pushed into the snow, the dielectric properties of the snow change the resonant frequency and the resonant bandwidth of the fork resonator. The snow wetness and density are calculated from the measured complex dielectric constant of the snow sample using empirical relations presented in (Tiuri & al. 1984). The wires of the fork are thin enough for the deformation of the snow caused by the measurement operation to be negligible. The snow temperature was measured with a temperature logger consisting of 8 temperature sensors on a vertical rod. The seven lowermost sensors are spaced in 10 cm intervals while the topmost sensor is 50 cm above the next sensor. The lowest sensor is 2 cm from the tip of the rod.

Snow crystals were photographed with a camera system developed by Pekka Pihkala of the Department of Physics, University of Helsinki. The magnification of the camera system is 8 times. Average crystal sizes were determined visually from the photographs.

Ice Station 1

There was no snow on 18 March at Ice Station 1. Before the field campaign there was a warm weather period and the snow cover on the ice melted. During the night of 18/19 March there was a light snowfall. The wind blew the snow away from level ice areas and these were only covered by very thin loose snow and a frost snow layer. There was some snow in the ridges and on rough ice areas, but the small snow thickness did not allow the measurement of snow properties. This very thin patchy snow cover is believed to have insignificant effects on the observed brightness temperatures and backscattered coefficients of the ice, except perhaps at 94 GHz.

Ice Station 2

At Ice Station 2, level ice areas were covered by a combined loose snow and frost snow layer only a few millimeters thick, and snow was packed in the ridges and rough ice areas. In the ridges, snow usually occurred as long narrow banks. The dominant wind direction could easily be seen in the ridge snow banks. Typically the maximum thickness of the snow banks was less than 50 cm. The snow was fine-grained new snow. The snow coverage within the footprints of the radiometers varied from 0 % (excluding frost snow) on level ice to a few tens of percent on rough ice.

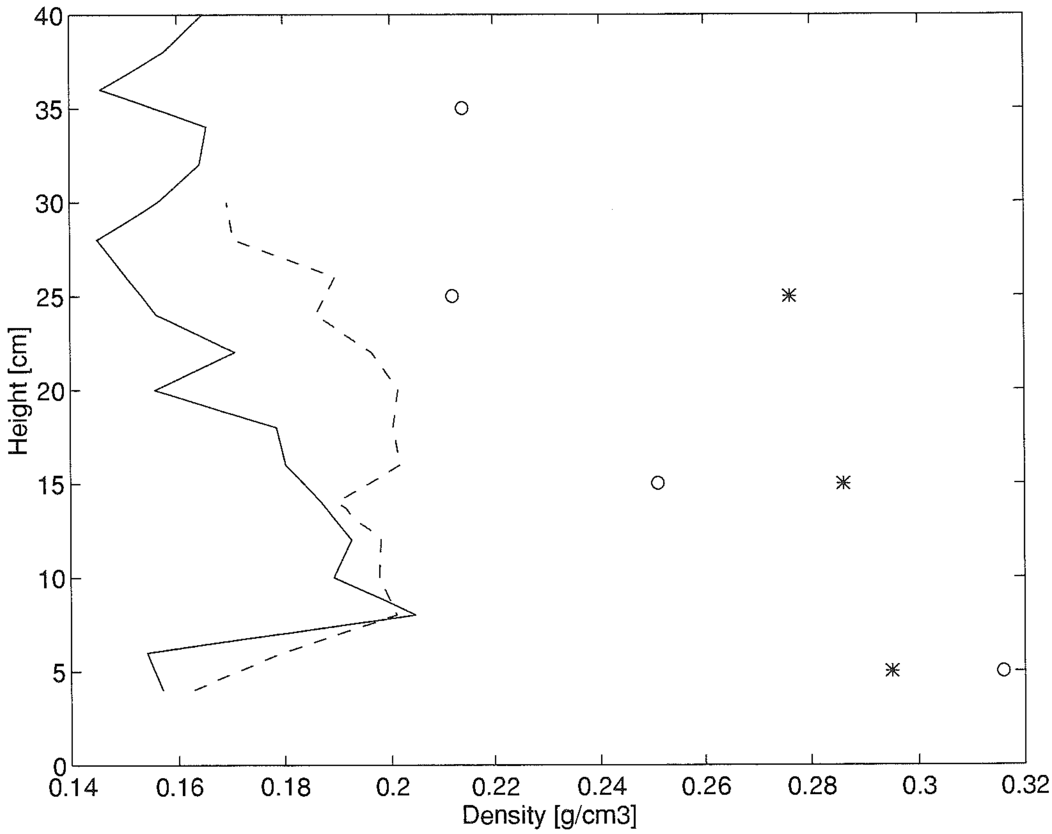
On the afternoon of 22 March snow measurements were conducted on three separate wind-packed snowbanks. On the morning of 23 March snow measurements were conducted on four snowbanks. The density was measured with both the sampling system and the snow fork. Snow fork measurements were first conducted with the snow fork owned by LST, but it was found that this instrument did not function properly and the results were unreliable. On 23 March two measurements were conducted using the FIMR snow fork. This snow fork worked properly. The results of the snow density and wetness measurements are presented in Table 1 and Figure 19. According to sampling measurements the snow density varied on 23 March from 0.212 to 0.332 g/cm^3. The densities measured by the sampling method are 1.3 - 1.8 times larger than those measured by the snow fork. The reason for this discrepancy is not clearly understood at present. The discrepancy could be due to crystal structure or to salinity. The densities measured by the sampling method are considered to be accurate values. The snow density was highest at the bottom of the snowbanks, probably due to the pressure of the upper layer. The wetness decreased with increasing height. At the bottom of the snowbank the snow was wet, with a mean wetness of 2.0 - 2.8 %, whereas in the top layer the snow was only slightly moist, with a mean wetness of 0.2 - 0.8

%. The wetness of the snowbanks was so high that even at the lowest radiometer frequencies the snow probably masked the underlying ice very effectively. The effect of the snow cover on the observed brightness temperatures and backscattering coefficients depends on the snow coverage percentage. The maximum coverage was estimated to be a few tens of percent, the main contribution to the brightness temperatures and backscattering coefficients coming from the ice. The combined loose snow and frost snow layer on the level ice is believed to have significant effects only at 94 GHz.

The snow crystals of the combined loose snow and frost layer were needle-like. A typical needle length was about 2 - 6 mm. The snow crystals in snowpacks were usually very irregular in shape and symmetric crystals were rare. The crystal size varied from less than 1 mm to a few millimetres.

Table 1. Results of the snow density and wetness measurements at Ice Station 2. The density and wetness shown are average values from 2 - 3 measurements.

Date	Location	Sampling method		Snow fork		
		Height [cm]	Density [g/cm^3]	Height [cm]	Density [g/cm^3]	Wetness [vol %]
22 March	Ridge snow pack at flag 12. Snow thickness 24 cm.	0 - 24	0.231	-	-	-
22 March	Ridge snow pack between flags 4 and 5. Snow thickness 36 cm.	30 - 36 20 - 30 10 - 20 0 - 10	0.211 0.248 0.251 0.244	-	-	-
22 March	Ridge snow pack between flags 2 and 3. Snow thickness 28 cm.	20 - 25 15 - 20 10 - 15 05 - 10	0.198 0.212 0.245 0.323	-	-	-
23 March	Ridge snow pack at flag 2. Snow thickness 16 cm.	10 - 15 05 - 10	0.227 0.254	-	-	-
23 March	Rough ice snow pack between flags 4 and 5. Snow thickness 15 cm.	10 - 15 05 - 10	0.212 0.332	-	-	-
23 March	Ridge snow pack between flags 4 and 5. 10 m from previous location. Snow thickness 40 cm.	30 - 40 20 - 30 10 - 20 0 - 10	0.214 0.212 0.251 0.316	30 - 40 20 - 30 10 - 20 04 - 10	0.159 0.156 0.181 0.176	0.2 0.4 1.6 2.8
23 March	Temperature logger snowbank. Between flags 2 and 3. Snow thickness 30 cm.	20 - 30 10 - 20 0 - 10	0.276 0.286 0.295	20 - 30 10 - 20 04 - 10	0.186 0.198 0.185	0.8 1.2 2.0



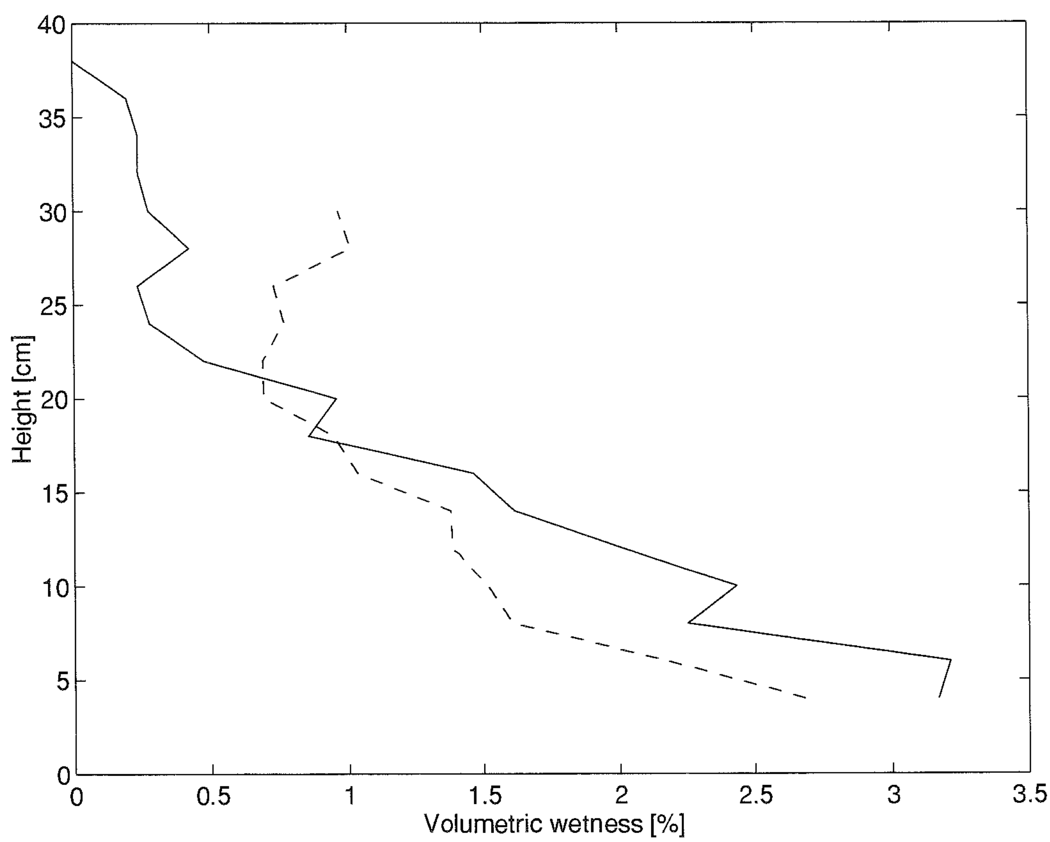


Fig. 19. Density and wetness profiles of two ridge snow packs at Ice Station 2 on 23 March. '—' (snow fork), 'o' (sampling method) Ridge snowpack between flags 4 and 5, snow thickness 40 cm. '---' (snow fork), '*' (sampling method) Temperature logger snowpack, snow thickness 30 cm.

On 22 March at 15.10 UTC the temperature logger was installed in a snowbank on rough ice between flags 2 and 3. The three lowermost sensors were inside the snowbank and one sensor was at the snow surface. The temperature logger was removed on 24 March at 06.55 UTC. The logging interval was 15 minutes. The snow temperature is presented in Figure 20. At the bottom of the snowbank the temperature was almost constant, except for a slight temperature rise at noon on 23 March. The mean, maximum and minimum temperatures during the observation period were -1.0°C, -0.1°C and -1.7°C, respectively. At heights of 10 cm and 20 cm from the bottom the mean temperatures were -2.6°C and -4.8°C, respectively. At noon on 23 March the temperature inside the snowbank clearly rose. The increase was smaller near the bottom of the snowbank due to the insulation of the snow cover. Snow temperature and wetness decreased with increasing height. The air temperature above the snowbank was very close to that at the snow surface.

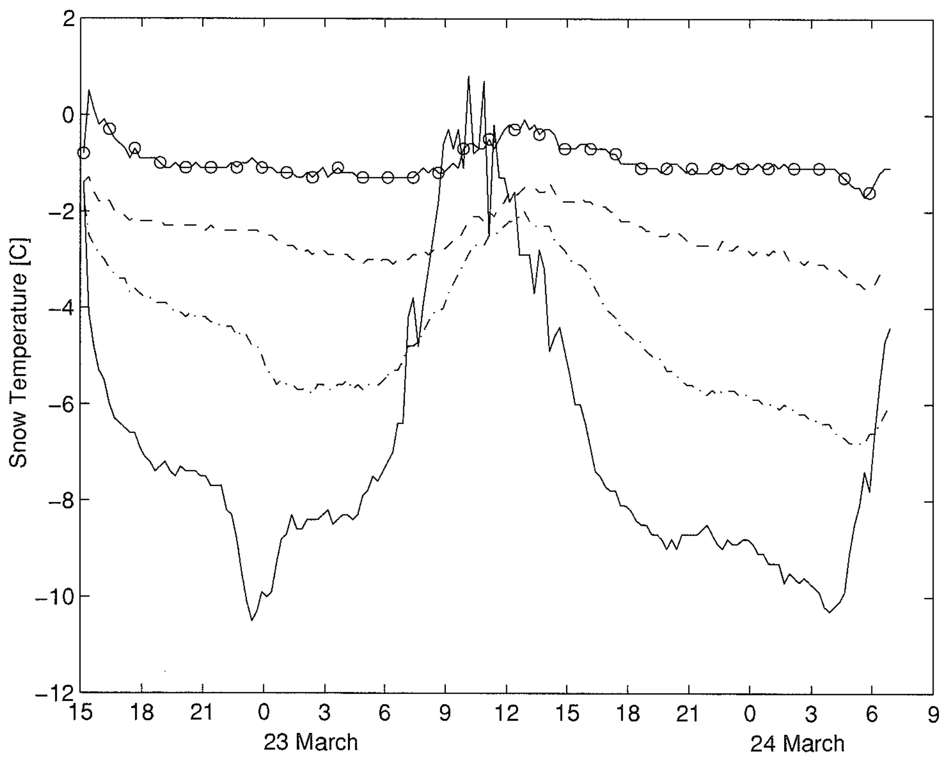


Fig. 20. Snow temperature profile in a rough ice snowbank between flags 2 and 3.'-o-' Bottom of the snowbank. '---' 10 cm from the bottom.'-.-' 20 cm from the bottom. '—' Snowbank surface, 30 cm from the bottom.

2.3. Ice data

2.3.1. Observation stations: ice thickness

The data of nine observation stations was available from the Bothnian Sea (Fig. 21). The stations are situated near the coastal area, where fast ice measurements could be taken. Ice thickness was measured once a week, on Tuesdays, by drilling three holes and measuring the thickness of black ice and snow ice. On 18 March the ice thickness was 61-78 cm in the northern part, 40-63 cm in the middle part and 15-47 cm in the southern part. On 25 March the ice thickness had grown in the northern part by 1-3 cm, but by 18 cm in the most northern part, staying unchanged in the other parts (Fig. 22 and Table 2).

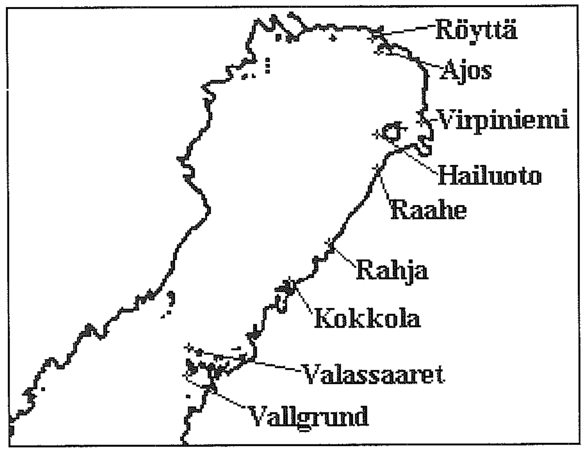


Fig. 21. Ice and snow observation stations.

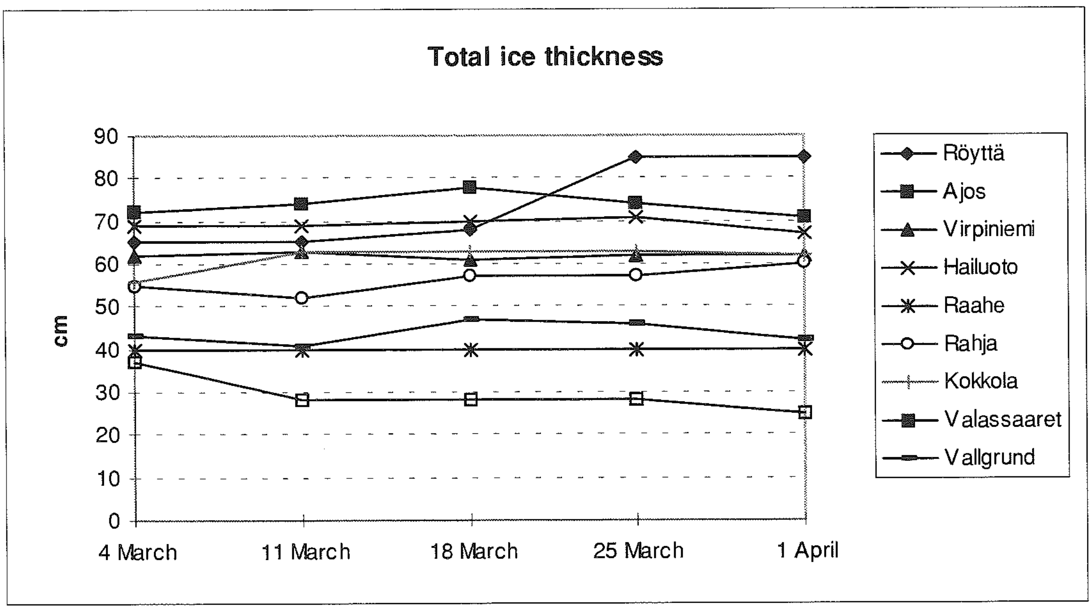


Fig. 22. Total ice thickness at the fixed stations in March 1997.

Table 2. Changes in total ice thickness (H), snow ice thickness (h) and in snow thickness (s) over the period 18-25 March 1997 at the ice observation stations.

	H	h	s
Röyttä	18	4	2-5
Virpiniemi	1	0	0
Hailuoto	3		2
Raahe	0	0	0
Rahja	0	0	12
Kokkola	0	0	2
Valassaaret	0	0	15
Vallgrund	-1	0	10
Avg.	3	1	6

2.3.2. R/V Aranda measurements

A total of 17 ice sampling sites were visited during the IMSI field campaign. There were two intensive areas with flag-marked measurement lines. The first was near Kemi One lighthouse (Ice Station 1) while the second was in the southern part of the Bothnian Bay (Ice Station 2). As the main interest was the ice upper layer (<0.05 m), at many ice coring sites only the upper part of the ice cover was measured. Ice crystal structures were not studied, but all ice cores are stored in the Finnish Institute of Marine Research's freezers. Nine ice samples were drilled from the measurement lines while the rest were drilled from other interesting sites in the Bothnian Bay. The first seven sites were in the fast ice, the rest being drift ice sites. All ice coring site positions are given in Table 3.

Table 3. Ice sampling site positions and ice thickness during the IMSI field expedition.

Site	Time	Position	Ice thickness (m)
PJK-6	18. March -97, Flag 8	65°16.150N, 23°58.658E	0.37
PJK-7	18. March -97, Flag 5	65°16.283N, 23°58.477E	0.40
PJK-8	18. March -97, Flag 12	65°16.102N, 23°58.874E	Broken sample
PJK-9	19. March -97, Flag 2	65°16.293N, 23°58.207E	0.75
PJK-10	20. March -97, Flag 7	65°16.226N, 23°58.554E	0.99
PJK-11	21. March -97	64°53.852N, 24°30.416E	0.66
PJK-12	21. March -97	64°37.503N, 24°18.309E	0.69
PJK-13	21. March -97	64°50.508N, 23°50.615E	0.99
PJK-14	22. March -97, Flag 2	64°13.270N, 22°24.748E	0.41
PJK-15	22. March -97, Flag 5	64°13.220N, 22°24.509E	Broken sample
PJK-16	22. March -97, Flag 11	64°13.292N, 22°24.109E	0.30
PJK-17	23. March -97, Flag 10	64°13.281N, 22°24.197E	0.30 and 0.34
PJK-18	23. March -97	64°07.980N, 22°11.514E	0.37
PJK-19	23. March -97	64°07.980N, 22°11.514E	0.44
PJK-20	23. March -97	64°12.020N, 22°16.249E	0.40
PJK-21	24. March -97	64°19.000N, 22°35.160E	0.47 - 1.08
PJK-22	24. March -97	64°29.132N, 22°34.418E	0.67

Thickness

Fast ice thicknesses measured at ice coring sites in the Ice Station 1 area and near Hailuoto and Raahe were between 0.37 - 0.99 m and drift ice thickness in the southern Bothnian Bay were 0.37 - 1.08 m. The ice thicknesses are presented in Table 3.

Ice samples from measurement lines

Five ice sampling sites (PJK-6 - PJK-10) were situated along the Ice Station 1 measurement line and four ice sampling sites (PJK-14 - PJK-17) along the Ice Station 2 measurement line. A total of

52 ice salinity samples were measured on the measurement lines. In order to get the optimal ice salinity measurements at all the ice coring sites, drilling was done through the ice and salinity samples were collected through the whole ice thickness. In some cases the ice core got broken and part of the ice sample was lost.

The variability in the ice depth is illustrated by the ice depth profile along the measurement line. In the Figure 23 this profile is presented for the measurement line at Ice Station 2. The ice depth at the middle point between each flag was also measured. The distance between the flags was about 50 m.

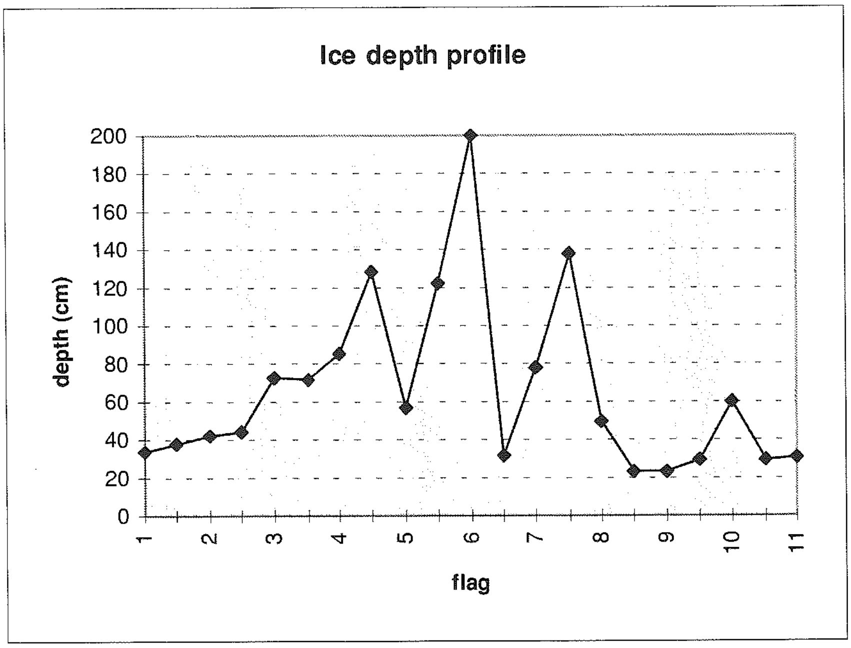


Fig. 23. The ice depth profile of the measurement line at Ice Station 2. Also included is one measurement between each flag. The distance between flags was about 50 m.

The mean salinity in the ice surface layers (< 0.05m) at Ice Station 1 was 0.28 ppt. The surface layer of thick compact drift ice had a lower salinity than thin drift ice. The mean ice salinity of the surface layer in the thick drift ice was 0.05 ppt and in thin drift ice was correspondingly 0.47 ppt. In the ice surface layers (< 0.05m) at Ice Station 2 the mean salinity was 0.33 ppt. All ice sampling sites' salinities are presented in *Appendix 3*.

Ice samples outside the measurement lines

Two ice coring sites (PJK-11 and PJK-12) were situated in fast ice south of Hailuoto island and west of Raahe. The rest (PJK-13, PJK-18 - PJK-22) were situated in the pack ice in the Bothnian Bay. A total of 66 ice salinity samples were measured outside the measurement lines.

The mean ice salinity in the surface layer (<0.05 m) was 0.17 ppt. In both the fast ice and the pack ice the mean salinity was 0.20 ppt. The old thick drift ice in the middle parts of the Bothnian Bay had a higher mean salinity (0.35 ppt) than the thin drift ice (mean 0.12 ppt) in the southern Bothnian Bay.

3. AIRBORNE DATA

3.1. Aerial photography

Side view photos were taken from the helicopter's window with the normal 35 mm cameras. A total of 113 aerial photographs was taken. Most of these aerial photographs were taken near the two ice research stations at Kemi 1 and in the southern Bothnian Bay. The rest of the aerial photographs were taken at ice sampling sites and during flights from R/V Aranda to the ice sampling stations.

A Panasonic WV-CP412 videocamera was installed in the helicopter. The videotape carried a timecode, which was manually synchronised to GPS time with an accuracy < 1 s. DGPS coordinates were recorded on a portable PC. Three separate profiles were recorded during the field expedition in the Bothnian Bay. The total length of the profiles was approximately 130 km.

3.2. Radiometer and scatterometer measurements

The laboratory of Space Technology (LST) conducted airborne measurements during the field campaign with a 12-channel profiling (non-imaging) microwave radiometer system, a two-channel imaging 93 GHz radiometer and the helicopter-borne C- and X-band FW-CW HUTSCAT-scatterometer.

Radiometer measurements

The radiometers are mounted on board the HUT twin-engine Short SC-7 Skyvan aircraft. They look backwards along the flight track through the rear cargo door. The incidence angle of the radiometer system is 50°. Profiling radiometer measurements were conducted at an altitude of 300 m and imaging radiometer measurements at 1000 m. The flight speed during the measurements was 110 kn (57 m/s). The technical characteristics of the radiometers are shown in Tables 4 and 5 (Hallikainen & al. 1996). The radiometers were designed and constructed by LST. During the measurements the target was recorded with a nadir-viewing video camera, and the DGPS-coordinates of the flight track were stored with the radiometer data. All radiometers were calibrated before and after each measurement flight with liquid nitrogen cooled cold calibration targets and with ambient temperature hot calibration targets in.

Profiling radiometer measurements were conducted on 20 and 23 March. On 20 March R/V Aranda was at Ice Station 1 and on 23 March at Ice Station 2. Measurement flights were conducted in the Bothnian Bay in a northeast-southwest direction. The 93 GHz imaging radiometer measurements were conducted at Ice Station 1 on 20 March. An overview of the measurements is presented in Table 6 and in Figure 24. The base for the radiometer measurement flights was Oulu airport. Video imagery will be used to assign radiometer data to different ice types. During the imaging radiometer measurements only the three highest frequency profiling radiometers were mounted on the aircraft and operated.

Table 4. Technical characteristics of the profiling radiometers (Hallikainen & al. 1996).

	6.8 GHz	10.65 GHz	18.7 GHz	23.8 GHz	36.5 GHz	94 GHz
Radiometer type	Dicke	Dicke	Dicke	Dicke	Dicke	Total power
Polarisation	H and V	H and V	H and V	H and V	H and V	H and V
Incidence angle	50°	50°	50°	50°	50°	50°
Bandwidth	310 MHz	120 MHz	750 MHz	650 MHz	400 MHz	2000 MHz
Integration time	0.5 s	0.5 s	0.5 s	0.5 s	0.5 s	0.5 s
Sensitivity V/H	0.22/0.19 K	0.55/0.57 K	0.33/0.28 K	0.14/0.21 K	0.29/0.25 K	0.50/0.50 K
Antenna 3 dB beamwidth	4.8°	3.1°	3.9°	3.8°	4.0°	3.0°
Footprint (altitude 300 m)	39 by 61 m	25 by 39 m	32 by 50 m	31 by 48 m	33 by 51 m	24 by 38 m

Table 5. Technical characteristics of the 93 GHz imaging radiometer.

Parameter	Value
Center frequency	93 GHz
Radiometer type	Total power
Polarisation	H and V
Incidence angle	50°
Bandwidth	2 GHz
Scan method	Conical parallel scan
Viewing direction	Backward along track
Scan angle	70°
Swath width	1324 m at 1000 m altitude
Antenna 3 dB beamwidth	1.6°
Footprint	44 m by 68 m at 1000 m altitude
Integration time	0.01 s
Sensitivity V/H	0.34/0.38 K
Sampling overlap	29 %

Simultaneously with the radiometer measurements, the surface temperature was measured with a pyrometer instrument owned by FIMR. The pyrometer was mounted in the nose cone of the aircraft and looked straight down. The pyrometer is manufactured by The Pyrometer Instrument Co,. Inc., USA. The technical characteristics of the pyrometer are presented in Table 7. On 20 March there were difficulties with the heating of the pyrometer; the ambient temperature inside the nose cone was probably below the operating ambient temperature of the pyrometer, and the data may not be reliable.

Table 6. Radiometer measurements in the Bothnian Bay during the IMSI field campaign on 17-24 March 1997.

Date	Time [UTC]	Radiometers	Measurement route
20 March	05.30 - 08.20	All profiling channels	Start: N 65°04.319, E 24°47.809 - R/V Aranda: N 65°16.305, E 23°58.209 - South end: N 63°38.688, E 21°58.206 - R/V Aranda: N 65°16.305, E 23°58.209 - End: N 65°07.023, E 24°36.685 Length 490 km
20 March	11.45 - 12.14	93 GHz imaging 23.8, 36.5 and 94 GHz profiling	Start: N 65°08.870, E 24°29.158 End: N 65°16.305, E 23°58.167 Length 28 km Start: N 65°16.268, E 23°58.246 End: N 65°02.802, E 23°40.681 Length 42 km
23 March	06.08 - 07.21	All profiling channels	Start: N 65°04.889, E 24°45.159 - Ice Station 1:N 65°16.305, E 23°58.209 - R/V Aranda: N 64°12.875, E 22°25.129 - End: N 64°03.733, E 22°12.497 Length 200 km

Table 7. Technical characteristics of the pyrometer instrument (Precision Radiation ...).

Parameter	Value
Spectral region	8 - 14 μm
Field of View	2°
Footprint, altitude 300/1000 m	21/70 m
Measurement frequency	10 Hz
Accuracy	0.5°C
Sensitivity	Better than 0.1°C

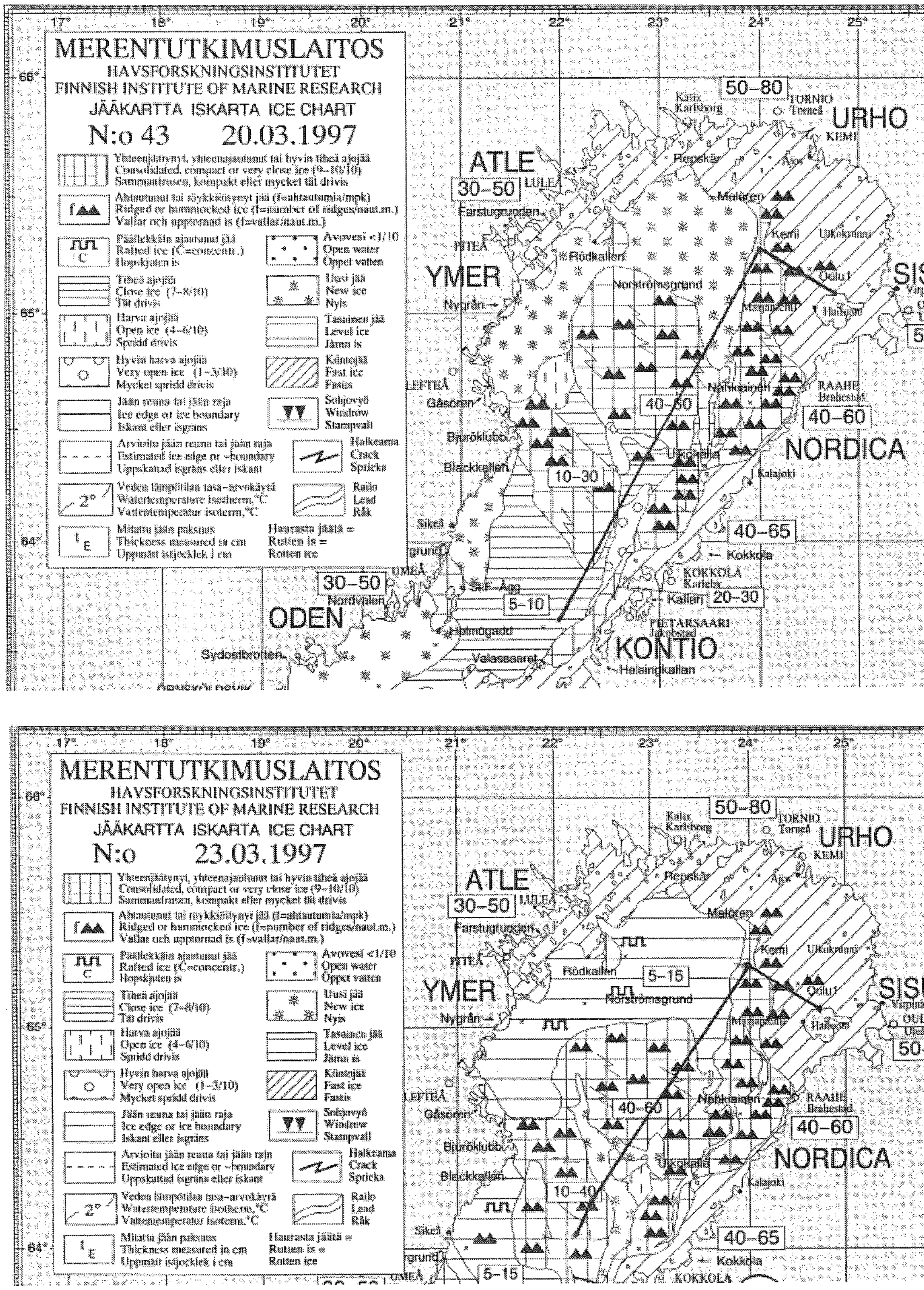


Fig. 24. Profiling radiometer measurements over the Bothnian Bay during the IMSI field campaign of 17-24 March 1997.

HUTSCAT measurements

The HUTSCAT (Helsinki University of Technology Scatterometer) is a helicopter-borne non-imaging FW-CW scatterometer operating simultaneously at frequencies of 5.4 GHz (C-band) and 9.8 GHz (X-band) and polarisations HH, VV, HV and VH (Hallikainen & al. 1993). HUTSCAT was designed and constructed during 1987-1990 by LST. The main parameters of HUTSCAT are presented in Table 8. The technical parameters for C-band were selected to be comparable with those of the ERS-1 SAR. The HUTSCAT measures 18 backscattered power spectra in each channel per second. Simultaneously with the backscattering measurements, the target is recorded by a video camera, and the DGPS-coordinates of the flight track are saved in a laptop computer. A typical flight altitude is 100 m and the flight speed is 25 m/s. The HUTSCAT is calibrated both internally and externally to eliminate short-term and long-term variations in the backscattered power level. Internal calibration is carried out using a delay line, which connects transmitted power to the receiver. External calibration is conducted with active radar calibrators (ARC).

Table 8. The main parameters of HUTSCAT scatterometer (Hallikainen & al. 1993).

Parameter	Value
Center frequencies	5.4 and 9.8 GHz
Modulation	FM-CW
Sweep bandwidth	230 MHz
Polarisation	HH, VV, HV, VH
Measurement range	8 to 167 m
Range resolution	0.68 m
Incidence angle	0° to 45° of nadir
Antenna effective two-way 3 dB beamwidth	4.7° (5.4 GHz) 4.4° (9.8 GHz)
Antenna sidelobe level	< -16.5 dB (5.4 GHz) < -16.5 dB (9.8 GHz)
Antenna polarisation isolation	26.0 dB (5.4 GHz) 28.5 dB (9.8 GHz)
Relative backscattering coefficient 90 % confidence interval	±0.4 dB (5.4 GHz) ±0.4 dB (9.8 GHz)
Absolute backscattering coefficient 90 % confidence interval	±0.5 - 0.9 dB (5.4 GHz) ±0.9 - 1.4 dB (9.8 GHz)

HUTSCAT measurements were conducted at Ice Station 1 on 20 and 21 March and at Ice Station 2 on 23 March. At both ice stations HUTSCAT measurements were conducted along a line, selected so that it included many different ice types (new ice, deformed ice, etc.). HUTSCAT measurements were conducted at incidence angles of 23, 34 and 45 degrees. The incidence angle in RADARSAT ScanSAR narrow images (width 300 km) varies from 20° to 40°. The incidence angle in ERS-2 SAR images is 23°. The video imagery will be used to assign HUTSCAT data to different ice types. The HUTSCAT measurements are summarized in Table 9.

Table 9. HUTSCAT measurements during the IMSI field campaign 17-24 March 1997.

Date	Time [UTC]	Measurements
20 March	16.26 - 17.17	Flag line. Two lines consisting of compact consolidated ice, new ice and a ship track. Total length 18 km.
21 March	06.07 - 08.23	Flag line. Curved line consisting of compact consolidated ice, new ice and fast ice. Line length 65 km.
23 March	14.47 - 16.46	Flag line. Straight line consisting of compact consolidated ice, frozen windrow, level ice. Line length 49 km (23°), 38 km (34°, 45°)

Most of the ground truth measurements were conducted along the flag line. On 20 March, only the 5.4 GHz subsystem of HUTSCAT was operated.

4. SPACEBORNE DATA

4.1. NOAA AVHRR

NOAA AVHRR data is used operationally for sea ice charting by the Finnish Ice Service. The NOAA images covering the time period of RADARSAT image acquisition were saved. This data will serve as an additional source of large-scale sea ice information when the geophysical validation for the RADARSAT data is performed. The NOAA images are especially valuable for sea ice and open water discrimination. Some information about ice thickness can also be extracted. The most useful channels are channel 2 (near infrared) and channel 4 (infrared). Naturally cloudiness dimishes the value of most images. Table 10 gives the saved channel 2 NOAA images with a cloudiness estimate. This estimate is based on the amount of cloud over the Bothnian Bay.

In the Table 10 the following codes are used:

0 = totally or almost cloudfree (cloud cover less than 2/10 over the Bothnian Bay)

1 = usable (cloud cover less than 5-6/10 over the Bothnian Bay)

2 = useless

Table 10. The usability of the channel 2 NOAA images from 19 March to 26 March.
For cloudiness codes see text above.

NOAA image	cloudiness
po_199703190833_ch2.tif	2
po_199703191033_ch2.tif	2
po_199703191333_ch2.tif	2
po_199703200933_ch2.tif	0
po_199703201333_ch2.tif	0
po_199703210933_ch2.tif	0
po_199703211533_ch2.tif	0
po_199703220833_ch2.tif	0
po_199703221433_ch2.tif	0
po_199703230833_ch2.tif	1
po_199703231433_ch2.tif	1
po_199703240833_ch2.tif	1
po_199703240933_ch2.tif	0
po_199703241433_ch2.tif	0
po_199703250933_ch2.tif	0
po_199703260933_ch2.tif	2
po_199703261433_ch2.tif	2

4.2. ERS-2 SAR

ERS SAR data was also used routinely by the Finnish Ice Service in the winter of 1996/97. ERS SAR only illuminates a 100 km-wide swath in a single orbit. In Table 11 are collected all the ERS-2 SAR images, which coincide with the field experiment, or which were recorded just before or just after it, and at least partly cover the Bothnian Bay or the northern part of the Bothnian Sea. Also denoted is a town or island which is covered by the SAR image.

4.3. RADARSAT SAR

The main objective of the whole field campaign was to gather enough field measurements to enable the geophysical validation of the RADARSAT data. The RADARSAT data acquired during the field campaign are presented in Table 12. All the other scenes mentioned in that table except that for 23 March were delivered to FIMR in early May. By the end of June this single scene still remained undelivered.

Table 11. All ERS-2 SAR scenes which at least partly cover the Bothnian Bay (BB) or the northern part of the Bothnian Sea (BS) from 12 March to 29 March. Orbit A refers to an ascending orbit and D to a descending one.

date	location	sea area	orbit
12.3.	Hailuoto	BB	A
12.3.	Kemi	BB	A
13.3.	Kemi	BB	D
13.3.	Raahe	BB	D
13.3.	Kokkola	BB	D
15.3.	Kokkola	BB	A
15.3.	Merikalla	BB	A
15.3.	Luleå	BB	A
16.3.	Luleå	BB	D
16.3.	Skellefteå	BB	D
16.3.	Pietarsaari	BB	D
16.3.	Vaasa	BB	D
18.3.	Kokkola	BB	A
18.3.	Skellefteå	BB	A
19.3.	Bjuröklubb	BB	D
19.3.	Umeå	BB	D
21.3.	Vaasa	BS	A
21.3.	Umeå	BS	A
24.3.	Kaskinen	BS	A
24.3.	Umeå	BS	A
28.3.	Oulu	BB	A
28.3.	Kemi	BB	A
29.3.	Kemi	BB	D
29.3.	Raahe	BB	D
29.3.	Rahja	BB	D

Table 12. The RADARSAT ScanSAR Wide images acquired during the field campaign. The 23 March image was still undelivered at the end of June -97.

date	time (UTC)	orbit
19.3.	4:58	D
20.3.	15:59	A
22.3.	5:10	D
23.3.*	16:12	A
26.3.	4:53	D

Four additional ScanSAR Wide scenes from in the winter of 1996/97 have also been delivered to FIMR. These scenes were for 26 February, Gulf of Bothnia, 27 February, Gulf of Finland and 8 March, one scene over the northern Baltic Sea and one over the southern Baltic Sea.

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Air temperatures at the weather stations 15-27 March 1997 (FMI 1997).

Station	Date	Time								Min	Avg.	Max
		00	03	06	09	12	15	18	21			
Oulu	15/03/97	-9	-9	-10	-7	-4	-4	-8	-10	-4	-7.6	-10
64° 56' N	16/03/97	-12	-12	-11	-10	-8	-5	-7	-7	-5	-9.0	-12
25° 22' E	17/03/97	-9	-11	-11	-8	-6	-3	-5	-7	-3	-7.5	-11
	18/03/97	-9	-10	-10	-7	-4	-3	-5	-7	-3	-6.9	-10
	19/03/97	-8	-8	-7	-4	-2	-2	-4	-5	-2	-5.0	-8
	20/03/97	-6	-6	-7	-5	-4	-3	-7	-11	-3	-6.1	-11
	21/03/97	-15	-15	-14	-8	-4	-5	-9	-13	-4	-10.4	-15
	22/03/97	-14	-16	-15	-7	-6	-7	-12	-13	-6	-11.3	-16
	23/03/97	-15	-15	-13	-9	-6	-6	-11	-13	-6	-11.0	-15
	24/03/97	-16	-17	-17	-8	-5	-5	-10	-15	-5	-11.6	-17
	25/03/97	-15	-17	-15	-5	-4	-3	-6	-10	-3	-9.4	-17
	26/03/97	-12	-12	-9	-6	-4	-4	-4	-4	-4	-6.9	-12
	27/03/97	-4	-4	-5	-4	-3	-4	-4	-4	-3	-4.0	-5
Hailuoto	15/03/97		-10	-9	-8	-5	-5	-9		-5	-7.7	-10
65° 02' N	16/03/97		-10	-11	-8	-7	-5	-6		-5	-7.8	-11
24° 44' E	17/03/97		-9	-10	-7	-5	-3	-5		-3	-6.5	-10
	18/03/97		-9	-8	-7	-4	-3	-5		-3	-6.0	-9
	19/03/97		-8	-7	-5	-3	-2	-3		-2	-4.7	-8
	20/03/97		-5	-6	-5	-4	-3	-8		-3	-5.2	-8
	21/03/97		-16	-13	-6	-4	-5	-9		-4	-8.8	-16
	22/03/97		-17	-16	-8	-6	-7	-12		-6	-11.0	-17
	23/03/97		-16	-15	-10	-5	-5	-11		-5	-10.3	-16
	24/03/97		-20	-18	-8	-5	-6	-11		-5	-11.3	-20
	25/03/97		-18	-16	-7	-5	-4	-10		-4	-10.0	-18
	26/03/97		-11	-9	-5	-3	-3	-4		-3	-5.8	-11
	27/03/97		-4	-4	-4	-3	-4	-4		-3	-3.8	-4
Ulkokalla	15/03/97	-4	-5	-6	-5	-5	-7	-8	-8	-4	-6.0	-8
64° 20' N	16/03/97	-9	-10	-10	-9	-6	-5	-5	-4	-4	-7.3	-10
23° 27' E	17/03/97	-5	-7	-8	-7	-6	-4	-5	-6	-4	-6.0	-8
	18/03/97	-6	-8	-8	-6	-6	-5	-5	-6	-5	-6.3	-8
	19/03/97	-7	-7	-6	-5	-4	-3	-3	-4	-3	-4.9	-7
	20/03/97	-5	-5	-6	-6	-5	-5	-6	-7	-5	-5.6	-7
	21/03/97	-9	-10	-11	-9	-6	-6	-7	-9	-6	-8.4	-11
	22/03/97	-9	-9	-9	-7	-6	-7	-8	-9	-6	-8.0	-9
	23/03/97	-9	-9	-9	-9	-7	-7	-9	-10	-7	-8.6	-10
	24/03/97	-12	-13	-13	-11	-8	-8	-9	-11	-8	-10.6	-13
	25/03/97	-12	-13	-13	-10	-6	-6	-7	-8	-6	-9.4	-13
	26/03/97	-9	-8	-6	-4	-3	-3	-3	-2	-2	-4.8	-9
	27/03/97	-1	-4	-4	-4	-3	-4	-4	-2	-1	-3.3	-4
Kokkola Öja	15/03/97				-1	-5	-6	-10	-12	-1	-6.8	-12
63° 53' N	16/03/97	-12	-14	-14	-7	-4	-6	-7	-9	-4	-9.1	-14
22° 56' E	17/03/97	-9	-10	-11	-5	-3	-5	-9	-7	-3	-7.4	-11
	18/03/97	-8	-9	-10	-5	-3	-5	-8	-8	-3	-7.0	-10
	19/03/97		-8		-5	-4	-3	-3	-4	-3	-4.5	-8
	20/03/97	-5	-5	-6	-4	-3	-4	-7	-8	-3	-5.3	-8
	21/03/97	-9	-11	-12	-8	-4	-5	-9	-9	-4	-8.4	-12
	22/03/97	-10	-11	-11	-7	-5	-5	-7	-8	-5	-8.0	-11
	23/03/97	-9	-9	-9	-7	-7	-7	-8	-11	-7	-8.4	-11
	24/03/97	-12	-13	-13	-9	-6	-7	-11	-11	-6	-10.3	-13

Air temperatures at the weather stations 15-27 March 1997 (FMI 1997).

Station	Date	Time 00	03	06	09	12	15	18	21	Max.	Avg.	Min
Kokkola Öja	25/03/97	-12	-13	-12	-5	-2	-3	-5	-7	-2	-7.4	-13
	26/03/97	-7	-6	-4	-2	-2	-1		0	0	-3.1	-7
	27/03/97	-1	-3	-3	-3	-2	-3	-2	0	0	-2.1	-3
Valassaaret	15/03/97	-1	-1	-2	-3	-2	-3	-4	-4	-1	-2.5	-4
63° 26' N	16/03/97	-4	-4	-5	-6	-3	-2	-3	-3	-2	-3.8	-6
21° 04' E	17/03/97	-5	-5	-6	-5	-2	-1	-3	-2	-1	-3.6	-6
	18/03/97	-4	-4	-5	-4	-4	-3	-4	-4	-3	-4.0	-5
	19/03/97	-5	-3	-6	-5	-4	-3	-3	-3	-3	-4.0	-6
	20/03/97	-2	-3	-3	-3	-3	-4	-5	-5	-2	-3.5	-5
	21/03/97	-6	-7	-8	-6	-5	-4	-6	-7	-4	-6.1	-8
	22/03/97	-8	-7	-8	-5	-5	-7	-9	-9	-5	-7.3	-9
	23/03/97	-9	-10	-9	-8	-7	-6	-6	-6	-6	-7.6	-10
	24/03/97	-7	-7	-9	-8	-6	-5	-7	-9	-5	-7.3	-9
	25/03/97	-9	-11	-11	-8	-2	-1	-3	-3	-1	-6.0	-11
	26/03/97	-4	-3	-2	-1	-1	0	0	0	0	-1.4	-4
	27/03/97	-1	-2	-2	-1	0	1	0	-1	1	-0.8	-2

Air pressure at the weather stations 15-27 March 1997 (FMI 1997).
The averages, maxima, and minima are calculated if three or more values are obtainable.

Station	Date	Time 0	6	12	18	Max	Avg.	Min
Oulu	15/3/1997	1002	1000	1001	1003	1003	1002	1000
64° 56' N	16/3/1997	1004	1006	1008	1010	1010	1007	1004
25° 22' E	17/3/1997	1012	1014	1016	1017	1017	1015	1012
	18/3/1997	1018	1017	1015	1014	1018	1016	1014
	19/3/1997	1009	1004	1003	1004	1009	1005	1003
	20/3/1997	1006	1009	1012	1015	1015	1011	1006
	21/3/1997	1017	1019	1020	1020	1020	1019	1017
	22/3/1997	1021	1022	1022	1023	1023	1022	1021
	23/3/1997	1023	1024	1025	1026	1026	1025	1023
	24/3/1997	1026	1026	1026	1026	1026	1026	1026
	25/3/1997	1026	1027	1026	1023	1027	1026	1023
	26/3/1997	1021	1016	1012	1005	1021	1014	1005
	27/3/1997	996	988	984	982	996	988	982
Hailuoto	15/3/1997		1001	1002	1004	1004	1002	1001
65° 02' N	16/3/1997		1008	1010	1011	1011	1010	1008
24° 44' E	17/3/1997		1016	1017	1019	1019	1017	1016
	18/3/1997		1018	1017	1015	1018	1017	1015
	19/3/1997		1006	1005	1006	1006	1006	1005
	20/3/1997		1010	1014	1016	1016	1013	1010
	21/3/1997		1019	1021	1022	1022	1021	1019
	22/3/1997		1023	1024	1024	1024	1024	1023
	23/3/1997		1025	1026	1026	1026	1026	1025
	24/3/1997		1027	1027	1027	1027	1027	1027
	25/3/1997		1027	1026	1024	1027	1026	1024
	26/3/1997		1016	1011	1005	1016	1011	1005
	27/3/1997		988	984	982	988	985	982

Air pressure at the weather stations 15-27 March 1997 (FMI 1997).
The averages, maxima, and minima are calculated if three or more values are obtainable.

Station	Date	Time				Max	Avg.	Min
		0	6	12	18			
Ulkokalla	15/3/1997	1002	999	1001	1003	1003	1001	999
64° 20' N	16/3/1997	1006	1008	1011	1012	1012	1009	1006
23° 27' E	17/3/1997	1013	1016	1018	1019	1019	1017	1013
	18/3/1997	1019	1019	1017	1014	1019	1017	1014
	19/3/1997	1011	1006	1004	1005	1011	1007	1004
	20/3/1997	1006	1009	1012	1015	1015	1011	1006
	21/3/1997	1017	1019	1020	1021	1021	1019	1017
	22/3/1997	1022	1023	1024	1024	1024	1023	1022
	23/3/1997	1024	1025	1026	1026	1026	1025	1024
	24/3/1997	1026	1027	1026	1026	1027	1026	1026
	25/3/1997	1026	1026	1025	1023	1026	1025	1023
	26/3/1997	1019	1014	1008	1002	1019	1011	1002
	27/3/1997	992	982	979	977	992	983	977
Kokkola Öja	15/3/1997		1000	1002				
63° 53' N	16/3/1997	1006	1008	1011	1012	1012	1009	1006
22° 56' E	17/3/1997		1014	1017	1019	1019	1017	1014
	18/3/1997		1018	1016	1014	1018	1016	1014
	19/3/1997			1004	1005			
	20/3/1997	1006	1008	1011	1014	1014	1010	1006
	21/3/1997		1018	1019	1021	1021	1019	1018
	22/3/1997		1022	1022	1023	1023	1022	1022
	23/3/1997	1024	1024	1025	1025	1025	1025	1024
	24/3/1997		1026	1025	1025	1026	1025	1025
	25/3/1997		1025	1024	1022	1025	1024	1022
	26/3/1997	1018	1012					
	27/3/1997	989	979	976	976	989	980	976
Valassaaret	15/3/1997	1002	999	1001	1003	1003	1001	999
63° 26' N	16/3/1997	1006	1009	1012	1013	1013	1010	1006
21° 04' E	17/3/1997	1014	1016	1019	1020	1020	1017	1014
	18/3/1997	1020	1019	1019	1015	1020	1018	1015
	19/3/1997	1012	1008	1006	1006	1012	1008	1006
	20/3/1997	1006	1008	1011	1014	1014	1010	1006
	21/3/1997	1015	1017	1019	1020	1020	1018	1015
	22/3/1997	1021	1023	1023	1023	1023	1023	1021
	23/3/1997	1023	1024	1024	1024	1024	1024	1023
	24/3/1997	1024	1024	1024	1023	1024	1024	1023
	25/3/1997	1023	1024	1023	1020	1024	1023	1020
	26/3/1997	1015	1009	1005	999	1015	1007	999
	27/3/1997	984	974	972	975	984	976	972

Wind speed at the weather stations 15-27 March 1997 (FMI 1997).
The averages, maxima, and minima are calculated if five or more values are obtainable.

Station	Date	Time								Max	Avg.	Min
		0	3	6	9	12	15	18	21			
Oulu	15/3/1997	2	1	1	2	2	4	3	3	4	2.3	1
64° 56' N	16/3/1997	4	5	6	7	6	5	4	3	7	5	3
25° 22' E	17/3/1997	3	3	2	4	5	5	5	4	5	3.9	2
	18/3/1997	4	4	3	4	6	7	4	5	7	4.6	3
	19/3/1997	5	6	6	8	7	7	4	4	8	5.9	4
	20/3/1997	3	3	2	4	3	2	1	2	4	2.5	1
	21/3/1997	1	1	2	1	1	3	2	2	3	1.6	1
	22/3/1997	1	1	1	0	2	3	2	2	3	1.5	0
	23/3/1997	1	1	1	0	2	1	1	1	2	1	0
	24/3/1997	1	1	1	1	0	2	2	2	2	1.3	0
	25/3/1997	1	1	1	2	1	3	3	3	3	1.9	1
	26/3/1997	4	4	5	5	6	6	6	6	6	5.3	4
	27/3/1997	8	9	10	11	11	11	10	9	11	9.9	8
Hailuoto	15/3/1997		1	1	3	3	3	2		3	2.2	1
65° 02' N	16/3/1997		4	4	5	4	4	3		5	4	3
24° 44' E	17/3/1997		3	3	3	5	4	2		5	3.3	2
	18/3/1997		4	5	6	6	5	4		6	5	4
	19/3/1997		7	7	7	6	5	4		7	6	4
	20/3/1997		4	3	3	3	2	1		4	2.7	1
	21/3/1997		1	1	1	1	2	1		2	1.2	1
	22/3/1997		1	0	2	1	2	1		2	1.2	0
	23/3/1997		0	1	1	2	2	0		2	1	0
	24/3/1997		0	0	0	1	2	1		2	0.7	0
	25/3/1997		1	1	1	3	2	1		3	1.5	1
	26/3/1997		3	4	5	5	5	5		5	4.5	3
	27/3/1997		7	8	7	8	8	7		8	7.5	7
Ulkokalla	15/3/1997	2	3	5	4	5	5	4	2	5	3.8	2
64° 20' N	16/3/1997	4	4	6	7	7	5	6	6	7	5.6	4
23° 27' E	17/3/1997	6	5	5	5	6	6	5	4	6	5.3	4
	18/3/1997	6	4	6	7	8	8	7	6	8	6.5	4
	19/3/1997	7	11	11	12	11	11	8	8	12	9.9	7
	20/3/1997	7	6	5	5	4	5	3	3	7	4.8	3
	21/3/1997	2	2	1	1	1	3	2	2	3	1.8	1
	22/3/1997	1	2	1	1	2	2	2	0	2	1.4	0
	23/3/1997	1	1	1	1	2	3	2	0	3	1.4	0
	24/3/1997		2	1	0	2	4	4	2	4	2.1	0
	25/3/1997	3	2	2	1	2	4	4	5	5	2.9	1
	26/3/1997	6	7	8	10	10	9	9	8	10	8.4	6
	27/3/1997	13	15	16	14	15	14	12	11	16	13.8	11
Kokkola Öja	15/3/1997				3	9	8	5	3	9	5.6	3
63° 53' N	16/3/1997	4	5	7	7	6	6	6	8	8	6.1	4
22° 56' E	17/3/1997			6	3	6	5	6	7	7	5.5	3
	18/3/1997			7	8	8	9	8	6	9	7.7	6
	19/3/1997		12		12	14	11	10		14	11.8	10
	20/3/1997	9	7	6	4	6	6	4	1	9	5.4	1
	21/3/1997			2	1	3	5	4	3	5	3	1
	22/3/1997			1	1	3		2	2	3	1.8	1
	23/3/1997	0		2	0	3	3	5	2	5	2.1	0

Wind speed at the weather stations 15-27 March 1997 (FMI 1997).
The averages, maxima, and minima are calculated if five or more values are obtainable.

Station	Date	Time								Max	Avg.	Min
		0	3	6	9	12	15	18	21			
Kokkola Öja	24/3/1997			1	0	5	6	2	3	6	2.8	0
	25/3/1997			3	3	4	5	5	6	6	4.3	3
	26/3/1997	6	9	8	10		8		10	10	8.5	6
	27/3/1997	14	15	15	15	15	13	9	4	15	12.5	4
Valassaaret 63° 26' N 21° 04' E	15/3/1997	6	8	8	8	6	7	3	3	8	6.1	3
	16/3/1997	4	6	8	6	7	7	8	9	9	6.9	4
	17/3/1997	8	8	8	7	5	6	3	6	8	6.4	3
	18/3/1997	8	9	8		8	8	9		9	8.3	8
	19/3/1997	9	13	12	14	14	12	11	11	14	12	9
	20/3/1997	12	11	9	7	7	7	4	4	12	7.6	4
	21/3/1997	2	2	2	1	3	3	3	3	3	2.4	1
	22/3/1997	3	3	3	3	3	1	1	2	3	2.4	1
	23/3/1997	2	3	3	2	5	5	6	6	6	4	2
	24/3/1997	5	4	4	5	6	8	7	5	8	5.5	4
	25/3/1997	4	4	4	4	4	4	3	4	4	3.9	3
	26/3/1997	7	8	9	11	9	8	8	11	11	8.9	7
	27/3/1997	10	10	10	9	8	7	7	5	10	8.3	5

Wind direction at the weather stations 15-27 March 1997 (FMI 1997).
0 = calm, 360 = North, 90 = East, 180 = South, 270 = West

Averages are calculated if five or more values are obtainable.

Station	Date	Time								Avg.
		0	3	6	9	12	15	18	21	
Oulu 64° 56' N 25° 22' E	15/3/1997	280	320	90	70	30	340	350	350	1
	16/3/1997	340	340	340	340	340	340	340	10	343
	17/3/1997	350	350	350	340	340	340	350	350	346
	18/3/1997	360	350	10	360	350	360	20	10	2
	19/3/1997	360	360	10	10	30	50	360	20	15
	20/3/1997	10	30	60	120	40	60	70	100	61
	21/3/1997	120	160	150	120	340	350	360	360	61
	22/3/1997	310	60	150	0	330	330	320	280	325
	23/3/1997	280	220	120	0	20	320	360	10	341
	24/3/1997	50	160	120	120	0	10	10	50	72
	25/3/1997	130	150	140	130	160	130	150	150	142
	26/3/1997	150	160	140	170	160	160	160	150	156
	27/3/1997	150	150	140	140	150	140	140	140	144
Hailuoto 65° 02' N 24° 44' E	15/3/1997		30	40	60	20	10	330		22
	16/3/1997		340	330	330	330	330	330		331
	17/3/1997		350	350	350	340	330	350		345
	18/3/1997		350	350	360	360	350	20		358
	19/3/1997		350	350	360	10	10	10		2
	20/3/1997		20	40	60	50	30	40		40
	21/3/1997		100	80	50	50	20	20		53
	22/3/1997		290	0	20	10	320	270		326
	23/3/1997		0	240	260	330	350	0		
	24/3/1997		0	0	0	50	70	30		

Wind direction at the weather stations 15-27 March 1997 (FMI 1997).
0 = calm, 360 = North, 90 = East, 180 = South, 270 = West

Averages are calculated if five or more values are obtainable.

Station	Date	Time								Avg.
		0	3	6	9	12	15	18	21	
Hailuoto	25/3/1997		90	70	70	60	70	90		75
65° 02' N	26/3/1997		140	130	150	140	140	140		140
24° 44' E	27/3/1997		140	120	120	120	120	120		123
Ulkokalla	15/3/1997	60	150	70	50	10	10	10	360	38
64° 20' N	16/3/1997	340	320	320	320	330	340	330	340	330
23° 27' E	17/3/1997	340	340	340	340	330	330	320	330	334
	18/3/1997	350	340	340	350	340	350	350	10	349
	19/3/1997	10	350	360	10	10	10	10	10	6
	20/3/1997	10	20	40	40	30	30	40	60	34
	21/3/1997	80	150	110	110	350	350	10	60	63
	22/3/1997	20	360	330	350	350	310	360	0	349
	23/3/1997	260	270	190	250	10	350	30	0	297
	24/3/1997		70	90	0	20	20	40	70	52
	25/3/1997	110	140	110	110	70	60	120	130	107
	26/3/1997	140	140	160	150	150	150	150	140	147
	27/3/1997	150	120	120	130	130	120	130	130	129
Kokkola Öja	15/3/1997				320	360	340	350	20	350
63° 53' N	16/3/1997	350	340	320	330	320	330	330	330	331
22° 56' E	17/3/1997			340	350	320	340	340	330	337
	18/3/1997			350	350	350	350	350	360	351
	19/3/1997		360		360	10	360	10		4
	20/3/1997	20	20	30	30	30	20	40	60	31
	21/3/1997			140	140	10	350	10	30	41
Kokkola Öja	22/3/1997			310	50	350		350	10	358
	23/3/1997	0		110	0	30	30	50	80	59
	24/3/1997			140	0	20	30	50	100	65
	25/3/1997			150	140	160	150	140	150	148
	26/3/1997	160	150	160	160		160		160	158
	27/3/1997	140	140	140	140	140	140	150	190	147
Valassaaret	15/3/1997	230	260	300	300	360	40	40	20	333
63° 26' N	16/3/1997	60	10	340	330	310	330	330	330	342
21° 04' E	17/3/1997	340	340	340	350	340	340	350	320	340
	18/3/1997	340	360	340		360	10	10		357
	19/3/1997	10	340	340	350	360	360	350	350	352
	20/3/1997	10	10	20	40	60	30	30	40	30
	21/3/1997	40	100	120	80	60	50	20	30	62
	22/3/1997	10	10	10	340	340	90	140	140	33
	23/3/1997	130	110	110	100	80	70	70	80	94
	24/3/1997	90	110	80	80	70	50	60	80	77
	25/3/1997	110	120	110	110	140	160	140	150	130
	26/3/1997	140	160	150	170	180	180	170	150	163
	27/3/1997	130	130	130	130	140	200	250	250	163

Air humidity at the weather stations 15-27 March 1997 (FMI 1997).

The averages, maxima, and minima are calculated if three or more values are obtainable.

Station	Date	Time				Max	Avg.	Min
		0	6	12	18			
Oulu	15/3/1997	85	90	49	64	90	72	49
64° 56' N	16/3/1997	75	70	69	78	78	73	69
25° 22' E	17/3/1997	82	88	69	74	88	78	69
	18/3/1997	79	85	66	70	85	75	66
	19/3/1997	85	89	70	93	93	84	70
	20/3/1997	90	85	58	64	90	74	58
	21/3/1997	86	84	54	79	86	76	54
	22/3/1997	87	85	67	90	90	82	67
	23/3/1997	88	90	65	88	90	83	65
	24/3/1997	81	86	46	70	86	71	46
	25/3/1997	80	76	38	44	80	60	38
	26/3/1997	67	64	81	96	96	77	64
	27/3/1997	87	88	71	94	94	85	71
Hailuoto	15/3/1997		72	55	69	72	65	55
65° 02' N	16/3/1997		65	60	64	65	63	60
24° 44' E	17/3/1997		75	58	74	75	69	58
	18/3/1997		76	62	70	76	69	62
	19/3/1997		84	75	89	89	83	75
	20/3/1997		86	57	70	86	71	57
	21/3/1997		88	50	73	88	69	50
	22/3/1997		85	72	86	86	81	72
	23/3/1997		87	55	78	87	73	55
	24/3/1997		87	46	65	87	66	46
	25/3/1997		86	42	58	86	62	42
	26/3/1997		62	85	86	86	78	62
	27/3/1997		89	71	86	89	82	71
Ulkokalla	15/3/1997	87	96	80	82	96	86	80
64° 20' N	16/3/1997	86	79	75	77	86	79	75
23° 27' E	17/3/1997	77	85	78	81	85	80	77
	18/3/1997	80	87	81	78	87	82	78
	19/3/1997	84	84	86	90	90	86	84
	20/3/1997	90	89	80	87	90	87	80
	21/3/1997	86	86	73	85	86	83	73
	22/3/1997	94	96	85	94	96	92	85
	23/3/1997	95	94	85	95	95	92	85
	24/3/1997	93	91	81	86	93	88	81
	25/3/1997	79	81	69	74	81	76	69
	26/3/1997	70	86	95	94	95	86	70
	27/3/1997	86	95	86	97	97	91	86
Kokkola Öja	15/3/1997			96	91			
63° 53' N	16/3/1997	89	88	78	89	89	86	78
22° 56' E	17/3/1997		90	75	89	90	85	75
	18/3/1997		91	78	88	91	86	78
	19/3/1997			90	95			
	20/3/1997	91	92	80	91	92	89	80
	21/3/1997		84	72	92	92	83	72
	22/3/1997		90	89	89	90	89	89

Air humidity at the weather stations 15-27 March 1997 (FMI 1997).

The averages, maxima, and minima are calculated if three or more values are obtainable.

Station	Date	Time 0	6	12	18	Max	Avg.	Min
Kokkola Öja	23/3/1997	93	91	82	92	93	90	82
	24/3/1997		88	76	87	88	84	76
	25/3/1997		73	39	54	73	55	39
	26/3/1997	74	90					
	27/3/1997	91	97	95	98	98	95	91
Valassaaret	15/3/1997	76	72	72	74	76	74	72
63° 26' N	16/3/1997	65	79	52	53	79	62	52
21° 04' E	17/3/1997	61	62	59	73	73	64	59
	18/3/1997	66	76	69	62	76	68	62
	19/3/1997	91	85	93	93	93	91	85
	20/3/1997	90	88	81	82	90	85	81
	21/3/1997	93	95	60	79	95	82	60
	22/3/1997	90	95	88	96	96	92	88
	23/3/1997	92	93	88	90	93	91	88
	24/3/1997	87	84	72	75	87	80	72
	25/3/1997	81	76	49	88	88	74	49
	26/3/1997	83	94	97	92	97	92	83
	27/3/1997	95	96	96	76	96	91	76

Cloudiness at the weather stations 15-27 March 1997 (FMI 1997).

0 = no clouds
1 = 1/8 or less of the sky covered by clouds
2 = 2/8 of the sky covered by clouds
3 = 3/8 of the sky covered by clouds
4 = 4/8 of the sky covered by clouds
5 = 5/8 of the sky covered by clouds
6 = 6/8 of the sky covered by clouds
7 = 7/8 of the sky covered by clouds
8 = the whole sky covered by clouds
9 = cannot be determined

Averages are calculated if three or more values are obtainable.

Station	Date	Time 0	6	12	18	Avg.
Oulu	15/3/1997	7	6	4	2	5
64° 56' N	16/3/1997	1	6	7	4	5
25° 22' E	17/3/1997	1	1	1	3	2
	18/3/1997	1	3	1	1	2
	19/3/1997	1	8	8	7	6
	20/3/1997	3	2	4	3	3
	21/3/1997	1	1	1	2	1
	22/3/1997	4	2	2	3	3
	23/3/1997	4	4	4	1	3
	24/3/1997	1	3	1	1	2
	25/3/1997	1	0	1	1	1
	26/3/1997	1	7	8	8	6
	27/3/1997	8	8	8	8	8
Hailuoto	15/3/1997		5	3	1	3
65° 02' N	16/3/1997		3	7	2	4
24° 44' E	17/3/1997		0	0	1	0
	18/3/1997		1	0	1	1

Cloudiness at the weather stations 15-27 March 1997 (FMI 1997).

0 = no clouds
1 = 1/8 or less of the sky covered by clouds
2 = 2/8 of the sky covered by clouds
3 = 3/8 of the sky covered by clouds
4 = 4/8 of the sky covered by clouds
5 = 5/8 of the sky covered by clouds
6 = 6/8 of the sky covered by clouds
7 = 7/8 of the sky covered by clouds
8 = the whole sky covered by clouds
9 = cannot be determined

Averages are calculated if three or more values are obtainable.

Station	Date	Time				Avg.
		0	6	12	18	
	19/3/1997		8	8	8	8
	20/3/1997		7	5	2	5
	21/3/1997		1	1	0	1
	22/3/1997		1	1	1	1
	23/3/1997		6	4	1	4
	24/3/1997		1	1	0	1
	25/3/1997		1	0	0	0
	26/3/1997		7	8	8	8
	27/3/1997		8	8	8	8
Kokkola Öja	15/3/1997			8	7	
63° 53' N	16/3/1997	2	3	4	4	3
22° 56' E	17/3/1997		1	0	1	1
	18/3/1997		4	2	2	3
	19/3/1997			7	7	
	20/3/1997	2	6	3	2	3
	21/3/1997		1	1	1	1
	22/3/1997		4	8	8	7
	23/3/1997	8	8	6	3	6
	24/3/1997		1	1	1	1
	25/3/1997		0	0	3	1
	26/3/1997	7	8			8
	27/3/1997	8	8	8	8	8
Valassaaret	15/3/1997	8	4	4	6	6
63° 26' N	16/3/1997	3	2	3	4	3
21° 04' E	17/3/1997	1	2	1	2	2
	18/3/1997	2	5	5	6	5
	19/3/1997	8	8	8	8	8
	20/3/1997	8	8	8	5	7
	21/3/1997	3	4	3	2	3
	22/3/1997	1	8	8	7	6
	23/3/1997	3	8	8	8	7
	24/3/1997	8	7	4	3	6
	25/3/1997	2	3	7	6	5
	26/3/1997	8	8	8	8	8
	27/3/1997	8	8	8	8	8

Visibility at the weather stations 15-27 March 1997 (FMI 1997).

The averages, maxima, and minima are calculated if three or more values are obtainable.

Station	Date	Time				Max	Avg.	Min
		0	6	12	18			
Oulu	15/3/1997	50000	50000	50000	50000	50000	50000	50000
64° 56' N	16/3/1997	50000	50000	50000	50000	50000	50000	50000
25° 22' E	17/3/1997	50000	50000	50000	40000	50000	47500	40000
	18/3/1997	50000	50000	50000	50000	50000	50000	50000
	19/3/1997	50000	3000	20000	9000	50000	20500	3000
	20/3/1997	40000	20000	30000	40000	40000	32500	20000
	21/3/1997	40000	40000	40000	40000	40000	40000	40000
	22/3/1997	15000	20000	40000	10000	40000	21250	10000
	23/3/1997	50000	8000	30000	25000	50000	28250	8000
	24/3/1997	20000	10000	40000	40000	40000	27500	10000
	25/3/1997	30000	40000	40000	50000	50000	40000	30000
	26/3/1997	50000	40000	<100	3000	50000	23250	<100
	27/3/1997	10000	1500	7000	1800	10000	5075	1500
Hailuoto	15/3/1997		30000	30000	20000	30000	26667	20000
65° 02' N	16/3/1997		30000	30000	20000	30000	26667	20000
24° 44' E	17/3/1997		30000	30000	30000	30000	30000	30000
	18/3/1997		30000	30000	20000	30000	26667	20000
	19/3/1997		1000	5000	1000	5000	2333	1000
	20/3/1997		20000	30000	20000	30000	23333	20000
	21/3/1997		30000	30000	20000	30000	26667	20000
	22/3/1997		30000	30000	20000	30000	26667	20000
	23/3/1997		20000	30000	20000	30000	23333	20000
	24/3/1997		30000	30000	20000	30000	26667	20000
	25/3/1997		30000	30000	20000	30000	26667	20000
	26/3/1997		20000	1000	600	20000	7200	600
	27/3/1997		500	2000	1000	2000	1167	500
Kokkola Öja	15/3/1997			25000				
63° 53' N	16/3/1997	30000	30000	30000	30000	30000	30000	30000
22° 56' E	17/3/1997		30000	35000	30000	35000	31667	30000
	18/3/1997		30000	35000	30000	35000	31667	30000
	19/3/1997		4000	9000				
	20/3/1997	20000	20000	25000	25000	25000	22500	20000
	21/3/1997		30000	30000	25000	30000	28333	25000
	22/3/1997		10000	2000	15000	15000	9000	2000
	23/3/1997	20000	5000	10000	25000	25000	15000	5000
	24/3/1997		25000	30000	30000	30000	28333	25000
	25/3/1997		25000	25000	30000	30000	26667	25000
	26/3/1997	30000	4000					
	27/3/1997	3000	1000	2000	2000	3000	2000	1000
Valassaaret	15/3/1997	9000	25000	25000	25000	25000	21000	9000
63° 26' N	16/3/1997	25000	30000	30000	30000	30000	28750	25000
21° 04' E	17/3/1997	30000	25000	25000	25000	30000	26250	25000
	18/3/1997	30000	25000	25000	25000	30000	26250	25000
	19/3/1997	2000	5000	2000	2000	5000	2750	2000
	20/3/1997	2000	10000	10000	20000	20000	10500	2000
	21/3/1997	20000	20000	20000	20000	20000	20000	20000
	22/3/1997	20000	20000	12000	500	20000	13125	500

Visibility at the weather stations 15-27 March 1997 (FMI 1997).

The averages, maxima, and minima are calculated if three or more values are obtainable.

Station	Date	Time				Max	Avg.	Min
		0	6	12	18			
Valassaaret	23/3/1997	20000	2000	5000	4000	20000	7750	2000
	24/3/1997	6000	20000	20000	20000	20000	16500	6000
	25/3/1997	25000	25000	20000	18000	25000	22000	18000
	26/3/1997	20000	2000	5000	10000	20000	9250	2000
	27/3/1997	1000	1000	2000	20000	20000	6000	1000

Date and time (UTC) (yyyy,mm,dd,time)	Air Pressure [mb]	T_{air} [°C]	Wind Speed [m/s]	Wind Direction [°]	Position
1997,03,20,140042	1012.9	-5.2	1.3	10	6516.28,N,02358.44,E
1997,03,20,140118	1012.9	-5.2	1.3	11	6516.28,N,02358.44,E
1997,03,20,141954	1012.9	-5.2	1.6	14	6516.28,N,02358.44,E
1997,03,20,143954	1013.0	-5.3	1.8	17	6516.28,N,02358.43,E
1997,03,20,145954	1013.1	-5.4	2.0	18	6516.28,N,02358.44,E
1997,03,20,151954	1013.3	-5.4	2.1	6	6516.28,N,02358.44,E
1997,03,20,153954	1013.6	-5.5	2.4	8	6516.28,N,02358.44,E
1997,03,20,155954	1013.7	-5.5	2.0	4	6516.28,N,02358.44,E
1997,03,20,161954	1013.8	-5.5	2.3	20	6516.28,N,02358.44,E
1997,03,20,163954	1014.0	-5.4	2.4	18	6516.28,N,02358.44,E
1997,03,20,165956	1014.1	-5.5	2.6	23	6516.28,N,02358.44,E
1997,03,20,171954	1014.1	-5.6	2.3	20	6516.28,N,02358.44,E
1997,03,20,173954	1014.2	-5.9	3.0	27	6516.28,N,02358.44,E
1997,03,20,175955	1014.3	-5.8	3.1	20	6516.28,N,02358.44,E
1997,03,20,181956	1014.3	-6.0	3.2	18	6516.28,N,02358.44,E
1997,03,20,183956	1014.5	-6.4	3.1	20	6516.28,N,02358.44,E
1997,03,20,185956	1014.6	-6.5	3.5	21	6516.28,N,02358.44,E
1997,03,20,191956	1014.6	-6.6	3.5	23	6516.28,N,02358.43,E
1997,03,20,193954	1014.7	-7.0	3.3	34	6516.28,N,02358.44,E
1997,03,20,195954	1014.8	-7.2	3.2	34	6516.28,N,02358.44,E
1997,03,20,201954	1014.9	-7.3	3.3	32	6516.28,N,02358.44,E
1997,03,20,203954	1015.1	-7.6	3.2	38	6516.28,N,02358.44,E
1997,03,20,205956	1015.2	-7.7	3.1	42	6516.28,N,02358.44,E
1997,03,20,211957	1015.2	-7.7	3.5	46	6516.28,N,02358.43,E
1997,03,20,213954	1015.4	-8.0	2.9	35	6516.28,N,02358.44,E
1997,03,20,215855	1015.5	-8.2	3.1	42	6516.28,N,02358.44,E
1997,03,20,221956	1015.6	-8.2	3.4	44	6516.28,N,02358.44,E
1997,03,20,223954	1015.7	-8.4	3.6	52	6516.28,N,02358.44,E
1997,03,20,225954	1015.7	-8.5	4.0	62	6516.28,N,02358.44,E
1997,03,20,231954	1015.7	-8.6	3.1	65	6516.28,N,02358.44,E
1997,03,20,233954	1015.9	-9.3	3.2	62	6516.28,N,02358.44,E
1997,03,20,235956	1016.0	-9.5	2.8	56	6516.28,N,02358.44,E
1997,03,21,001954	1016.1	-9.6	2.3	65	6516.28,N,02358.44,E
1997,03,21,003954	1016.3	-10.0	2.1	68	6516.28,N,02358.44,E
1997,03,21,005954	1016.3	-10.2	1.9	72	6516.28,N,02358.44,E
1997,03,21,011954	1016.4	-10.3	1.7	70	6516.28,N,02358.44,E
1997,03,21,013957	1016.4	-10.5	1.5	76	6516.28,N,02358.44,E
1997,03,21,015957	1016.5	-10.7	1.7	82	6516.28,N,02358.44,E
1997,03,21,021956	1016.5	-10.9	2.1	82	6516.28,N,02358.44,E
1997,03,21,023956	1016.6	-11.4	1.8	84	6516.28,N,02358.44,E
1997,03,21,025956	1016.7	-11.5	1.7	90	6516.28,N,02358.44,E
1997,03,21,031958	1016.7	-11.5	1.5	96	6516.28,N,02358.44,E
1997,03,21,033956	1016.9	-11.4	1.7	100	6516.28,N,02358.43,E
1997,03,21,035956	1016.9	-11.6	1.9	101	6516.28,N,02358.43,E
1997,03,21,041956	1017.0	-11.7	1.6	96	6516.28,N,02358.44,E

Date and time (UTC) (yyyy,mm,dd,time)	Air Pressure [mb]	T_{air} [°C]	Wind Speed [m/s]	Wind Direction [°]	Position
1997,03,21,043959	1017.3	-11.6	1.7	115	6516.28,N,02358.44,E
1997,03,21,045958	1017.3	-11.5	2.0	127	6516.28,N,02358.44,E
1997,03,21,051949	1017.4	-11.3	2.2	127	6516.28,N,02358.44,E
1997,03,21,053946	1017.6	-10.7	1.2	153	6516.28,N,02358.44,E
1997,03,21,055948	1017.7	-10.7	0.7	167	6516.28,N,02358.44,E
1997,03,21,061951	1017.7	-10.6	1.1	138	6516.28,N,02358.44,E
1997,03,21,062850	1017.7	-10.6	1.1	125	6516.28,N,02358.44,E
1997,03,21,063950	1017.7	-10.4	0.9	125	6516.28,N,02358.45,E
1997,03,21,070002	1017.7	-9.9	0.2	94	6516.28,N,02358.44,E
1997,03,21,071955	1017.8	-10.4	1.0	68	6516.28,N,02358.44,E
1997,03,21,073955	1018.1	-10.8	1.5	66	6516.28,N,02358.44,E
1997,03,21,075952	1018.1	-11.0	1.3	91	6516.28,N,02358.44,E
1997,03,21,081955	1018.1	-10.8	1.2	91	6516.28,N,02358.44,E
1997,03,21,083954	1018.2	-10.5	1.3	100	6516.28,N,02358.44,E
1997,03,21,085954	1018.2	-10.2	0.7	84	6516.28,N,02358.44,E
1997,03,21,091954	1018.3	-10.2	0.4	346	6516.28,N,02358.44,E
1997,03,21,093954	1018.6	-10.3	0.6	4	6516.28,N,02358.44,E
1997,03,21,095956	1018.6	-10.2	0.7	24	6516.28,N,02358.44,E
1997,03,21,100008	1018.6	-10.2	0.8	25	6516.28,N,02358.44,E
1997,03,21,101956	1018.6	-10.1	1.4	49	6516.28,N,02358.44,E
1997,03,21,103958	1018.8	-9.6	1.5	53	6516.28,N,02358.44,E
1997,03,21,105958	1018.9	-9.6	1.2	70	6516.28,N,02358.44,E
1997,03,21,111956	1018.9	-9.5	1.1	75	6516.28,N,02358.44,E
1997,03,21,113946	1019.1	-8.1	1.6	138	6516.25,N,02358.28,E
1997,03,21,115958	1019.2	-8.2	1.3	79	6516.41,N,02357.86,E
1997,03,21,200002	1020.1	-6.7	3.1	37	6432.17,N,02310.95,E
1997,03,21,201948	1020.1	-6.8	2.4	24	6432.10,N,02310.66,E
1997,03,21,203951	1020.3	-7.5	2.1	3	6431.05,N,02307.58,E
1997,03,21,205948	1020.4	-7.1	3.8	354	6428.13,N,02306.35,E
1997,03,21,211948	1020.4	-6.1	3.4	34	6427.33,N,02305.94,E
1997,03,21,213952	1020.6	-6.2	3.2	15	6427.27,N,02305.91,E
1997,03,21,215952	1020.7	-6.3	2.9	25	6427.25,N,02305.88,E
1997,03,21,221950	1020.7	-6.4	2.2	38	6427.23,N,02305.85,E
1997,03,21,223950	1020.9	-7.0	1.8	45	6427.21,N,02305.83,E
1997,03,21,225950	1020.9	-7.0	1.3	51	6427.19,N,02305.81,E
1997,03,21,231950	1020.9	-7.1	1.1	55	6427.18,N,02305.79,E
1997,03,21,233950	1020.9	-7.3	0.8	48	6427.17,N,02305.77,E
1997,03,21,235950	1021.0	-7.4	1.2	56	6427.15,N,02305.76,E
1997,03,22,001952	1021.0	-7.3	0.9	42	6427.12,N,02305.75,E
1997,03,22,003950	1021.0	-6.9	0.5	14	6427.11,N,02305.74,E
1997,03,22,005950	1021.0	-5.6	1.0	1	6427.08,N,02305.73,E
1997,03,22,011951	1021.0	-5.9	1.0	335	6427.07,N,02305.73,E
1997,03,22,013952	1021.0	-6.2	1.3	347	6427.06,N,02305.73,E
1997,03,22,015950	1021.0	-6.2	2.0	336	6427.04,N,02305.73,E
1997,03,22,021950	1021.0	-6.3	2.2	342	6427.03,N,02305.74,E

Date and time (UTC) (yyyy,mm,dd,time)	Air Pressure [mb]	T_{air} [°C]	Wind Speed [m/s]	Wind Direction [°]	Position
1997,03,22,023952	1020.9	-6.4	2.3	354	6427.01,N,02305.75,E
1997,03,22,025950	1020.9	-6.5	3.2	346	6427.01,N,02305.75,E
1997,03,22,031950	1020.9	-6.5	2.6	350	6426.99,N,02305.76,E
1997,03,22,033950	1021.0	-7.0	1.6	352	6426.99,N,02305.76,E
1997,03,22,035953	1021.0	-6.7	2.2	10	6426.98,N,02305.77,E
1997,03,22,041950	1021.1	-5.8	1.7	347	6426.96,N,02305.78,E
1997,03,22,043950	1021.3	-6.2	1.2	343	6426.94,N,02305.79,E
1997,03,22,045953	1021.4	-6.5	3.2	315	6425.28,N,02305.87,E
1997,03,22,051950	1021.4	-6.6	3.8	330	6422.42,N,02305.68,E
1997,03,22,053952	1021.5	-6.9	3.6	346	6419.56,N,02305.74,E
1997,03,22,055952	1021.5	-6.4	2.4	340	6417.65,N,02304.80,E
1997,03,22,061952	1021.5	-6.8	2.1	335	6417.20,N,02303.51,E
1997,03,22,063952	1021.7	-7.7	2.1	319	6416.98,N,02302.82,E
1997,03,22,065952	1021.8	-7.5	2.6	13	6416.48,N,02300.82,E
1997,03,22,071952	1021.8	-6.9	3.3	330	6416.17,N,02257.90,E
1997,03,22,073952	1021.9	-7.4	3.2	3	6415.56,N,02253.70,E
1997,03,22,075954	1021.9	-7.4	5.0	337	6416.42,N,02247.93,E
1997,03,22,081954	1021.9	-7.5	4.8	342	6415.40,N,02241.68,E
1997,03,22,083954	1022.2	-7.2	6.4	343	6415.10,N,02233.51,E
1997,03,22,085957	1022.4	-6.8	5.9	342	6413.90,N,02227.24,E
1997,03,22,091954	1022.5	-7.0	4.6	352	6413.45,N,02225.20,E
1997,03,22,093954	1022.8	-7.5	3.6	347	6413.42,N,02225.20,E
1997,03,22,095957	1022.7	-7.4	3.4	359	6413.38,N,02225.20,E
1997,03,22,101954	1022.7	-7.4	3.0	353	6413.35,N,02225.19,E
1997,03,22,103955	1022.6	-7.2	3.0	354	6413.32,N,02225.18,E
1997,03,22,105957	1022.6	-7.2	3.2	343	6413.30,N,02225.17,E
1997,03,22,111958	1022.6	-7.1	2.7	350	6413.27,N,02225.15,E
1997,03,22,113956	1022.7	-7.1	2.7	352	6413.25,N,02225.14,E
1997,03,22,115956	1022.7	-7.0	2.5	352	6413.23,N,02225.13,E
1997,03,22,121958	1022.7	-6.9	2.3	349	6413.22,N,02225.12,E
1997,03,22,123959	1022.7	-6.8	3.0	354	6413.21,N,02225.11,E
1997,03,22,125958	1022.7	-6.8	2.6	346	6413.21,N,02225.11,E
1997,03,22,131959	1022.7	-6.8	2.4	343	6413.21,N,02225.10,E
1997,03,22,133958	1022.8	-7.0	2.2	4	6413.20,N,02225.10,E
1997,03,22,140000	1022.8	-7.1	2.0	13	6413.20,N,02225.09,E
1997,03,22,142000	1022.8	-7.1	2.0	0	6413.20,N,02225.09,E
1997,03,22,143948	1022.7	-7.1	2.0	25	6413.20,N,02225.08,E
1997,03,22,150000	1022.7	-7.2	1.7	354	6413.20,N,02225.08,E
1997,03,22,151958	1022.8	-7.2	2.0	350	6413.20,N,02225.08,E
1997,03,22,153946	1022.8	-7.3	1.3	345	6413.20,N,02225.08,E
1997,03,22,155948	1022.8	-7.3	1.5	357	6413.20,N,02225.08,E
1997,03,22,162000	1022.8	-7.4	1.4	13	6413.20,N,02225.08,E
1997,03,22,164000	1022.6	-7.6	1.4	3	6413.20,N,02225.08,E
1997,03,22,170000	1022.6	-7.5	0.5	24	6413.20,N,02225.08,E
1997,03,22,172000	1022.7	-7.6	0.7	1	6413.20,N,02225.08,E

Date and time (UTC) (yyyy,mm,dd,time)	Air Pressure [mb]	T_{air} [°C]	Wind Speed [m/s]	Wind Direction [°]	Position
1997,03,22,174000	1022.8	-7.7	1.2	17	6413.20,N,02225.08,E
1997,03,22,180000	1022.8	-7.7	1.0	352	6413.20,N,02225.08,E
1997,03,22,181949	1022.8	-7.9	0.8	340	6413.20,N,02225.09,E
1997,03,22,184000	1023.0	-8.3	0.8	353	6413.20,N,02225.09,E
1997,03,22,190000	1023.0	-8.4	0.3	83	6413.20,N,02225.08,E
1997,03,22,191948	1023.1	-8.3	1.3	13	6413.20,N,02225.09,E
1997,03,22,194002	1023.1	-8.5	0.9	27	6413.20,N,02225.09,E
1997,03,22,194302	1023.1	-8.4	0.8	21	6413.20,N,02225.09,E
1997,03,22,195950	1023.1	-8.4	0.6	39	6413.20,N,02225.09,E
1997,03,22,201949	1023.1	-8.4	0.4	311	6413.20,N,02225.09,E
1997,03,22,203949	1023.0	-8.2	0.5	273	6413.20,N,02225.08,E
1997,03,22,205949	1023.0	-8.6	0.2	278	6413.20,N,02225.09,E
1997,03,22,211949	1023.0	-8.4	0.5	302	6413.20,N,02225.09,E
1997,03,22,213950	1023.1	-8.5	0.4	345	6413.20,N,02225.09,E
1997,03,22,215948	1023.1	-8.4	0.8	312	6413.20,N,02225.09,E
1997,03,22,221951	1023.1	-8.4	0.1	293	6413.20,N,02225.09,E
1997,03,22,223950	1023.0	-8.9	0.2	218	6413.20,N,02225.10,E
1997,03,22,225950	1023.0	-8.9	0.2	225	6413.20,N,02225.09,E
1997,03,22,231950	1023.0	-9.0	0.4	183	6413.20,N,02225.09,E
1997,03,22,233950	1023.1	-9.0	0.2	212	6413.20,N,02225.10,E
1997,03,22,235950	1023.1	-9.0	0.4	186	6413.20,N,02225.09,E
1997,03,23,001951	1023.1	-9.1	0.7	179	6413.20,N,02225.09,E
1997,03,23,003950	1023.1	-9.4	0.8	143	6413.20,N,02225.09,E
1997,03,23,005950	1023.1	-9.4	0.8	114	6413.20,N,02225.09,E
1997,03,23,011950	1023.1	-9.3	0.7	122	6413.20,N,02225.08,E
1997,03,23,013950	1023.1	-8.8	0.7	138	6413.20,N,02225.07,E
1997,03,23,015950	1023.1	-8.7	0.9	93	6413.20,N,02225.06,E
1997,03,23,021950	1023.2	-8.7	1.0	113	6413.21,N,02225.06,E
1997,03,23,023950	1023.2	-8.8	1.1	148	6413.21,N,02225.05,E
1997,03,23,025951	1023.1	-8.8	1.0	150	6413.22,N,02225.04,E
1997,03,23,031951	1023.2	-7.8	1.2	127	6413.22,N,02225.03,E
1997,03,23,033950	1023.3	-8.6	1.9	129	6413.22,N,02225.01,E
1997,03,23,035950	1023.3	-7.8	2.0	142	6413.23,N,02225.00,E
1997,03,23,041950	1023.3	-7.5	2.1	135	6413.23,N,02224.99,E
1997,03,23,043950	1023.4	-7.9	2.0	127	6413.24,N,02224.98,E
1997,03,23,045950	1023.5	-7.7	2.5	131	6413.25,N,02224.97,E
1997,03,23,051951	1023.5	-8.6	1.8	128	6413.26,N,02224.96,E
1997,03,23,053952	1023.7	-8.6	2.3	156	6413.26,N,02224.95,E
1997,03,23,055952	1023.8	-8.9	2.4	169	6413.28,N,02224.95,E
1997,03,23,061953	1023.9	-9.0	2.1	150	6413.28,N,02224.95,E
1997,03,23,063952	1024.1	-9.2	1.6	172	6413.29,N,02224.95,E
1997,03,23,070003	1024.0	-9.1	1.8	166	6413.30,N,02224.95,E
1997,03,23,071952	1024.1	-9.1	1.4	160	6413.30,N,02224.96,E
1997,03,23,073952	1024.2	-8.9	1.2	170	6413.30,N,02224.96,E
1997,03,23,075952	1024.2	-8.8	1.3	163	6413.31,N,02224.96,E

Date and time (UTC) (yyyy,mm,dd,time)	Air Pressure [mb]	T_{air} [°C]	Wind Speed [m/s]	Wind Direction [°]	Position
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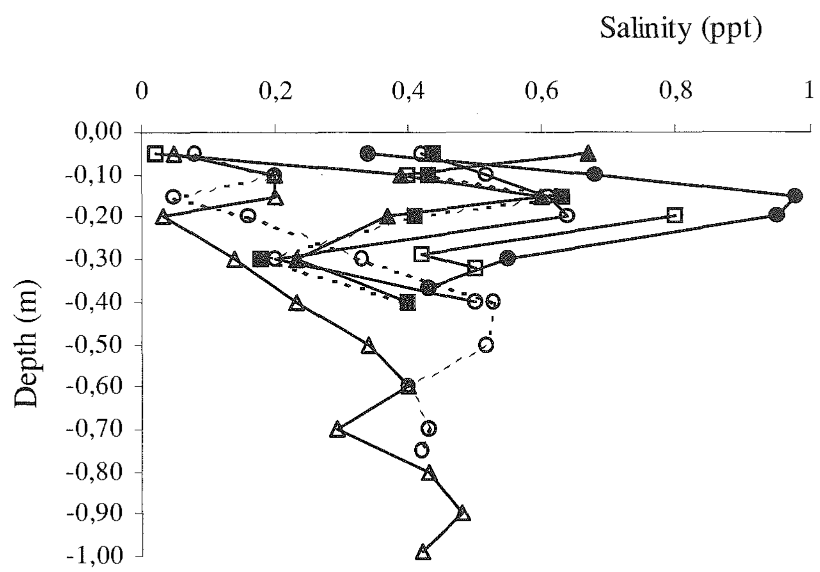
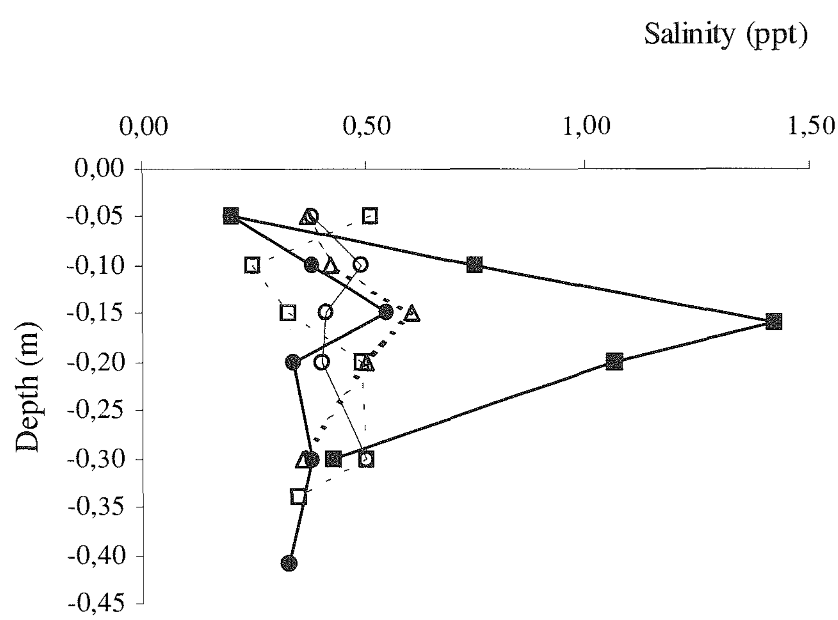
1997,03,23,085952	1024.4	-6.0	1.0	146	6413.30,N,02224.96,E
1997,03,23,091952	1024.3	-8.3	0.9	145	6413.30,N,02224.96,E
1997,03,23,093952	1024.4	-7.8	0.7	148	6413.30,N,02224.96,E
1997,03,23,095952	1024.4	-8.0	1.3	103	6413.29,N,02224.96,E
1997,03,23,101952	1024.4	-6.5	1.5	128	6413.29,N,02224.95,E
1997,03,23,103952	1024.6	-6.7	1.1	135	6413.28,N,02224.94,E
1997,03,23,105952	1024.7	-7.9	1.0	111	6413.27,N,02224.93,E
1997,03,23,111952	1024.7	-6.4	0.9	128	6413.26,N,02224.92,E
1997,03,23,113952	1024.7	-6.9	0.7	75	6413.25,N,02224.91,E
1997,03,23,115952	1024.7	-6.9	1.6	77	6413.24,N,02224.89,E
1997,03,23,121952	1024.7	-6.9	1.7	91	6413.22,N,02224.87,E
1997,03,23,123952	1024.6	-6.9	1.9	63	6413.21,N,02224.84,E
1997,03,23,125952	1024.6	-6.9	3.0	58	6413.19,N,02224.81,E
1997,03,23,131952	1024.6	-6.9	3.0	59	6413.17,N,02224.77,E
1997,03,23,133952	1024.5	-6.9	2.6	73	6413.15,N,02224.72,E
1997,03,23,135953	1024.6	-6.9	2.9	66	6413.13,N,02224.67,E
1997,03,23,141952	1024.6	-7.0	2.8	60	6413.11,N,02224.62,E
1997,03,23,143953	1024.6	-6.9	2.1	58	6413.09,N,02224.57,E
1997,03,23,145954	1024.6	-6.8	2.6	62	6413.08,N,02224.52,E
1997,03,23,151954	1024.5	-6.9	2.8	49	6413.06,N,02224.48,E
1997,03,23,153954	1024.3	-7.1	3.0	52	6413.04,N,02224.44,E
1997,03,23,155954	1024.3	-7.1	3.3	53	6413.01,N,02224.40,E
1997,03,23,161954	1024.3	-7.2	3.4	51	6412.99,N,02224.36,E
1997,03,23,163954	1024.4	-7.2	3.4	49	6412.97,N,02224.33,E
1997,03,23,165954	1024.4	-7.2	3.9	58	6412.95,N,02224.29,E
1997,03,23,171954	1024.4	-7.2	3.2	56	6412.93,N,02224.26,E
1997,03,23,173954	1024.5	-7.2	3.7	59	6412.91,N,02224.23,E
1997,03,23,175954	1024.5	-7.3	4.0	65	6412.90,N,02224.20,E
1997,03,23,181954	1024.5	-7.3	3.6	66	6412.88,N,02224.18,E
1997,03,23,183954	1024.7	-7.4	2.9	69	6412.87,N,02224.16,E
1997,03,23,185954	1024.8	-7.4	3.0	70	6412.87,N,02224.13,E
1997,03,23,191952	1024.8	-7.4	2.8	68	6412.86,N,02224.12,E
1997,03,23,193952	1024.8	-7.3	3.0	69	6412.86,N,02224.11,E
1997,03,23,195954	1024.8	-7.4	2.5	77	6412.86,N,02224.11,E
1997,03,23,201954	1024.7	-7.4	2.9	91	6412.86,N,02224.11,E
1997,03,23,203955	1024.7	-7.3	3.6	90	6412.86,N,02224.11,E
1997,03,23,205952	1024.7	-7.4	3.5	91	6412.86,N,02224.11,E
1997,03,23,211954	1024.7	-7.4	3.9	91	6412.85,N,02224.11,E
1997,03,23,213952	1024.7	-7.4	4.1	94	6412.86,N,02224.11,E
1997,03,23,215953	1024.7	-7.4	4.1	93	6412.86,N,02224.11,E
1997,03,23,221952	1024.7	-7.5	4.0	91	6412.86,N,02224.11,E
1997,03,23,223953	1024.7	-7.6	3.4	97	6412.86,N,02224.11,E
1997,03,23,225952	1024.7	-7.6	3.2	107	6412.86,N,02224.11,E

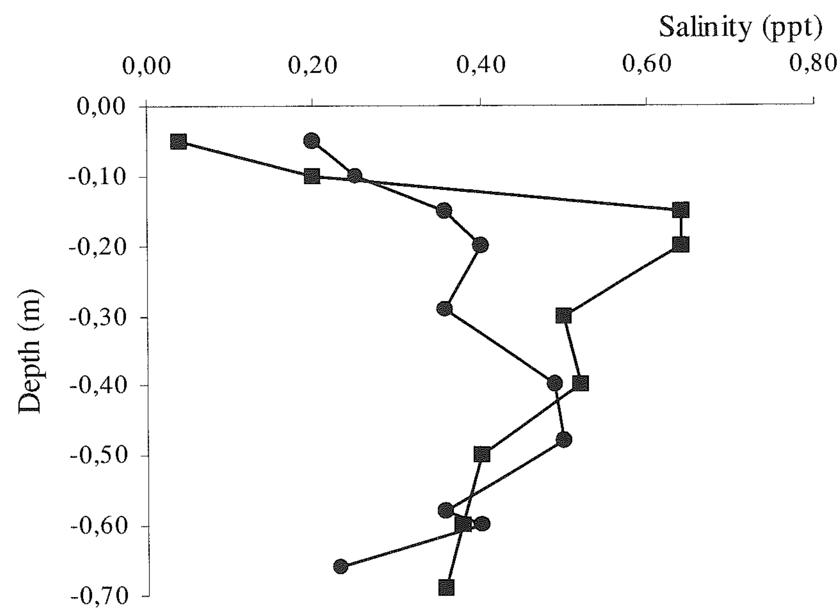
Date and time (UTC) (yyyy,mm,dd,time)	Air Pressure [mb]	T_{air} [°C]	Wind Speed [m/s]	Wind Direction [°]	Position
1997,03,23,231952	1024.7	-7.7	3.6	101	6412.86,N,02224.11,E
1997,03,23,233953	1024.6	-7.8	4.1	101	6412.85,N,02224.11,E
1997,03,23,235954	1024.6	-7.9	3.9	103	6412.85,N,02224.10,E
1997,03,24,001954	1024.7	-7.9	3.8	100	6412.85,N,02224.10,E
1997,03,24,003952	1024.7	-8.1	4.1	96	6412.85,N,02224.10,E
1997,03,24,005954	1024.8	-8.2	3.9	101	6412.85,N,02224.10,E
1997,03,24,011954	1024.8	-8.2	3.1	108	6412.85,N,02224.11,E
1997,03,24,013955	1024.8	-8.7	3.2	113	6412.85,N,02224.11,E
1997,03,24,015952	1024.8	-8.6	3.2	104	6412.85,N,02224.10,E
1997,03,24,020006	1024.8	-8.6	3.2	104	6412.85,N,02224.11,E
1997,03,24,021954	1024.8	-8.6	2.8	101	6412.85,N,02224.10,E
1997,03,24,023954	1024.8	-8.7	3.3	103	6412.85,N,02224.10,E
1997,03,24,025954	1024.8	-8.7	3.2	107	6412.85,N,02224.10,E
1997,03,24,031954	1024.8	-8.7	2.7	111	6412.85,N,02224.10,E
1997,03,24,033956	1024.9	-8.8	2.4	105	6412.85,N,02224.10,E
1997,03,24,035954	1024.9	-8.7	2.3	105	6412.85,N,02224.10,E
1997,03,24,041954	1024.9	-8.7	2.4	113	6412.85,N,02224.11,E
1997,03,24,043952	1024.9	-8.9	2.0	114	6412.85,N,02224.11,E
1997,03,24,045954	1024.9	-9.3	1.4	93	6412.85,N,02224.10,E



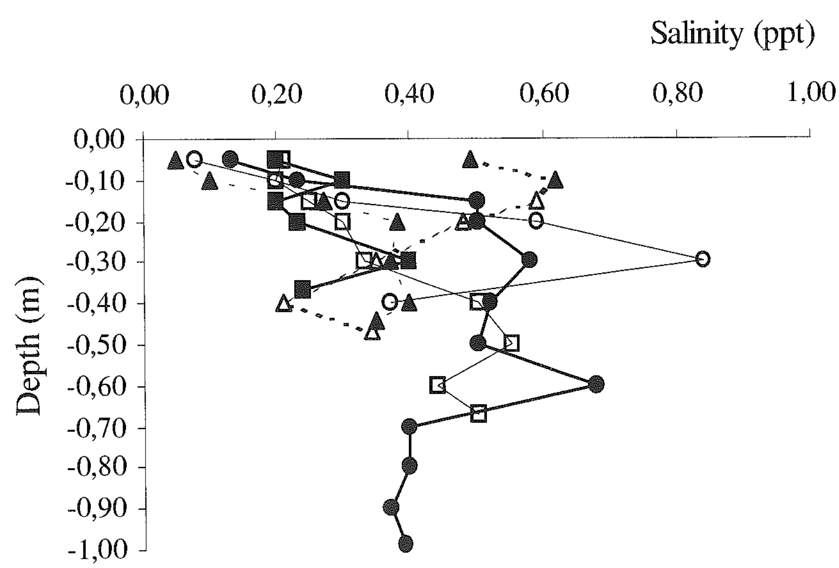
Ice salinities at sites PJK-6 - PJK-10 at the intensive studying line in the Ice Station 1.



Ice salinities at sites PJK-14 - PJK-17 at the intensive studying line in the Ice Station 2.



Ice salinities in the fast ice area in the Bay of Bothnia.



Ice salinities in the pack ice in the Bay of Bothnia.

IMSI report no. 3: Dissemination of test products to selected users in the Baltic Sea area

Report on activities in the winter of 1997

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1. INTRODUCTION

During the winter of 1997 several IMSI activities were launched in the Baltic Sea. One of them was ICEPILOT-97, an experiment in delivering digital ice information products and spaceborne data to merchant vessels at sea. During this experiment automatically classified SAR data were also delivered to the ICEPILOT -97 and to the Finnish icebreakers. In addition, ice drift forecasts, whose initial stage was based on remote sensing, were delivered to the Estonian, German, Russian and Swedish ice services.

The ice season of 1996/97 was rather mild. The maximum extent of the ice cover was reached on 18 February, when there was 128 000 km^2 of ice. This represents 30 % of the total Baltic Sea area. The mild conditions hampered the usefulness of the satellite data delivered. Ice conditions in the Gulf of Finland were especially mild and the need for extra sea ice information was very small. However, the experiment gave valuable information on the possibilities that this kind of technique could offer for merchant vessels at sea.

This report is partly based on the ICEPILOT-97 unpublished technical report produced by Robin Berglund at the VTT / Information Systems, Espoo, Finland.

2. ICE SEASON 1 JANUARY-30 APRIL 1997

2.1. The weather conditions

The winter of 1996/97 was mild. Between October and November the air temperatures were 1-3 °C above normal. In December the air temperature anomalies varied between +0.5 and -1.5 °C. In mid-winter (January-March) the temperature was 2-4 °C above normal. In April temperatures were 0.5 - 3 °C below normal (Finnish Meteorological Institute 1997).

2.2. Ice conditions from January to April 1997

1st January 1997

Gulf of Bothnia

The northern parts of the Bothnian Bay were covered with 10 - 25 cm of ice. Southwards there was ice along the coasts. The high sea was open. The Quark was covered by new ice. In the

Bothnian Sea there was ice in the archipelago areas. *The ice conditions corresponded to average conditions at the end of December.*

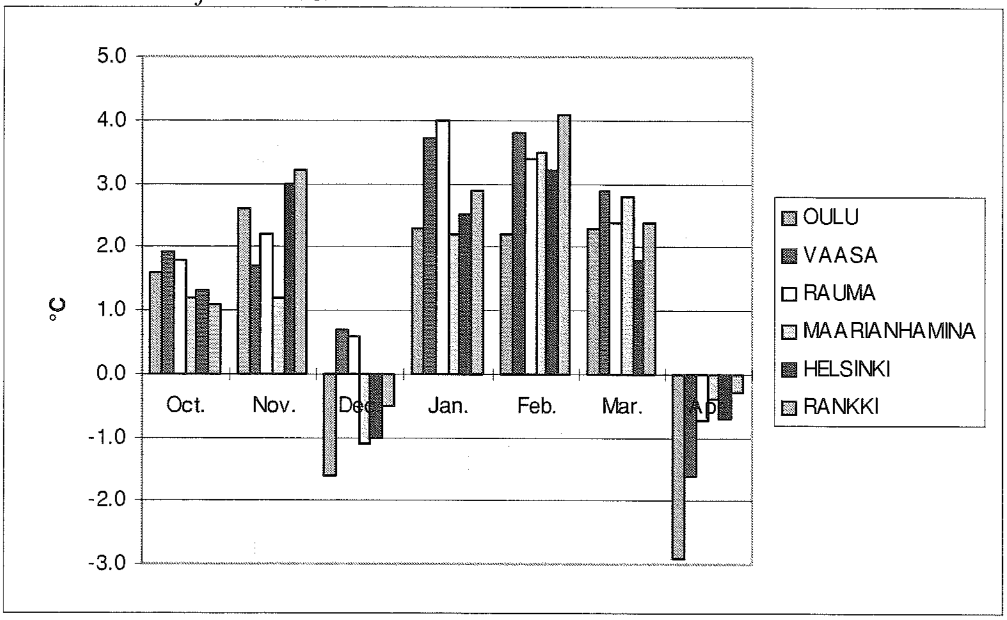


Fig. 1. Air temperature anomalies along the Finnish coast October 1996 - April 1997.

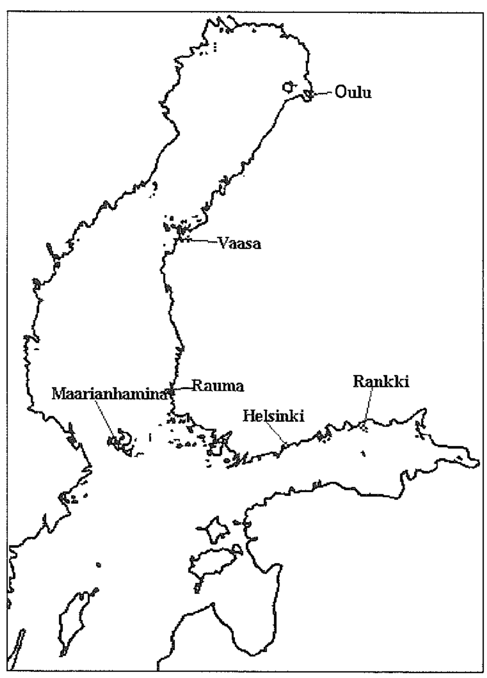


Fig. 2. Locations of the weather stations in Figure 1.

Gulf of Finland

Approx. 1/3 of the Gulf of Finland was ice-covered. The 5 - 20 cm ice cover reached from the east to approx. a line from Hamina to Vigrund, Estonia. Further west, there was some ice on the Finnish coast. *The ice conditions were near average.*

15th January 1997

Gulf of Bothnia

Approx. 1/3 of the Bothnian Bay was covered with a 5 - 30 cm layer of ice. The ice reached southwards to approximately line Raahe - Nygrån. *The ice conditions corresponded to those of mid-December.* On average, the Bothnian Bay and the Quark should be totally covered with 15 - 30 cm of ice. Some ice should exist on the coasts of the Bothnian Sea and the Archipelago Sea.

Gulf of Finland

5 - 15 cm of ice covered 1/3 of the Gulf, from the east to approx. line Hamina - Vigrund. *The ice conditions corresponded to those of early January.*

1st February 1997

Gulf of Bothnia

The Bothnian Bay and the Quark were totally ice-covered with the ice thickness ranging from 10 - 35 cm in the north to 5 - 30 cm in the south. The Bothnian Sea was ice-free, except for the Finnish coast which had ice reaching some kilometres off the coast. There was also some ice in the Archipelago Sea. *The ice conditions were near average, except that the ice thickness was less and the total Archipelago Sea should have been ice-covered.*

Gulf of Finland

The Gulf of Finland was covered by 5 - 30 cm of ice from the east to approximately a line Hamina - Vigrund. Further west there was ice on the Finnish coast. *The ice conditions corresponded to those of early January.* On average, the Gulf of Finland should have been totally covered by 10 - 25 cm ice.

15th February 1997

Gulf of Bothnia

The Bothnian Bay and the Quark were totally ice-covered, the ice thickness ranging from 20-35 cm in the northern parts to 10 - 15 cm in the Quark. In the Bothnian Sea there was ice cover on the Finnish coast. The Archipelago Sea was partly ice covered. *The ice conditions corresponded to those of mid-January.* On average, the Gulf of Bothnia should be totally ice-covered, except for the high sea area of the Bothnian Sea. The ice thickness should range from 25 - 50 cm in the north down to 20 - 30 cm in the south.

Gulf of Finland

The ice cover extended from the east to approximate line Hamina -Vigrund. The ice thickness ranged from 30 - 45 cm in the eastern parts down to 15 - 25 cm going westward. More westward still there was some ice on the Finnish coast. *The ice conditions corresponded to those of early January.* On average, the Gulf should be totally ice-covered with the thickness ranging between 15 - 40 cm.

1st March 1997

Gulf of Bothnia

The Bothnian Bay and the Quark were totally ice-covered with the ice thickness ranging from 20 - 40 cm in the Bay of Bothnia to 10 - 30 cm in the Quark. In the Sea of Bothnia there was ice cover near the Finnish coast. The Archipelago Sea was totally ice covered. *The ice conditions corresponded to those of late January.* On average, the Gulf of Bothnia should be totally ice-covered with 30 - 65 cm of ice in the north down to 20 - 40 cm in the south.

Gulf of Finland

The Gulf was covered from the east to approximately line Helsinki - Vigrund. The ice thickness ranged from 35 - 50 cm in the east to 15 - 30 cm going westward. The western part of the Gulf had on ice cover on the Finnish side extending some kilometres off the coast. *The ice conditions corresponded to those of early January.* On average, the Gulf should be totally covered by 20 - 40 cm of ice.

15th March 1997

Gulf of Bothnia

The Bothnian Bay was starting to open on the Swedish side. The northernmost parts, as well as the Finnish side, were still covered with 30 - 50 cm of ice. In the Quark the Swedish side was almost ice-free. There was some ice on the Finnish coast of the Bothnian Sea. The western parts of the Archipelago Sea started to open. *The ice conditions corresponded in the north to those of mid-May and in the south to mid-April.* On average, the Gulf of Bothnia should be totally ice-covered with the ice thickness ranging from 30 - 70 cm in the north down to 20 - 40 cm in the south.

Gulf of Finland

The eastern part of the Gulf of Finland was covered by 30 - 50 cm of ice ranging approximately to a line Kotka - Vigrund. There was some ice on the Finnish coast. *The ice conditions corresponded to those at the beginning of May.* On average, the Gulf of Finland should be totally covered by 20 - 40 cm of ice.

1st April 1997

Gulf of Bothnia

The Bothnian Bay was again totally ice-covered, except for some leads. The ice thickness varied, depending on location, from 10 - 20 cm up to 40 - 60 cm. The Quark was ice-covered, except for the southern parts, with the ice thickness ranging from 10 - 40 cm. There was some ice on the Finnish coast of the Sea of Bothnia, and the Archipelago Sea was almost ice-free. *The ice conditions corresponded to those of mid- May.* On average, the Gulf of Bothnia should be starting to open in the southern parts. Otherwise, the ice thickness should range from 30 - 70 cm in the north to 15 - 35 cm in the south.

Gulf of Finland

The Gulf of Finland was ice-covered from the east to approximately a line Porvoo - Vigrund. The ice thickness ranged from 30 - 50 cm in the east to 5 - 15 cm going westward. Some ice was remained on the western part of the Finnish coast. *The ice conditions corresponded to those at the end of April.* On average, the Gulf of Finland should be totally ice-covered by 15 - 40 cm of ice.

15th April 1997

Gulf of Bothnia

The Bothnian Bay started to open up on the Swedish side, otherwise the ice thickness varied, depending on location, from some centimetres up to 40 - 60 cm. The Quark was starting to open up from the Swedish side. Some ice was still found on the coasts of the Bothnian Sea and Archipelago Sea. *The ice conditions corresponded to those at the beginning of May in the north and late April in the south.* On average, the southern parts should be ice-free, and the ice should be 30 - 70 cm thick in the north and 10 - 30 cm in the south.

Gulf of Finland

The ice reached from the east to approximately a line Hamina - Vigrund. The ice thickness ranged from 25 - 45 cm in the east down to 10 - 30 going westward. Some ice was still remained on the western part of the Finnish coast. *The ice conditions corresponded to those at the beginning of May.* On average, the Gulf of Finland should be starting to open up in the western parts; elsewhere, it should be covered by 15 - 40 cm of ice.

1st May 1997

Gulf of Bothnia

The Bothnian Bay had opened up on the Swedish side, otherwise, the ice thickness varied, depending on location, from 40 - 70 cm down to 20 - 40 cm. The Quark had opened in its southern parts, and was almost completely open on the Swedish side. The Bothnian Sea and Archipelago Seas were ice-free. *The ice conditions corresponded to those in mid-May.*

Gulf of Finland

Only in the easternmost parts was there 20 - 40 cm of ice. *The ice conditions corresponded to those at the beginning of May.* On average the high sea of the Gulf of Finland should be ice-covered from the east to the island of Gogland.

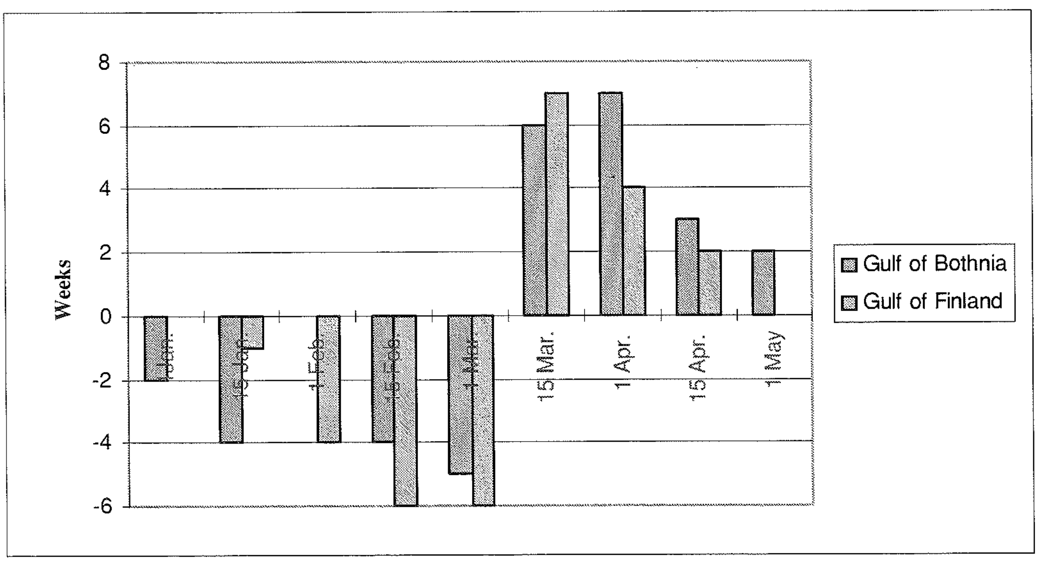


Fig. 3. The ice conditions in the Gulf of Bothnia and the Gulf of Finland compared to the normal conditions (in weeks). Melting starts in March.

3. THE DATA DELIVERED

3.1. Ice drift forecasts and forecasting methods

The Finnish Ice Service produces two kinds of sea ice forecasts, a general one for 10 d for the use of the Finnish icebreaking command and a numerical one of 42 h for the use of those at sea.

General ten-day forecasts: ice forecasts for to next ten days are provided for the icebreaking service on a daily basis. They describe in general terms the expected ice developments such as ice drift, opening of leads, areas with ice pressure, ice formation or melting. The forecasts are not published.

Ice dynamics forecasts: These forecasts are based on dynamic methods, and are run on the institute's computer using the numerical weather forecast as input. The parameters of the forecasts are: ice drift (direction and speed), ice concentration (in per cent), changes in ice concentration, ice deformation. Input data are wind forecasts produced by the Finnish Meteorological Institute (general +42 h forecast for sea areas) and the European Weather Centre (+5 d on a c. 50 km grid). For the initial stage of the ice conditions, digital ice charts have been used. These ice charts are based on the data from the remote-sensing and on ground truth produced by the Finnish Ice Service. The time-scale of the forecast has been +42 h in six-hour steps, and has been delivered to the icebreaking service, operational icebreakers and other users. Forecasts in plain language in Finnish, Swedish and English are distributed to users daily at 10 o'clock UTC. The format of the forecast is : Forecast for tomorrow morning, forecast for tomorrow.

3.2. Data delivered to users at sea

Digital spaceborne data have been delivered to users at sea. Attempts at delivering the hard-copy satellite images by fax in the 1980's were unsuccessful, after which the development of digital network was started. By the early 1990's, all Finnish and Swedish icebreakers were in the shared network called IRIS. IRIS links the Finnish and Swedish icebreaking commands, the icebreakers and certain of the pilot stations into one network. IRIS has many facilities, such as traffic control, e-mail, forecasts of the merchant vessels' sailing times to the assisting area, etc. As part of IRIS there is an application called ICEPLOTT by which e. g. satellite images can be received via the ice services and displayed on overlaid the ice chart on a computer screen. At first the data consisted only of AVHRR data, but very soon SAR data was also included in the facilities. Today hundreds of AVHRR images and some one hundred ERS SAR images are sent to the icebreakers annually. The one kilometre spatial resolution of the AVHRR data is only able to rough information on the ice conditions to the operational icebreakers. In the case of ERS SAR, with a spatial resolution of 100-150 m, the data have been used directly in navigation.

Unlike AVHRR, SAR data is cloud and daylight independent with a resolution sufficient for use in navigation. Although ERS is a research satellite and not originally designed as an operational one, it has been used as a semi-operational satellite because of the lack of better substitutes. The ERS frequency cycle is too sparse and its swath too narrow for advantageous sea ice mapping.

AVHRR data are normally available for users at sea within 30 min - 2 hours and the SAR data of ERS-2 within 3-5 hours of receiving them.

These time-tables are in general satisfactory for current needs. However, during fast-changing ice conditions the SAR data is needed more often: optimally once an hour.

3.3. Spaceborne data

The first polar-orbiting NOAA satellite, NOAA-1 (also known as TIROS-A) was launched in December 1970. Launching of NOAA-6 in June 1979 introduced a new era for sea ice mapping, being equipped with an AVHRR with five bands in visible and infrared frequencies (channel 1 at 0.58-0.68 μm, channel 2 at 0.725-1.10 μm, channel 3 at 3.44-3.94 μm, channel 4 at 10.3-11.3 μm and channel 5 at 11.5-12.5 μm). The swath was 2940 km and nadir resolution 1.1 km. Channels one (visible) and two (near infrared) could be used during daylight and channels four (thermal) and five (thermal) in darkness for sea ice mapping. The series had two satellites permanently operational thus the number of useful orbits were and still are large. With NOAA-7 a new AVHRR/2 sensor came into use with an improved resolution in channel one of 0.5 km. The frequencies were changed a little (channel 1 at 0.58-0.68 μm, channel 2 at 0.725-1.10 μm, channel 3 at 3.55-3.93 μm, channel 4 at 10.3-11.3 μm and channel 5 at 11.5-12.4 μm). At 60° N there are 8-12 useful orbits daily, which can be used in sea ice monitoring?

The SAR on ERS has become a powerful tool for sea ice mapping. Weather independence and good resolution are the positive aspects of the ERS mission. Unfortunately, its area coverage is too modest for real-time sea ice mapping.

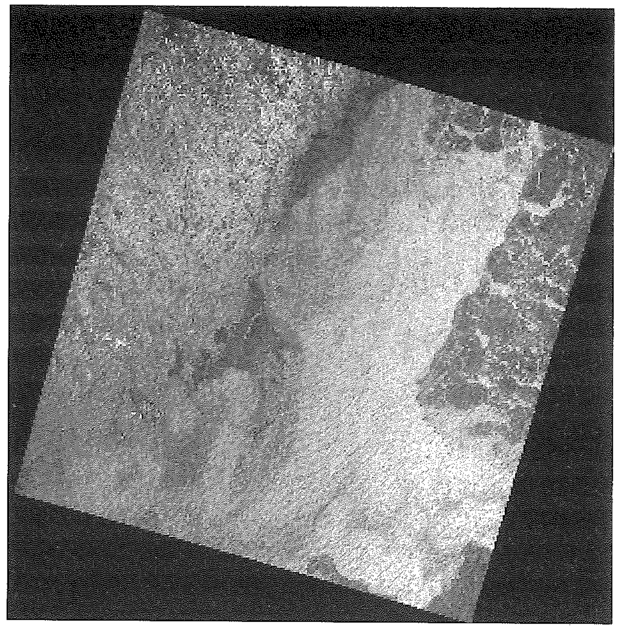
A radar image consists of spots, a characteristic which is emphasised in the SAR images. For this reason interpretation has been difficult, and has led to intensive development of image processing. On the other hand using an average (in low resolution images) has in many cases been enough for elucidating the image, but in these cases the resolution has become worse. Another interpretation problem has been the complexity of the image information content. Classifications using only intensity values are unsuitable, because the intensity value of a pixel depends on both the surface shape and the dielectric constant of the object, the latter also being normally temperature dependent.

The most important issue in SAR studies has been the transformation of ice information into user-comprehensible form. This has lead to an active development of image processing. An absolute prerequisite for the development of these methods is on understanding of the mechanism and context of SAR in "seeing" the sea ice. This is why studies of scattering processes are important. So far studies have aimed at one SAR instrument (that on ERS-1 and ERS-2) functioning at only one frequency, polarisation, and incidence angle (5.3 GHz, VV, 23°). The swath of ERS is 100 km and the spatial resolution used in the ice services and the data delivered to the users at sea is 100 * 100 m.

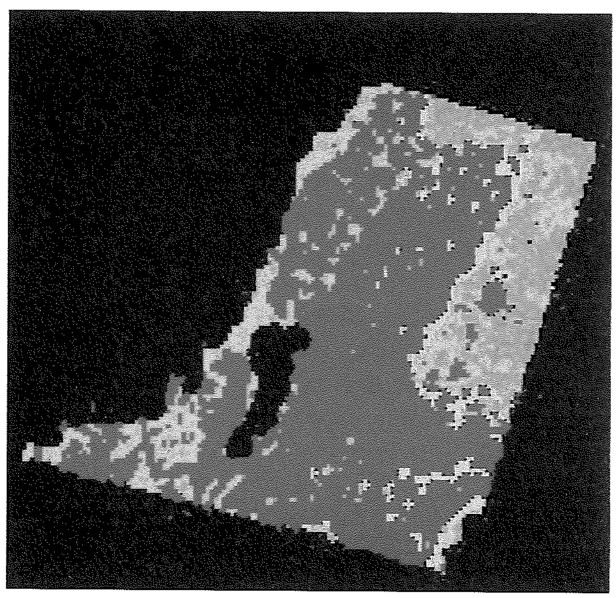
3.4. Visual and automatic interpretation of the usefulness of ERS SAR data for winter navigation

Altogether the Finnish Ice Service has received c. 250 Fast Delivery Low Resolution ERS SAR images during the ESA AO project OSIC in 1993-1995, and has bought 170 ERS SAR scenes in 1996 and 300 in 1997. FIMR is one of the largest SAR data users in Finland. The images were used in routine ice service activities, and most of them were delivered within a few hours to the operational icebreakers at sea using the special Swedish-Finnish icebreaker communication net (IRIS). The data have available for use the Finnish Ice Service within 1-2 hours of receiving them. To validate the visual interpretation of the data, SAR images were compared with AVHRR data and ground truth. Field campaigns were also carried out. The validation results of images in the period 1993-1995 by visual interpretation gave the usefulness of the SAR data mainly between good and very good. On average, 69 % of images contained no interpretation problems, interpretation problems related to edges in 18 %, to undefined areas in 5 % and to the water/ice definition in 4 % of the scenes (Grönvall & al. 1996).

During these years the possibilities of automated sea ice mapping were also consistently examined. The current version of the sea ice mapping algorithm produces an ice chart with five qualitative ice categories, including open water fully automatically. The classification algorithm is bivariate and utilises wavelet decomposition at several resolution levels as its starting point. From this decomposition, two variables are constructed, the intensity and the wavelet coefficient based on a local roughness texture measure. Through this measure the structure of the sea ice fields has been taken into account. The decision on the occurrence of open water is made for each image separately. The occurrence of all the ice classes is assumed and hence the ice categories in the resulting ice map are only relative. It can be said that ERS SAR, although not designed for operational use, has become semi-operational in sea ice monitoring. It diversifies the sea ice information sources, and in certain difficult situations can give highly valuable and very detailed knowledge about ice conditions, which would otherwise be inaccessible.



ERS-2 SAR image on 4th April 1997 in the Quark area off the city of Umeå. The image covers approx. the area 63°-64°N and 20°-22°E.
(© ESA 1997, the image processed by the Tromsø Satellite Station, 1997.)



As above, but classified.
Blue = open water
Light blue = new ice or open drift ice
Light green = close drift ice
Light brown = ice edge
(© FIMR 1997, the image processed by the Finnish Institute of Marine Research, 1997.)

Fig. 4. The possibilities of SAR-based automatic sea ice mapping have been investigated at the Finnish Institute of Marine Research. The current version of sea ice mapping algorithm produces an ice chart with five qualitative ice categories, including open water. Wavelet decomposition serves as a starting point for the classification.
(For more details see Grönvall & al. 1996.)

4. ACTIVITIES IN 1997

4.1. Ice drift forecasts

Between January and April the sea ice drift forecasts in text format were sent daily to the ice services of Estonia, Germany, Russia (St. Petersburg) and Sweden (in English). The forecasts were also sent to the Finnish icebreakers (in Finnish) and the FG Shipping Company (in Swedish). All this was done by fax. The forecasts in digital format were made available daily on the network to three merchant vessels (in Finnish and English).

Feedback

Icebreakers and ice services: The ice drift forecasts for +42 h or 1.5 d should be expanded to at least +5 d. The text format which was in use was considered fine.

Merchant vessels: The forecasts are useful, but too rough for ships moving in small areas.

Future plans

The format of the ice drift forecast should be developed. The forecast must also extent to + 5 days. Special forecasts in e. g. chart format for smallish areas like the Quark area must be developed.

4.2. ICEPILOT-97: A pilot project for transferring and using ice information on merchant vessels in the Baltic Sea

4.2.1. General

The ICEPILOT-97 experiment was carried out during the period 1.1.1997 - 30.4.1997. In the experiment a satellite image display system, ICEPLOTT, designed by VTT, was installed on merchant vessels owned by three shipping companies. The system tested was a simplified version of that used by Finnish icebreakers since 1993 (Figure 5). The data transfer took place by contacting the VTT server by using NMT and GSM networks. The Finnish Ice Service delivered ice charts, processed ERS SAR images (100*100 km with a spatial resolution of 100*100 m), automatic classificated ERS-2 SAR images (classified into open water and four classes of ice according to surface roughness with a spatial resolution of 800*800 m), and ice drift forecasts in text format to the VTT server. The AVHRR data (8-bit data cut into images varying in size of 250-350* 350-650 km with a spatial resolution of 1*1 km) of the NOAA satellites were received by the Finnish Ice Service via the Finnish Meteorological Institute. At the Finnish Ice Service the images were compressed and sent semi-automatically to the VTT server. The data transfer protocols and applications used were standard Internet TCP/IP and FTP protocols.

The ice conditions did not favour the experiment: especially in the Gulf of Finland, the conditions were so mild that the information to facilitate navigation was not necessary.

The merchant vessels participating in the experiment were the m/s *Kemira* sailing between Germany and various harbours in Finland, the m/s *Fennia*, a ferry sailing daily between Vaasa and Umeå in the Quark and the m/s *Containership III* sailing mostly between Central European ports and St. Petersburg.

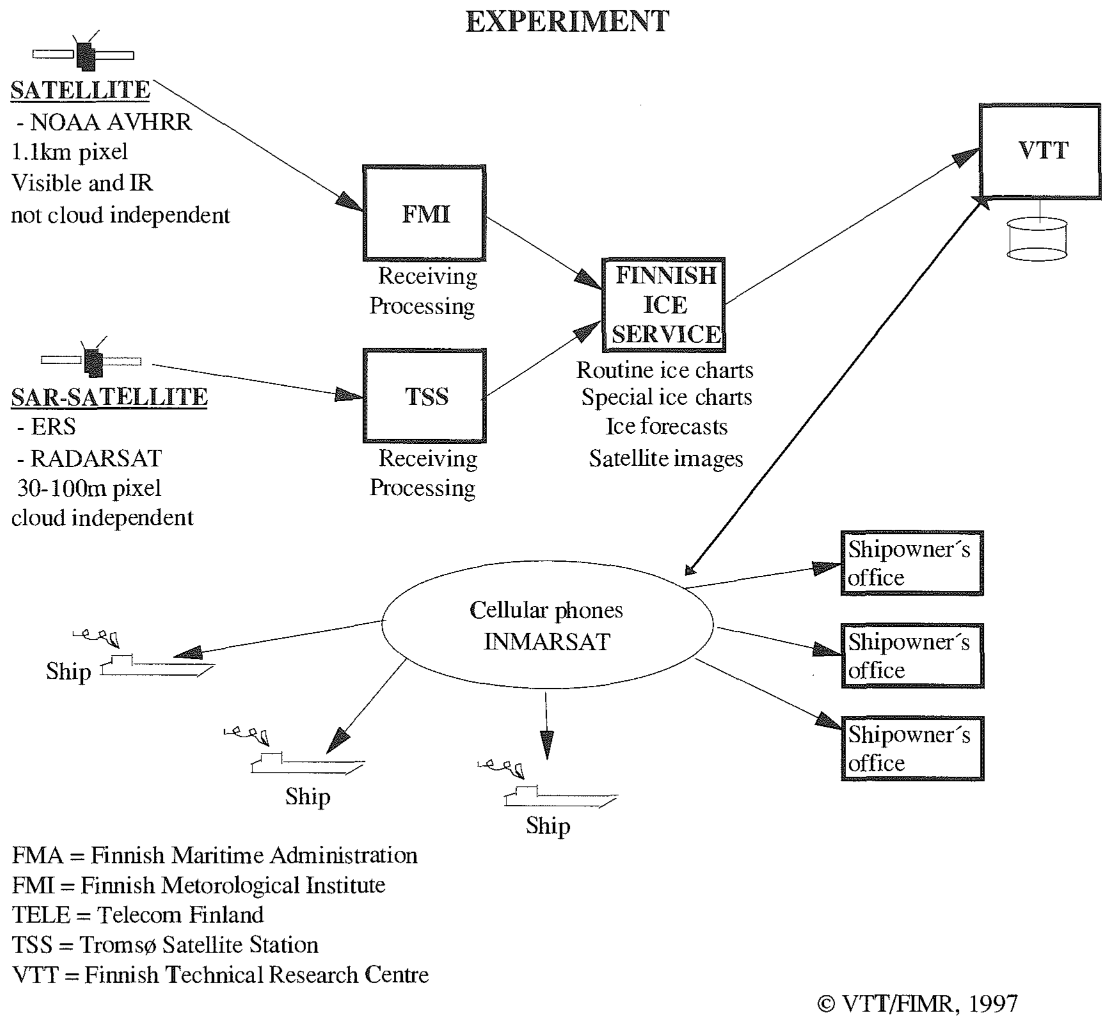


Fig. 5. The system description.

The sea ice information products which were delivered to the vessels were:

Forecasts	NOAA-images	ERS-images	Ice charts	Messages	Classified images
76	132	18	20	21	13

4.2.2. System description

The NOAA AVHRR images were transferred automatically from the Finnish Meteorological Institute to the Finnish Ice Service, where they were compressed using Adaptive Laplace Pyramid Compression. The transfer from the Finnish Ice Service to the VTT server was semi-automatic. The files in a redefined destination directory situated in a computer in the Finnish Ice Service were automatically copied every ten minutes to a computer in VTT. The transfer of the image files to the destination directory had to be done manually because the process included visual checking of the images, and the correct positioning with respect of the coastline overlay on the image. Using the VTT server the information service was made as reliable as possible - the acquisition of information was made independent of the state of the Finnish Ice Service computer. The same mechanism could be used to secure the availability of information in the situation where the computer is not functioning.

The vessels contacted the VTT modem bank, and created a TCP/IP connection via the modem bank to the server (Fig. 6).

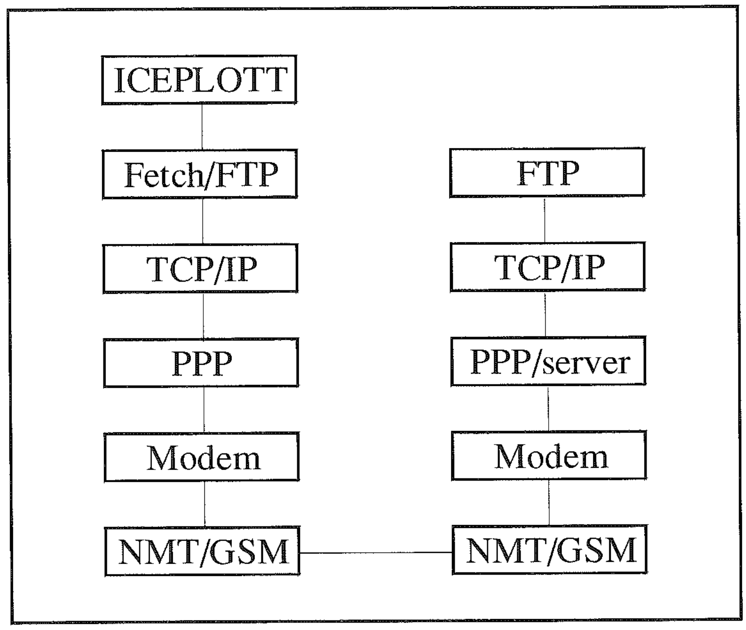


Fig. 6. The information transformation protocols and applications.

4.2.3. The test phases

13.-17.1.1997	Macintosh computers were installed on m/s *Fennia* and m/s *Kemira*.
20.1.1997	Training on m/s *Kemira* in Kokkola.
22.-23.1.1997	Training on m/s *Fennia* in Vaasa and Umeå.
11.2.1997	Installation of the ICEPLOTT and data transfer applications in the CONTAINERSHIPS shipping company's Macintosh computer. There were problems in finding a suitable NMT-adapter and a modem.
16.2.1997	Installation of a Macintosh computer to m/s *Containership III*.
26.2.1997	The first ERS images for the experiment.
28.4.1997	An interview on m/s *Kemira*, and removal of the Macintosh computer.

4.2.4. Feedback

To collect the feedback, a questionnaire was sent to the users. Interviews were also carried out on m/s *Kemira*. All the captains of the three vessels replied, as did also the deck officers from the m/s *Kemira*.

4.2.5. Summary

Technical feasibility:

The Macintosh computers functioned well, except on the *Containership III*, where the display driver was damaged after a week. The operating system language should be in a language, that can be understood by the captain (Finnish was used on the *Containership III*).

The data transfer system was considered easy to use, but unreliable. The system was considered to be too slow. The data transfer rates were as follows: on *Kemira* 30 - 150 bytes/s (NMT-450), on *Containership III* 110 - 150 bytes/s (occasionally 250 bytes/s) (NMT-450), and on *Fennia* 60 - 220 bytes/s (GSM). GSM was considered better than NMT, but not perfect. With NMT the data transfer had sometimes to be restarted up to ten times.

The ICEPLOTT program functioned well, but there was some confusion with the contrast regulation at the beginning.

There were too many files in the server, which made fetching of new data confusing. An easy way to solve the problem would be to divide the data into daily sub-directories.

Daily operational navigation needs new information every day, also during weekends.

Feedback for the products:

Ice charts: The users would have preferred charts more frequently.

NOAA AVHRR images: Problems in interpreting the images because of cloud cover. Resolution was not enough for navigation.

ERS SAR images: The resolution is very good, but coverage too small, and the interval between images too long. In the *Fennia* images were too old for useful application.

Useful products, which could be included in the service concept:

- The ice dynamics in the Quark area issued at least twice a day in chart format.
- Ice charts and satellite images for an overview.
- Weather forecasts and waveheight information. However, weather reports should be more detailed. For example, wind speed could be divided in percentual probabilities.
- Reports and warnings from the Finnish Maritime Administration.
- Notices to Mariners.

The benefits gained:

m/s *Fennia*: In practice, only NOAA images and text reports were used. More specific information is needed more frequently.

m/s *Containership III*: No useful use during this winter. Better coverage is needed in the eastern parts of the Gulf of Finland. The information needs to be available in real-time.

m/s *Kemira*: The benefits are greatest for vessels that can navigate through the ice independently without icebreaker assistance.

4.2.6. Future plans

The end users would be willing to continue during the following winter. Notice should be taken of the following subjects:

- The computer on board should be used for other applications as well, and a Windows version of ICEPLOTT would be useful.
- Products should be updated daily, also during weekends. New ice charts should be available daily.
- SAR images are useful, but they need to be in real time, and cover the area where the ship is positioned.

- New products should be planned: weather conditions in image form, wave information, reports from the Finnish Maritime Administration, such as restrictions to navigation, Notices to Mariners, waypoints given by the icebreakers.
- A pull type of data transfer is enough, no automatic push functionality is needed, but an e-mail application should be added. The quality of data transfer should be improved. In the future satellite connections may provide the answer.
- Organisation of the service: who will maintain the server?
- Development of a system requires investments in development work. Funding of this work must be arranged?

5. CONCLUSIONS

The mild ice season was not favourable for the experiment. The need for better sea ice information, especially in the Gulf of Finland, was small.

In general the products were sent successfully to the users at sea. The technical bottlenecks were identified and will be removed for the next season.

The experiment was not originally designed as a real-time service. The users at sea, however, had the feeling that the experiment was operational. By testing the various sea ice information products, the data providers got valuable information for developing new products and improving the old ones. The users at sea were also able to receive spaceborne data and use it in planning their navigation. In particular, the experiment gave valuable information about the possibilities that the spaceborne data could offer to merchant vessels at sea.

References

Finnish Meteorological Institute 1997: The weather statistics.

Grönvall, H., Seinä, A. & Similä, M. 1996: The Finnish Ice Service and Real-Time Automatic Classification of SAR Data. - Nordic Space Activities, Vol. 4, No 4/96, pp. 28-29, 33-35.

Appendix 1. List of IMSI products delivered to the users at the Baltic Sea 10 January - 11 May 1997 by the Finnish Ice Service.

Although formally commencing in February 1997, the IMSI was already started in the Finnish Ice Service in January because of the ongoing Baltic Sea ice season.

In the user-category Finnish icebreakers, the mean number of icebreakers at sea is shown. Three merchant vessels with the IRIS application on board participated. The participating ice services were Finland, Russia, Estonia, Sweden and Germany. The Finnish Maritime Administration also received products.

The list contains only the products delivered and received by the users. A large number of telephone consultation also took place between the Finnish Ice Service and these users.

The products were delivered to the users by hand, by fax or via the net.

User	Number of users	**Ice drift forecasts**	Deliv-ery
Finnish icebreakers	5	122	fax
Merchant vessels	3	76	net
Ice services	5	122	fax
Administration	1	122	hand
Sum	14	442	

User	Number of users	**Ice charts**	Deliv-ery
Finnish icebreakers	5	15	fax, net
Merchant vessels	3	20	net
Ice services	5	122	fax
Administration	1	122	hand
Sum	14	279	

User	Number of users	**Special ice charts**	Deliv-. ery
Finnish icebreakers			
Merchant vessels	3	5	net
Ice services			
Administration			
Sum	3	5	

User	Number of users	**AVHRR data**	Deliv-ery
Finnish icebreakers	5	366	net
Merchant vessels	3	132	net
Ice services			
Administration	1	366	net
Sum	9	864	

User	Number of users	**ERS-2 SAR data**	Deliv-. ery
Finnish icebreakers	5	87	net
Merchant vessels	3	18	net
Ice services			
Administration	1	87	net
Sum	9	192	

User	Number of users	**ERS-2 automatic classification**	Deliv-ery
Finnish icebreakers	5	15	net
Merchant vessels	3	13	net
Ice services			
Administration	1	15	net
Sum	9	43	

Products delivered to the users 10 Jan. - 11 May 1997 1825

Date	Time	File name	Date	Time	File name
10.01	10:11	bo_199701100947_ch4.ice	31.01	11:41	po_199701311133_ch4.ice
10.01	10:13	si_199701100943_ch4.ice	31.01	11:41	po_199701311133_ch5.ice
10.01	10:22	bo_199701100447_ch4.ice	31.01	13:28	bo_199701311147_ch4.ice
10.01	10:43	po_199701100933_ch4.ice	31.01	15:53	P1_CL012920.ICE
10.01	10:43	po_199701100933_ch5.ice	3.02	11:04	bo_199702020947_ch4.ice
10.01	15:25	po_199701101433_ch4.ice	3.02	11:04	po_199702021333_ch4.ice
10.01	17:44	bo_199701101447_ch4.ice	3.02	13:38	bo_199702030947_ch4.ice
15.01	11:50	map_gof_970115.ice	3.02	17:34	bo_199702031447_ch2.ice
15.01	11:59	map_quark_970115.ice	5.02	11:02	bo_199702050847_ch4.ice
16.01	11:25	po_199701160933_ch4.ice	5.02	11:02	po_199702050833_ch4.ice
16.01	13:58	map_gof_970116.ice	5.02	13:08	si_199702050843_ch4.ice
16.01	14:04	bo_199701151547_ch2.ice	5.02	15:00	forecast.txt
16.01	14:05	bo_199701151947_ch4.ice	5.02	15:31	970205_forecast.txt
16.01	15:12	970116_INFO.txt	5.02	16:22	bo_199702051547_ch2.ice
17.01	13:31	po_199701161533_ch4.ice	5.02	16:22	si_199702051543_ch2.ice
17.01	13:31	po_199701161933_ch4.ice	5.02	16:22	su_199702051521_ch2.ice
17.01	13:32	bo_199701161947_ch2.ice	5.02	16:23	po_199702051533_ch2.ice
17.01	13:32	bo_199701161947_ch4.ice	6.02	09:06	po_199702060433_ch4.ice
17.01	13:32	si_199701161443_ch2.ice	6.02	09:06	su_199702060821_ch4.ice
17.01	13:33	su_199701161521_ch2.ice	6.02	10:43	bo_199702060947_ch4.ice
20.01	15:19	map_gof_970120.ice	6.02	15:00	970206_forecast.txt
22.01	09:34	p2.ZIP	7.02	10:37	bo_199702061447_ch2.ice
22.01	09:34	p2_cl022109.ice	7.02	10:53	bo_199702070947_ch4.ice
22.01	10:08	ui_920226094840.ice	7.02	11:06	po_199702061433_ch2.ice
23.01	15:26	P0_CL012020.ICE	7.02	15:00	970207_forecast.txt
23.01	15:26	P1_CL012020.ICE	8.02	15:00	970208_forecast.txt
24.01	14:51	bo_199701241347_ch2.ice	9.02	15:00	970209_forecast.txt
24.01	14:51	bo_199701241347_ch4.ice	10.02	08:56	po_199702091433_ch2.ice
24.01	14:51	po_199701241333_ch4.ice	10.02	08:56	po_199702091433_ch4.ice
24.01	14:51	su_199701241321_ch2.ice	10.02	15:00	970210_forecast.txt
24.01	14:55	po_ers_Kokkola_sample.ice	11.02	15:00	970211_forecast.txt
27.01	13:37	po_199701261833_ch5.ice	12.02	15:00	970212_forecast.txt
27.01	15:08	970127_LUEMUT_SAR.txt	12.02	17:35	bo_199702121447_ch2.ice
27.01	15:08	LUEMUT_SAR.TXT	12.02	17:37	su_199702121321_ch4.ice
27.01	15:34	970127_INFO.txt	13.02	10:17	bo_199702130847_ch4.ice
28.01	09:32	bo_199701280847_ch4.ice	13.02	10:17	po_199702130533_ch4.ice
28.01	09:32	po_199701280833_ch5.ice	13.02	10:17	po_199702130933_ch4.ice
28.01	09:32	si_199701280843_ch4.ice	13.02	15:00	970213_forecast.txt
28.01	09:32	su_199701280821_ch4.ice	13.02	15:09	po_199702131433_ch2.ice
28.01	12:20	bo_199701280947_ch4.ice	13.02	15:09	po_199702131433_ch4.ice
29.01	11:52	map_970129.ice	14.02	10:11	po_199702140433_ch4.ice
29.01	13:36	bo_199701290947_ch4.ice	14.02	10:11	po_199702140833_ch4.ice
29.01	13:36	su_199701290921_ch4.ice	14.02	15:00	970214_forecast.txt
29.01	13:37	po_199701290933_ch5.ice	14.02	15:18	po_199702141433_ch2.ice
29.01	16:05	map_gof_970129.ice	14.02	15:18	po_199702141433_ch4.ice
30.01	08:57	su_199701300421_ch4.ice	15.02	15:00	970215_forecast.txt

Date	Time	File name	Date	Time	File name
30.01	12:07	map_970130.ice	16.02	15:00	970216_forecast.txt
30.01	15:36	bo_199701301447_ch2.ice	17.02	11:13	su_199702161421_ch4.ice
31.01	09:48	bo_199701310847_ch4.ice	17.02	11:17	po_199702170933_ch4.ice
31.01	09:48	su_199701310921_ch4.ice	17.02	11:17	si_199702170943_ch4.ice
17.02	15:00	970217_forecast.txt	5.03	17:41	si_199703051443_ch2.ice
18.02	10:28	bo_199702171647_ch2.ice	5.03	17:41	su_199703051432_ch2.ice
18.02	10:28	po_199702171433_ch2.ice	6.03	15:00	970306_forecast.txt
18.02	10:28	si_199702171643_ch2.ice	7.03	11:03	po_quark_map_970307.ice
18.02	10:43	970217_icemap.ice	7.03	11:08	po_199703070933_ch2.ice
18.02	14:23	970218_icemap.ice	7.03	15:00	970307_forecast.txt
18.02	15:00	970218_forecast.txt	8.03	15:00	970308_forecast.txt
18.02	15:43	bo_199702181347_ch2.ice	9.03	15:00	970309_forecast.txt
18.02	15:43	po_199702181433_ch2.ice	10.03	09:41	su_199703091423_ch2.ice
18.02	15:43	si_199702181343_ch2.ice	10.03	13:30	su_199703101023_ch2.ice
19.02	14:11	970219_icemap.ice	10.03	13:38	su_qof_map_970310.ice
19.02	14:44	si_199702191343_ch2.ice	10.03	15:00	970310_forecast.txt
19.02	15:00	970219_forecast.txt	11.03	15:00	970311_forecast.txt
20.02	15:00	970220_forecast.txt	11.03	15:13	bo_199703111347_ch2.ice
21.02	15:00	970221_forecast.txt	12.03	10:01	po_199703120533_ch4.ice
22.02	15:00	970222_forecast.txt	12.03	15:00	970312_forecast.txt
23.02	10:25	970223_icemap.ice	13.03	15:00	970313_forecast.txt
23.02	15:00	970223_forecast.txt	13.03	15:36	po_ers_kof_970313094242.ice
24.02	15:00	970224_forecast.txt	14.03	09:34	su_199703140821_ch4.ice
25.02	12:42	970225_gof_icemap.ice	14.03	09:35	po_199703140833_ch4.ice
25.02	12:46	CONTAINER_README.txt	14.03	09:37	po_199703140833_ch5.ice
25.02	15:00	970225_forecast.txt	14.03	13:09	po_CL_kof_970313.ice
26.02	12:45	po_ers_kal_970225094536.ice	14.03	14:00	su_ers_stp_970314091206.ice
26.02	12:49	KEMIRA_LUEMUT.txt	14.03	15:00	970314_forecast.txt
26.02	13:28	su_ers_vyb_970226091458.ice	14.03	15:12	970314KEMIRA.LUEMUT.txt
26.02	13:31	CONTAINER_README_970226.txt	14.03	15:14	970314README.CONTAINER.txt
26.02	14:04	po_kal_CL_970225094536.ICE	15.03	15:00	970315_forecast.txt
26.02	14:04	po_vaa_CL_970225094550.ICE	16.03	15:00	970316_forecast.txt
26.02	14:28	970226_gof_icemap.ice	17.03	09:09	po_ers_kof_970315200920.ice
26.02	15:00	970226_forecast.txt	17.03	09:21	970317KEMIRA.LUEMUT.txt
26.02	15:22	su_vyb_CL_970226091458.ICE	17.03	10:30	po_ers_vaf_970316094843.ice
26.02	15:22	su_vyb_CL_970226091513.ICE	17.03	10:32	970317FENNIA.LUEMUT.txt
27.02	15:00	970227_forecast.txt	17.03	10:39	po_199703170933_ch4.ice
28.02	15:00	970228_forecast.txt	17.03	13:15	po_quark_map_970317.ice
28.02	19:43	CL_970228095050.ICE	17.03	13:32	su_gof_map_970317.ice
28.02	19:43	CL_970228095105.ICE	17.03	13:35	su_ers_som_970317091751.ice
28.02	19:43	CL_970228095120.ICE	17.03	13:39	970317CONTAINER.README.txt
28.02	19:43	CL_970228095135.ICE	17.03	15:00	970317_forecast.txt
28.02	19:46	970228_LUEMUT.txt	18.03	15:00	970318_forecast.txt
1.03	15:00	970301_forecast.txt	19.03	15:00	970319_forecast.txt
2.03	15:00	970302_forecast.txt	19.03	15:23	po_ers_nov_970319095412.ice
3.03	10:26	po_199703011533_ch2.ice	19.03	15:25	970319FENNIA.LUEMUT.txt

Date	Time	File name
3.03	15:00	970303_forecast.txt
4.03	13:39	su_199703040921_ch4.ice
4.03	15:00	970304_forecast.txt
4.03	15:09	bo_199703041447_ch2.ice
4.03	15:09	po_199703041433_ch2.ice
4.03	15:09	si_199703041443_ch2.ice
5.03	12:57	po_199703051033_ch2.ice
5.03	12:57	po_199703051033_ch4.ice
5.03	13:53	po_quark_970305.ice
5.03	15:00	970305_forecast.txt
5.03	17:41	bo_199703051447_ch2.ice
5.03	17:41	po_199703051433_ch2.ice
24.03	10:22	po_199703240833_ch4.ice
24.03	10:22	po_199703240933_ch2.ice
24.03	10:22	po_199703240933_ch4.ice
24.03	10:22	su_199703240821_ch4.ice
24.03	10:26	si_199703240943_ch4.ice
24.03	15:00	970324_forecast.txt
24.03	16:42	po_199703241433_ch2.ice
24.03	16:42	po_199703241433_ch4.ice
24.03	16:42	po_199703241433_ch5.ice
24.03	16:42	si_199703241443_ch4.ice
25.03	09:53	po_199703250933_ch2.ice
25.03	09:54	bo_199703250947_ch4.ice
25.03	09:54	po_199703250433_ch4.ice
25.03	09:54	po_199703250933_ch4.ice
25.03	12:48	bo_ers_nos_970324202619.ice
25.03	12:50	970325FENNIA.LUEMUT.txt
25.03	15:00	970325_forecast.txt
26.03	13:29	bo_199703251447_ch2.ice
26.03	13:29	po_199703251433_ch2.ice
26.03	15:00	970326_forecast.txt
27.03	15:00	970327_forecast.txt
28.03	15:00	970328_forecast.txt
29.03	11:37	su_ers_som_970328195927.ice
29.03	11:37	su_ers_vyb_970328195942.ice
29.03	11:40	970328CONTAINER.README.txt
29.03	15:00	970329_forecast.txt
30.03	15:00	970330_forecast.txt
31.03	13:16	su_ers_stp_970330090915.ice
31.03	13:19	970331CONTAINER.README.txt
31.03	15:00	970331_forecast.txt
1.04	13:31	po_199703311308_ch2.ice
1.04	15:00	970401_forecast.txt
2.04	12:27	po_199704021033_ch2.ice
2.04	12:27	su_199704021123_ch2.ice
20.03	15:00	970320_forecast.txt
20.03	16:00	po_199703201533_ch2.ice
21.03	15:00	970321_forecast.txt
21.03	17:39	po_199703211533_ch2.ice
21.03	17:40	si_199703211443_ch2.ice
22.03	11:15	po_ers_hol_970321202049.ice
22.03	11:15	po_ers_vaf_970321202034.ice
22.03	11:19	970322FENNIA.LUEMUT.txt
22.03	15:00	970322_forecast.txt
23.03	15:00	970323_forecast.txt
24.03	10:22	bo_199703240947_ch2.ice
24.03	10:22	po_199703240433_ch4.ice
9.04	15:00	970409_forecast.txt
10.04	15:00	970410_forecast.txt
11.04	15:00	970411_forecast.txt
12.04	15:00	970412_forecast.txt
13.04	15:00	970413_forecast.txt
14.04	09:05	su_ers_stb_970413195634.ice
14.04	09:09	970414CONTAINER.README.txt
14.04	15:00	970414_forecast.txt
15.04	15:00	970415_forecast.txt
16.04	15:00	970416_forecast.txt
17.04	15:00	970417_forecast.txt
18.04	13:53	po_199704181033_ch2.ice
18.04	15:00	970418_forecast.txt
19.04	10:28	su_ers_stp_970418091205.ice
19.04	10:29	970419CONTAINER.README.txt
19.04	10:47	970419_icemap.ice
19.04	15:00	970419_forecast.txt
20.04	15:00	970420_forecast.txt
21.04	11:13	970421_icemap.ice
21.04	15:00	970421_forecast.txt

Sum 6071873 Bytes

Date	Time	File name			
2.04	15:00	970402_forecast.txt			
3.04	15:00	970403_forecast.txt			
4.04	09:14	po_ers_kok_970403201212.ice			
4.04	09:18	970404KEMIRA.LUEMUT.txt			
4.04	15:00	970404_forecast.txt			
5.04	15:00	970405_forecast.txt			
6.04	15:00	970406_forecast.txt			
7.04	09:09	bo_199704070647_ch4.ice			
7.04	09:09	po_199704070633_ch4.ice			
7.04	09:09	su_199704070821_ch4.ice			
7.04	09:09	su_199704070823_ch2.ice			
7.04	13:17	po_199704071033_ch2.ice			
7.04	13:17	po_199704071033_ch4.ice			
7.04	15:00	970407_forecast.txt			
7.04	15:02	po_199704071433_ch2.ice			
7.04	15:02	su_199704071423_ch2.ice			
8.04	15:22	po_199704081433_ch2.ice			
8.04	15:23	su_199704081423_ch2.ice			
9.04	13:41	po_199704091033_ch2.ice			
9.04	13:41	su_199704091023_ch2.ice			

From: **Finnish Institute of Marine Research, Finnish Ice Service**
fax: +358-9-6857638 or 6857639

Model-based forecast on ice drift processes **#72/97**
26.03.97 12 am

Forecast from tomorrow morning

Bothnian Bay: Very slow (0.2 knots) drift to the NE, in the evening faster-growing drift (0.4-0.5 knots).

The Quark and the Bothnian Sea: Very slow (0.3-0.4 knots) drift to the NE, in the evening to the E. Difficulties in the traffic to Kaskinen.

Gulf of Finland: Slow (0.2-0.4 knots) drift to the N. A brash ice barrier is forming off the Finnish coast.

Forecast for tomorrow

Bothnian Bay: Fast (0.4-0.5 knots) drift, at night to the NE, in the daytime to the E. Ice pressure on the Finnish coast.

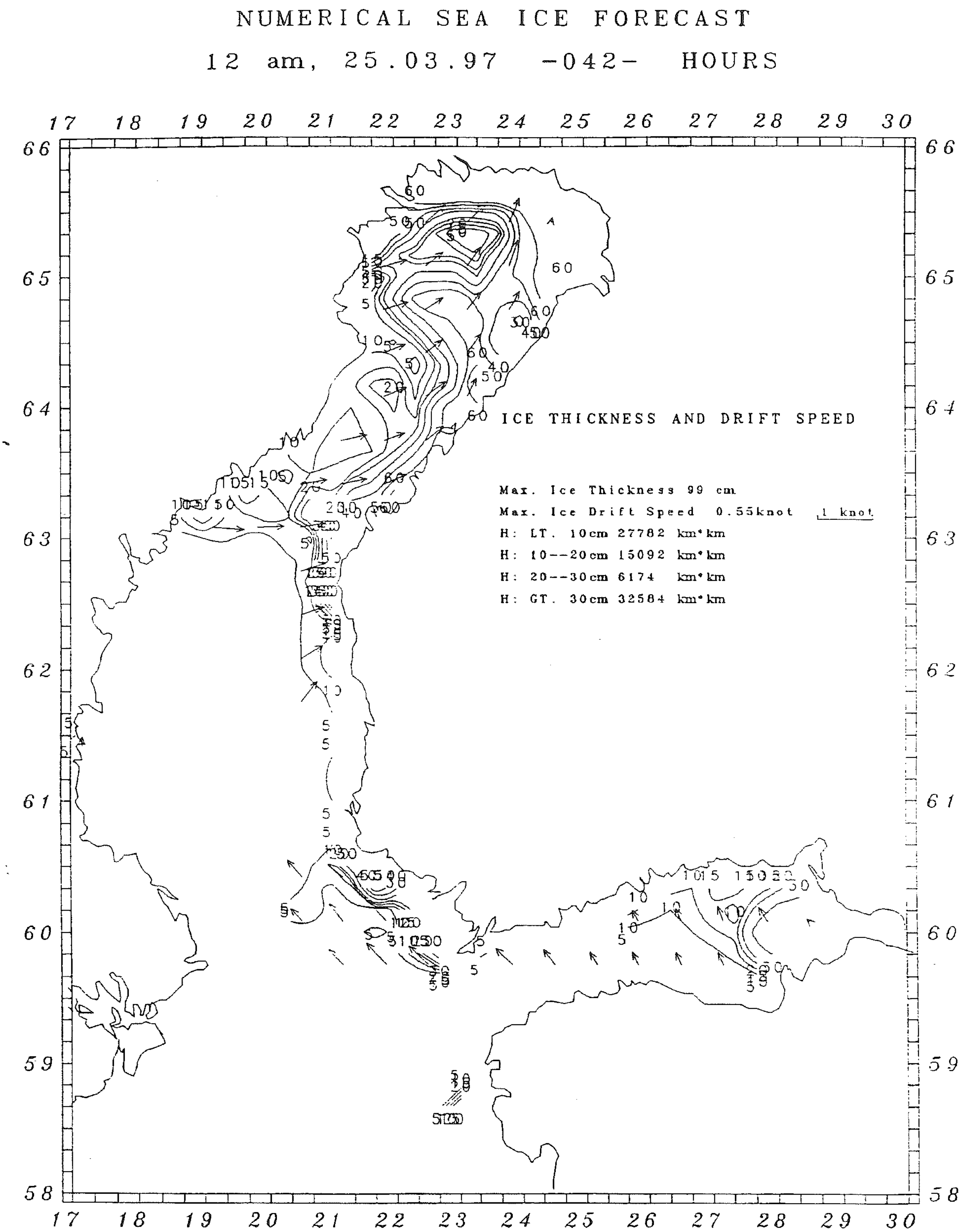
The Quark: Fast (0.4-0.5 knots) drift to the E. Ice pressure off Vaasa.

Bothnian Sea: At night fast (0.4-0.5 knots) drift to the E; in the daytime slower-growing drift which comes to a halt in the evening.

Gulf of Finland: At night slow (0.3-0.4 knots) drift to the NW; in the daytime slower-growing drift which comes to a halt in the evening.

jv

Appendix 3. Example of an ice drift forecast in text format and in chart format.



No.33

IMSI REPORT NO. 2: THE BALTIC SEA ICE FIELD CAMPAIGN 17-24 March 1997 Data report

IMSI REPORT NO. 3: DISSEMINATION OF TEST PRODUCTS TO SELECTED USERS IN THE BALTIC SEA AREA Report on activities in the winter of 1997

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