BALTEX

Baltic Sea Experiment

World Climate Research Programme / Global Energy and Water Cycle Experiment
WCRP GEWEX

BALTEX - BASIS

Data Report 1998

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Baltic Air-Sea-Ice Study

BASIS

A BALTEX/GEWEX Experiment

BALTEX-BASIS
Data Report 1998

Jouko Launiainen (Editor)

Executive Summary

The Baltic Air-Sea-Ice Study (BASIS) is a sub-project of BALTEX. The overall objective of the project is to create and analyse an experimental data set for verification and optimization of coupled atmosphere-ice-ocean models. In the experimental stage the field campaign carried out in February-March, 1998, formed the central element. Experiments were centered in a location in the boundary zone between the open and the ice-covered sea in the Gulf of Bothnia in the Baltic Sea. The aim was to gather meteorological, sea ice and hydrographic data to quantify the physical processes of energy and mass transfer between the atmosphere and the sea ice and the sea. An ice going research vessel anchored in the sea ice formed the central basis and platform for the surface meteorological, sea ice and oceanographic studies. In addition, airborne meteorological and turbulence measurements made from an aircraft and a helicopter carried equipment, and, measurements from specific coastal stations were gathered for BASIS. In spite of rather unstationary sea ice conditions and mild and windy mid-winter weather, the observations were carried out successfully and offered good data sets from highly variable conditions. This report introduces the observations and data sets gained.

BASIS is performed as an international project under the Contract MAST3-CT97-0117 of the EC and scheduled for 1997-2000.

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1. Introduction

1.1 Physical motivation and aims

The Baltic Air-Sea-Ice Study (BALTEX-BASIS) is a sub-project of the Baltic Sea Experiment (BALTEX). BALTEX is a program of GEWEX/WCRP and will explore, model and quantify the main physical processes that control the energy and water exchange within the Baltic Sea and its drainage area. The project BASIS aims at an improved understanding of the energy and water cycles during winter conditions by conducting a versatile air-ice-sea experiment in the Baltic Sea. BASIS is scheduled for three years in 1997-2000 during which the winter experiment in 1998 formed the central element. A pilot experiment was organized in March, 1997. BASIS has cooperation and coordination with the Northern Hemisphere Climate-Processes Land-Surface Experiment (NOPEX) and its winter experiments (WINTEX).

The Baltic Sea is a semi-enclosed sea located in the seasonal sea ice zone with an ice cover forming and melting each year, at least in the northern areas. By acting as a thermal insulator and a mechanical cover, the sea ice strongly influences the air-sea exchange of energy, water and momentum, and affects prominently to weather and meteorological conditions. Since the sea ice is typically less than 1 m thick, its presence and extent are highly sensitive indicators to a climate change. Considering the winter navigation, sea ice is of practical importance to various countries, and therefore has major economical influences.

The overall objective of the BASIS is

- to create and analyse an experimental data set for optimization and verification of coupled atmosphere-ice-ocean models.

The specific objectives cover

a)Investigation of water budget and momentum and thermal interaction at the air-ice, air-sea and sea-ice boundaries.

b)Investigation of the physical structure of the atmospheric boundary layer (ABL), especially close to the sea ice margin.

c)Investigation of the physical structure of the ocean boundary layer (OBL).

d)Validation of coupled atmosphere-ice-ocean models.

1.2 Project organization and tasks

Project (MAST3-CT97-0117) Contractors and Associate Contractors:
Finnish Institute of Marine Research (FIMR)
Universität Hamburg, Meteorologisches Institut, Germany (UHAM)
Universität Hannover, Inst. fur Meteorologie und Klimatologie, Germany (UHAN)
Uppsala University, Dept. of Earth Sciences and Meteorology, Sweden (UUP)

Swedish Meteorological and Hydrological Institute, Sweden (SMHI)
Chalmers Univ. of Technology, Dept. of Radio and Space Sci., Sweden (CUT)

Subcontractors:
Aerodata Flugmesstechnik GmbH (subcontractor to UHAN)
Universität Hamburg, Inst. fur Meereskunde (UHAM, subcontractor to FIMR)
University of Helsinki, Department of Geophysics (UHDG, subcontractor to SMHI)
University of Hokkaido, Sea Ice Research Lab. (UHOK, subcontractor to FIMR)

Coordinator: Prof. Jouko Launiainen, FIMR
The members and addresses of the Project Management Committee are listed in Appendix A.

The project is divided into four Tasks with subtasks as follows:

Task 1. Atmospheric boundary layer

Task 1.1 Airborne measurements
Objective: to measure the horizontal and vertical profiles of the air temperature and humidity, wind speed and direction, cloud properties, turbulent fluxes and radiation

1.2 Ground-based measurements
to measure at five coastal sites the vertical profiles of the air temperature and humidity, wind speed and direction

1.3 Ship/Ice-based measurements
to measure over the sea ice the turbulent and radiative fluxes and vertical profiles of the air temperature and humidity, wind speed and direction

1.4 ABL process studies
to study the ABL structure, air-ice, and air-sea interaction processes on the basis of the field data obtained in Tasks 1.1-1.3.

Task 2. Ice and surface properties

Task 2.1 Sea ice concentration and movement
Objective: to measure the sea ice concentration and its changes during the field experiment over the Gulf of Bothnia, and to detect the ice movement

2.2 Ice and snow properties, surface topography and roughness
to measure the distribution of the ice and snow thickness, water content, temperature, and salinity, as well as that of the surface topography and roughness

2.3 Ice and surface process studies
to study the role of ice and snow in the processes controlling the air-ice-sea exchange of momentum, heat and moisture.

Task 3. Ocean boundary layer

Task 3.1 Hydrographic and current measurements

Objective: to measure the large-scale temperature and salinity distribution in the Gulf of Bothnia, the currents below the ice, and the temperature profiles below the ice and in the open sea

3.2 Eddy flux measurements

to measure the turbulent fluxes of momentum, heat and salt below the ice.

3.3 OBL process studies

to study the OBL structure, ice-sea, and air-sea interaction processes on the basis of the field data obtained in Tasks 3.1 and 3.2.

Task 4. Modelling Activities

Objective: to model the physical processes during the experiment for planning and logistical purposes. In the study phase, models will be verified against the experimental data, and models will finally be improved and optimized with the analyzed project data sets.

The scale of the various experiments varies from microscale to meso-γ-scale, i.e. the spatial scale from 10^{-1} m to 10^{2} km and the temporal scale from hours to days. This report presents the BASIS field experiment in the winter 1998 and introduces the data sets gained. The detailed research plan including the studies to be made by the data was defined as the Technical Annex of the Contract MAS3-CT97-0117 of EC.

2. General layout of the field experiment

The field phase of the Baltic Air-Sea-Ice Study was carried out in 16 February to 7 March, 1998, in the Baltic Sea, in the Quark between the Bothnian Sea and Bay of Bothnia (Figure 2.1). Location was in the boundary zone between the ice-covered and open sea. In the field experiment, meteorological, sea ice and hydrographic data were gathered to quantify physical processes of energy and mass transfer between the sea, ice, and atmosphere. The objective was to create an experimental data set for verification and optimization of coupled atmosphere-ice-ocean models. The Finnish *R/V Aranda*, anchored in the sea ice, formed the central basis and platform for meteorological, sea ice and oceanographic studies. In addition to the ship-based activities, aircraft and helicopter studies, and studies carried out from specific coastal marine meteorological stations formed the field campaign of BASIS-98.

From mid-December 1997, the winter in the Baltic Sea area was generally mild and windy, but occasionally had strong variations. Accordingly, in February 1998 the sea ice cover in the Baltic was poor and unstationary in the planned area proper for BASIS. The final site chosen for the Ice Station was a compromise, which had to be made for getting any area in the ice-edge zone, but keeping the risk of loosing and destroying the research equipment as tolerable.

The ice conditions and the weather were very variable and rather difficult during the first two weeks of the experiment. The winds were frequently strong and the air temperature was above freezing for 42% of the time (Figure 2.2). The sea ice cover was few and the ice was drifting fast. The highest drift velocities indicated by drifting buoys were of the order of 0.7 m/s. Large decreasing and increasing sea level variations were associated with strong winds and storms from north and south, respectively (Figure 2.2c). Strong winds and unstable sea ice conditions caused some problems and damages for the measuring equipment. On the other hand, valuable experimental data were obtained from the highly variable conditions and the net outcome of the expedition can be still regarded as very successful.

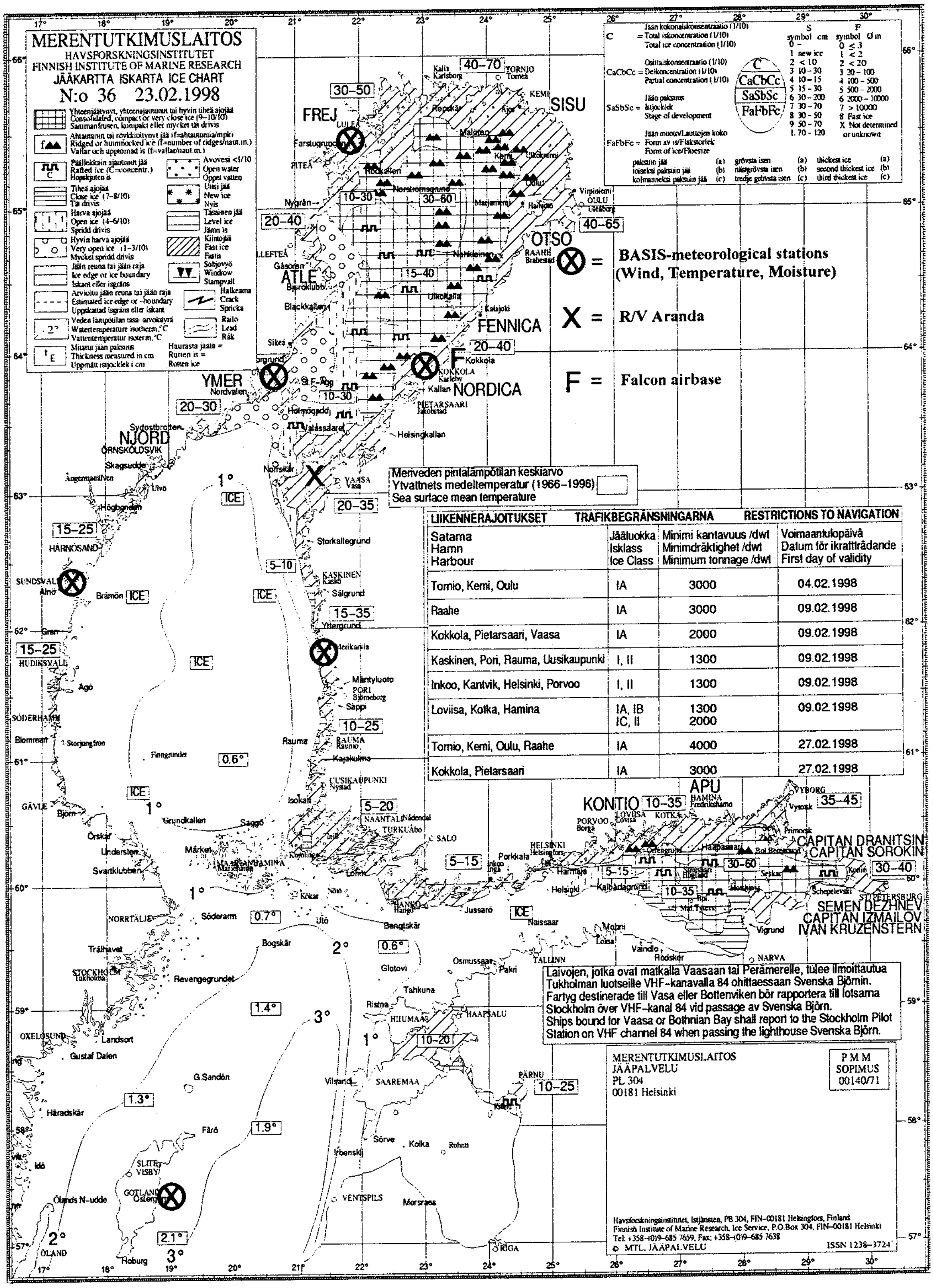


Figure 2.1. Sea ice conditions according to a routine ice chart of FIMR (23 February, 1998) with BASIS observation sites marked.

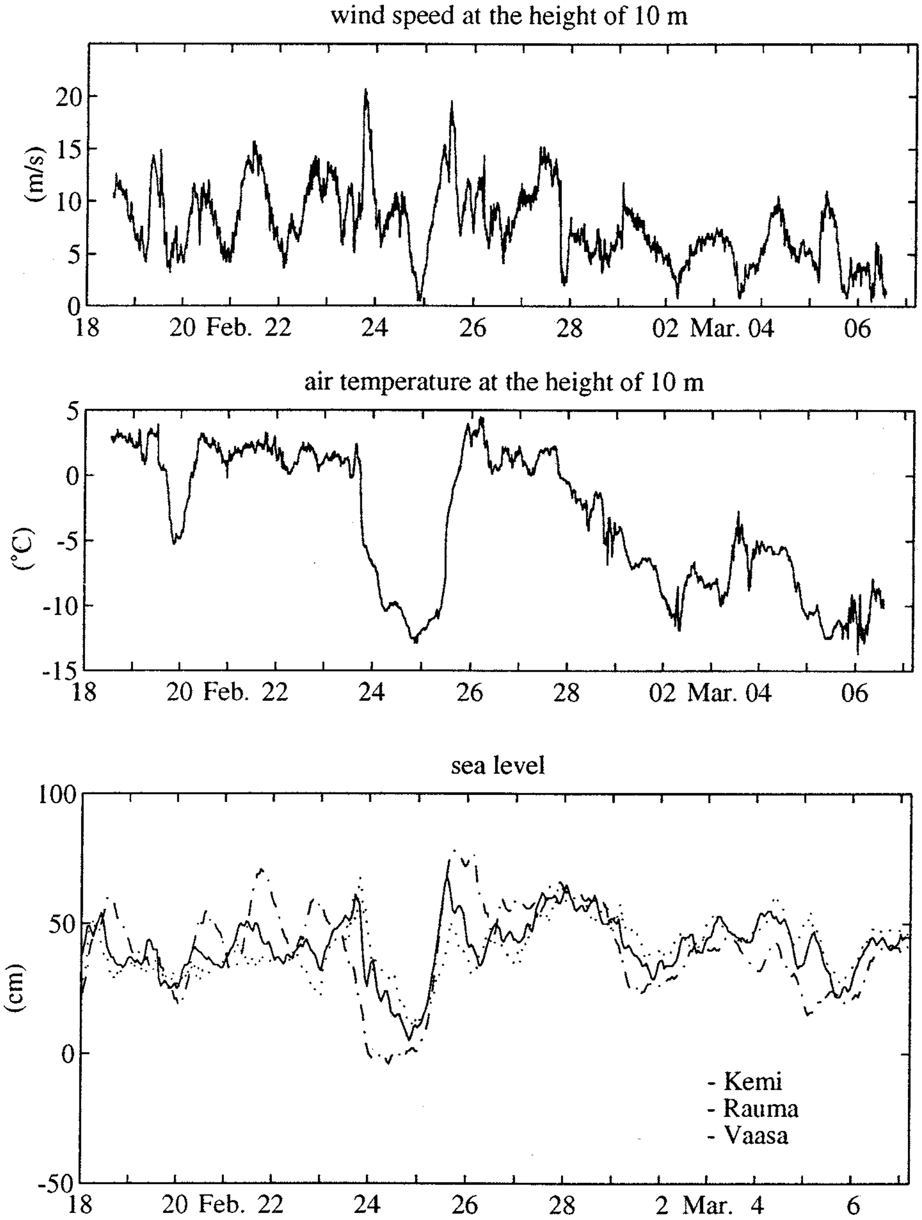


Figure 2.2. Time series of the (a) wind speed, and (b) air temperature during the field experiment, as measured at a meteorological mast on the ice close to *R/V Aranda*. In (c) is given the time development of the sea level in Kemi, Vaasa, and Rauma.

Various studies and observations are shortly listed in Chapters 2.1 - 2.4. The specific field works and observations are introduced in more detail in the reports given by the institutes in Chapters 3-8. Additionally, it is noteworthy that some of the quantities and parameters were measured by two or more institutes and working groups, and the data of these quantities are thus augmented by several data sets, with respect to time and/or space.

2.1. Ice Station

R/V Aranda anchored in the Ice Station on 16 February, 1998, 15 UTC, at the site 63° 08.12′ N, 21° 14.66 E, and left the Ice Station on 6 March, 1998, at 17.30 UTC. The sites of *R/V Aranda* and the measurements in the surroundings are shown in Figure 2.3 (scale 150 x 75 km) and Figure 2.4 (scale 0.7 x 0.4 km). The sea ice thickness at the *R/V Aranda* site varied in space and time from 25 to 45 cm. The measurements are described in more detail by the responsible institutes in Chapters 3-8. During the intensive field experiment, a Finnish helicopter operated from *R/V Aranda* and deployed most of the equipment on the ice. A Swedish helicopter visited *R/V Aranda* on 18 February and on 5 March, 1998, to deploy and pick up ice drift buoys.

2.2. Airborne and remote sensing observations

Airborne observations were made by the German research aircraft Falcon (UHAM), operating from Kokkola airport during 25 February - 6 March, 1998, and by the German Helipod (UHAN) helicopter, operating from *R/V Aranda* from 24 February to 1 March, 1998. The Falcon aircraft made six flight missions with a total duration of about 11.5 h. The missions took place under different large-scale flow directions with respect to the ice edge, i.e. under on-ice, off-ice and ice-parallel flows. The Helipod made three flights yielding a vertical sounding on each flight, and two horizontal legs of 8 km length at the height of 20 m. The observation quantities of both the aircraft and Helipod included the wind speed, air temperature and humidity, surface temperature, and the turbulent fluxes of momentum, heat and moisture. The aircraft additionally measured the upward and downward components of both the shortwave and longwave radiative fluxes, as well as the liquid water contents and particle sizes of cloud droplets. The ice surface roughness was measured by laser profilometry from the FIMR helicopter.

As a ground truth for utilizing radar satellite images (ERS-2, RADARSAT), various sea and sea ice observations were carried out (by SMHI) in the near-site of the Ice Station and more remote areas. Data from the ice buoys are used as a ground truth for remote sensing as well.

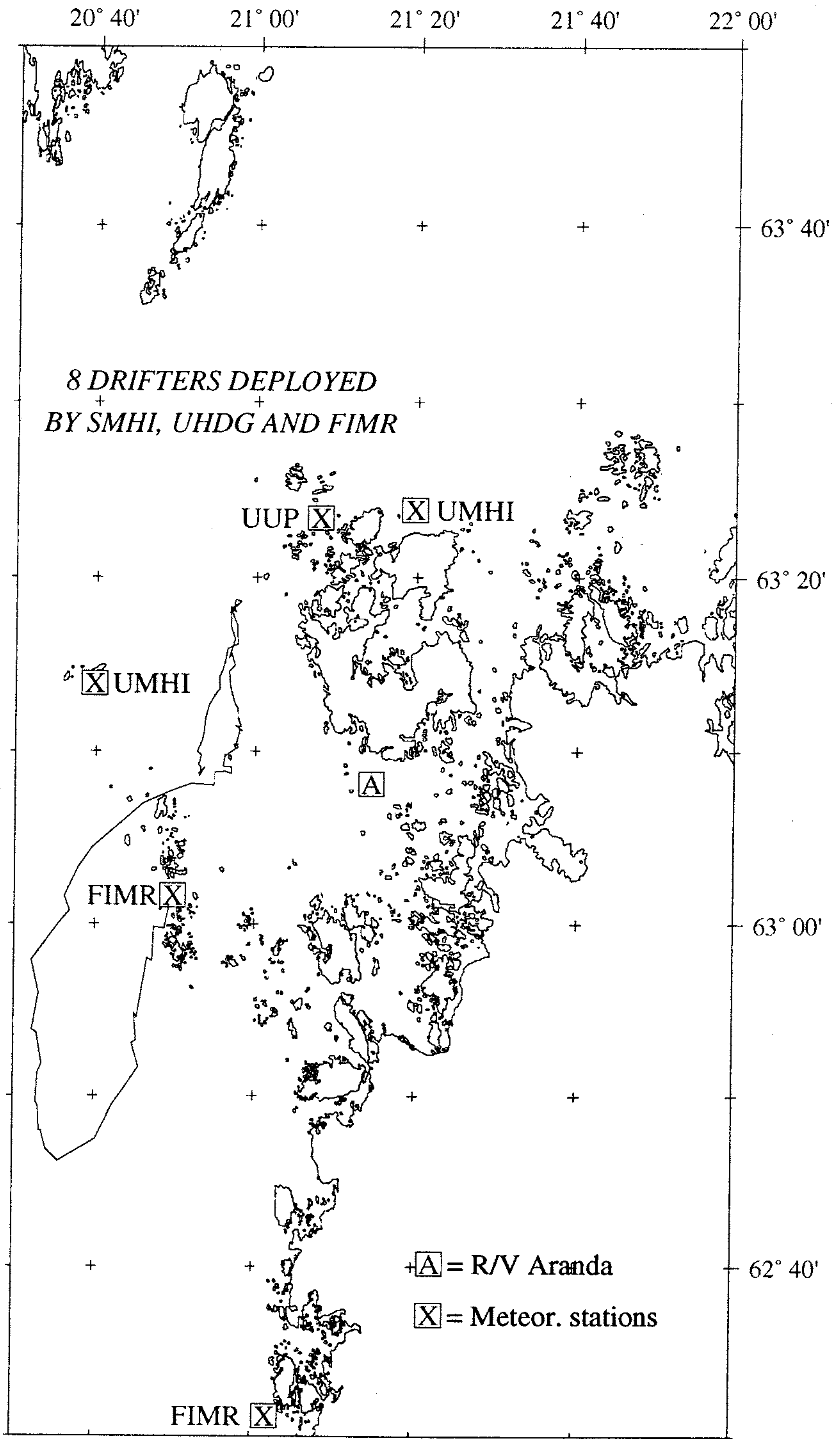


Figure 2.3. Meteorological stations and the near-site Ice Station (A; in the vicinity of *R/V Aranda*) on the sea ice during BASIS-98. (For sites of UUPP meteorological station at Umeå and UHAM meteorological station see Figure 2.1).

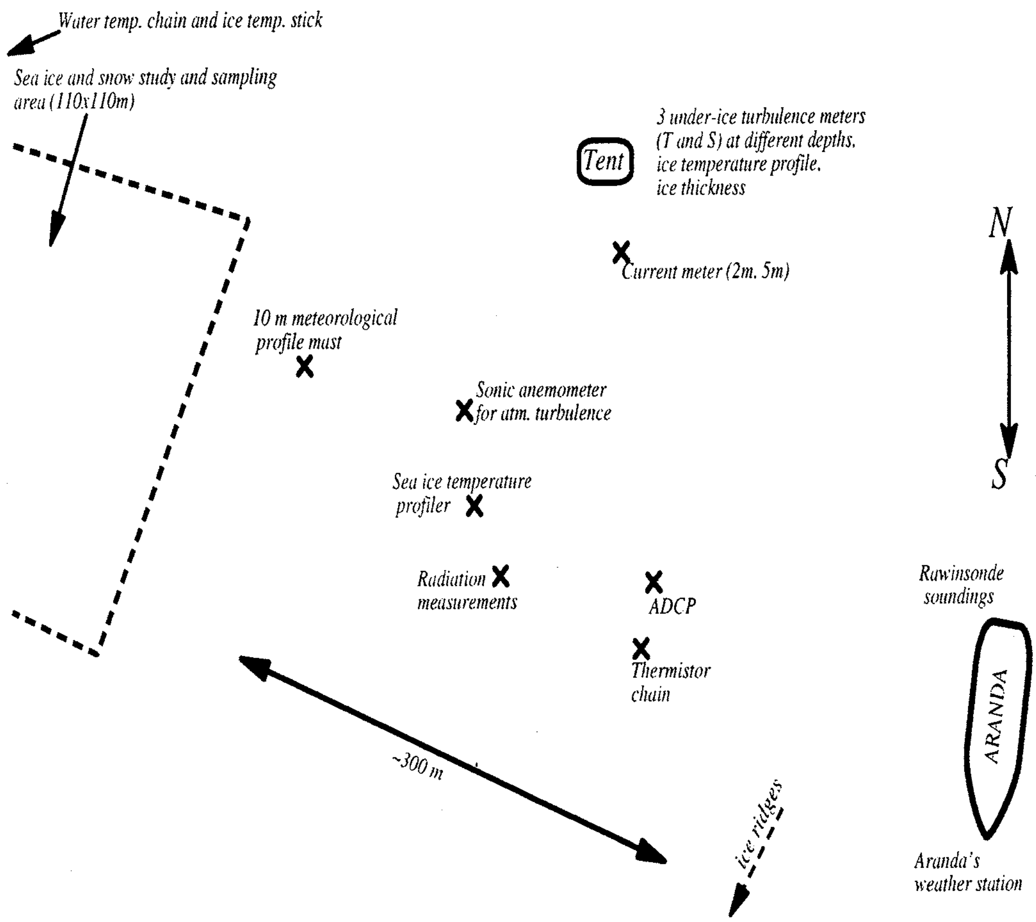


Figure 2.4. Near-site observation field at the Ice Station during BASIS-98.

2.3. Coastal and land-fast ice stations

Two stations were operated on the Finnish coast of the Gulf of Bothnia:

a) Meteorological station for rawinsonde soundings (soundings with 6 h intervals) and surface-layer observations (UHAM), including turbulence and radiation measurements and cloud observations at Kokkola, Trullevi (63.8°N, 23.3°E)
b) A meteorological rawinsonde station (UHAN, 6 h intervals) at Merikarvia, Mericamping (61.9°N, 21.5°E)

Three stations were operated on the Swedish coast of the Gulf of Bothnia:

a) Meteorological station for radiosonde and pibal soundings (6 h intervals) and surface-layer observations (UUPP), including a 30-m mast, turbulence and radiation measurements at Umeå (63°40.5'N, 20°24.0'E)
b-c) Two meteorological rawinsonde stations (SMHI, 6 h intervals) at Sundsvall (62°22.5'N, 17°19.5'E) and Kallax (65°30.7'N 22°6.5'E)

As a reference for the atmospheric conditions over open water, the Östergarnsholm station (57^{O} 25,78' N 18^{O} 54.25' E) was used. It has a 30-m-high tower with temperature and wind sensors, as well as turbulence equipment.

The stations are marked is Figure 2.1. Most of the sounding stations started at 12 UTC of 18 February, 1998, and continued up to 12 UTC of 6 March, 1998.

2.4. Pre- and past- Intensive Period hydrographic monitoring, other operations

A pre-experiment hydrographic monitoring was carried out in the Gulf of Bothnia by the *R/V Argos* (SMHI) during 5 - 10 December, 1998. 22 hydrographic CTD stations were taken. Additionally, a vertical water temperature chain was deployed in the Bay of Bothnia. The *R/V Aranda* made a hydrographic pre-experiment monitoring during 26 January - 5 February, 1998, by taking 38 CTD stations. *R/V Aranda* made a past-experiment monitoring during 9 - 13 March, 1998. In that time, the ice conditions and schedule allowed only 19 hydrographic stations in the Gulf of Bothnia.

For the BASIS research phase, daily ice maps and other ice information for the whole winter are to be obtained from FIMR and SMHI, which can also supply sea level data from various mareographs. Additionally, supportive meteorological data were obtained from the synoptic and automatic Finnish and Swedish coastal meteorological stations.

2.5 Acknowledgment

BASIS is carried out as the Contract MAST3-CT97-0117 of the EC. In thinking up of the project BASIS, Dr. Peter Lemke, Intitut für Meereskunde an der Universität Kiel, and Dr. Anders Omstedt, Sveriges Meteorologiska och Hydrologiska Institut, had a role of a primary importance. Dr. Eberhard Ruprecht, Intitut für Meereskunde an der Universität Kiel, chairman of the BALTEX Working Group on Process Studies, is appreciated for promoting the realization of the project. Prof. Dr. Christoph Kottmeier is acknowledged for his comments in the scientific study plan. Finally, we may note that during the BASIS field campaign the cooperation between the various international scientists and institutions was exemplary good.

3. Marine meteorological, sea ice and oceanographic observations by the Finnish Institute of Marine Research

Timo Vihma, Juha Uotila, Bin Cheng, Tero Purokoski, Pekka Kosloff, Jouko Launiainen, and Corinna Schrum*

*University of Hamburg, Department of Oceanography

3.1 Objectives

The objective of the field experiment was to gather data of physical processes in the air-ice-sea interfaces and in the atmospheric and oceanic boundary layers. In particular, data are required of the turbulent and radiative air-ice/sea fluxes and vertical profiles of the wind speed, and direction, air, ice and water temperature, air humidity, water salinity, and current speed and direction and, finally, water-ice turbulent fluxes. In the first stage, the objective is to study the physical processes on the basis of the field data gathered. In a later stage, the data and the results of the process studies will be applied in validation of coupled atmosphere-ice-ocean models. Comparisons of the model results with the field data will provide basis for verification and optimization of the models.

3.2 Measurements and methods

FIMR conducted the measurements listed below in Table 3.1.

Table 3.1. Measurements of FIMR during BASIS field experiment

Measurement Quantity	Principle	Number of Devices
Ice drift	Argos and GPS buoys	1 Argos 1 GPS
Surface layer wind, air temperature, air humidity	- profile mast - ship weather station - sonic anemometer - buoy	1 1 1 1
ABL wind, air temperature, air humidity	rawinsonde soundings	1 rawinsonde set, 71 soundings
Atmospheric turbulence	sonic anemometer	1
Radiation over ice	- net radiometers - infrared thermometers - pyranometers	2 2 2
Currents below ice	- ADCP - mechanical current meters	1 2
Water temperature and salinity	- thermistor chain - portable CTD	1 chain, 12 sensors 1, profiles 2 / day
Ice and snow temperature	- thermistor stick - ice samples	1 7 sites, 3 cores / site
Ice structure and salinity	- ice samples	7 sites, 3 cores / site
Ice roughness	laser profilometry	7 hours

a) Meteorological and ice drift buoys

FIMR deployed three buoys on the sea ice during the field experiment. A buoy (Argos ID 1154) was deployed on 18 February, 1998, at 11 UTC, on land-fast ice at the site 63°01.655'N, 20°49.825'E. The level fast ice was smooth having a snow cover of 0-10 cm. The ice was 30 cm thick, and the ice edge was in the southwest in a distance of 1 nm from the buoy. The buoy measured the atmospheric pressure, wind speed and direction, air temperature at two different heights, air humidity, and the ice floe orientation (with respect to north). The location was detected by Argos. The fast ice broke on 24 February, and the buoy began to drift.

A buoy (Argos ID 5893) was deployed on 19 February, 15 UTC, on a drifting sea ice floe at 63°30.871'N, 21°22.946'E, some 26 nm north of *R/V Aranda*. The floe size was about 0.5 x 1 nm, and the floe was rafted and ridged with a level thickness of about 0.5 m. The buoy measured the atmospheric pressure, snow/ice surface temperature, and location by a GPS receiver with data transmission via Argos. The last signal from the buoy was received on 26 February, 1998, at 03.30 UTC. A buoy with an Argos ID 5892 was deployed on 19 February, 11.50 UTC, on a flat (2m) rock at 62°31.20'N, 21°04.84'E, some 37 nm south of *R/V Aranda*. The buoy measured the atmospheric pressure, and was recovered on 6 March, 1998, at 12.40 UTC. All the buoys were manufactured by Metocean Data Systems.

(b) Surface-layer wind, air temperature and humidity

A 10-m-high meteorological mast (with sensors from Aanderaa Instruments) was erected on the ice 300 m northwest from *R/V Aranda*. The wind speed was measured at 5 levels above the ice surface: 0.4, 1.0, 2.3, 4.6, and 10.0 m. The air temperature was measured at the heights of 0.4, 2.3, and 10.0 m, and the air humidity at the height of 4.6 m. The wind direction and the gust wind speed (2 s maximum) were measured at the height of 10.0 m. The data were recorded with 10 min intervals. The measurements were started on 18 February, 1998, at 12.50 UTC and continued up to 6 March, 1998, 14 UTC.

The ship automatic weather station (Vaisala Co, Milos 200) recorded the atmospheric pressure, air temperature, wind speed and direction, downward solar irradiance, air humidity, and rainfall. For most of the quantities, two sensors were used, on port side and starboard side of the ship, and the values from the upwind side were recorded. The basic data set includes the instantaneous values at 10 min intervals, the 10 min averages, and the maximum and minimum values during the 10 min periods. The logging was started at 16 February, 14.00 UTC and finished at 6 March, 1998, 19.00 UTC. For short periods (when there were no helicopter operations), also the meteorological sensors at the 8.5 m long bow sprit were in use.

(c) Atmospheric turbulence

A sonic anemometer (Metek) was deployed on the ice 40 m from the profile mast. The equipment measured the three perpendicular wind components and the air temperature at the height of 2.0 m with a sampling rate of 20 Hz. The turbulent fluxes of heat and momentum were calculated on the basis of these data. The instantaneous wind and temperature data, as well as the fluxes based on 10 min averaging, were recorded. The sonic anemometer started on 17 February at 14.30 UTC and the measurements were finished on 6 March at 13 UTC. Some interruptions occurred because of hard weather and snow storms leading to low battery and mains supply disconnections, for example.

(d) Radiation measurements

Radiation measurements above the ice were made from 18 February, 17 UTC, to 6 March, 1998, 13 UTC. The net radiation was measured by two Suomi-Franssila radiometers, and the upward longwave radiation from the surface by two infrared radiometers (Barnes PRT-5 and Everest Interscience 4000.4GL). The downward solar irradiance was measured by an upward-looking pyranometer (CM-5), and the solar radiation reflected from the ice/snow surface by a similar downward-looking pyranometer. The ratio of the pyranometer readings provides the surface albedo. The ice temperature was measured by a Pt-100 thermometer. Existence of snow and meltwater were monitored. Cloudiness was observed visually once an hour during daylight. Downward solar radiation was also measured by the ship weather station.

(e) Meteorological soundings

The vertical profiles of the air temperature, humidity and wind speed and direction were measured by rawinsonde soundings. The soundings were made with Vaisala RS80-15G radiosondes, and a Vaisala DigiCora MW11 Automatic Rawinsonde Set was used for the data collection and evaluation. The soundings were made principally with 6-h intervals, at the launching times of 5.30, 11.30, 17.30, and 23.30 UTC. Four additional soundings were made prior to the Falcon aircraft missions. The wind detection was based on the GPS satellites. Whenever the wind conditions allowed, the balloons were launched from the ice, but in cases of strong (> 10 m/s) wind the balloons were launched from the rear deck of the ship. In several cases the wind data from the lowermost 100-200 m were missing due to interruptions in the GPS connections.

(f) Current measurements

The ocean current below the ice was measured by three devices (Figure 2.4). An Acoustic Doppler Current Profiler (ADCP, RD Instruments) was deployed on 19 February, at 12.55 UTC. It was installed looking downward in a hole in the ice, to measure the current profile (speed and direction) with 1 m depth intervals. Two mechanical current meters were deployed below the ice on 20 February, one 2 m below the ice and the other one 2 m from the bottom. The current data were recorded with 10 min intervals until 6 March, 1998 UTC.

(g) Water temperature and salinity profiles

The temperature profile in the water below the ice was measured by a thermistor chain having thermometers with 1 m intervals. The data were recorded every 10 min from 26 February, 8.50 UTC, to 6 March, 6.40 UTC. The water depth at the near field (in the vicinity of *R/V Aranda*) measurement site was 12 m. A portable CTD sonde was used to measure water temperature and salinity profiles. The measurements were made twice a day at two sites within 200 and 500 m from the ship. The measurement period was from 20 February to 6 March, 1998.

(h) Ice thickness, temperature, salinity and structural properties

The temperature profile through the ice and snow was measured by a thermistor stick having seven sensors in the ice or snow, two in the water, and two in the air. The data were recorded with 10 min intervals. The measurement period was from 17 February, 13.20 UTC, to 6 March, 1998, 15 UTC. The snow and ice thickness was measured once a day.

Ice samples were taken from near-site and from remote areas. A total of seven ice coring sites were visited. At least three ice cores were drilled at each site, one for structural analysis, one for salinity measurements and one core for tomography analysis. The tomography cores were sent to the University of Hokkaido, Japan. The ice structure cores are stored in a freezer for forthcoming analysis. The temperature of ice was measured immediately after drilling with a digital thermometer and a needle probe. The vertical profile of ice salinity was determined by measuring the conductivity of melted sections 5-10 cm long each. Measurements of small-scale spatial distribution of ice and snow thickness were made close to *R/V Aranda*.

A wide angle high precision laser profilometer (810 nm) and video camera was used from helicopter for detecting ice roughness of various scales. The flying altitude was about 30 m and speed 25-30 km/h. The laser line was visible only in video and it deformed corresponding to the surface roughness. The measurements were done in co-operation with VTT/Automation, Finland. Seven flight hours were made, and the flights covered the near-site field, a special Radarsat ground-check area (SMHI) and offshore areas of various ice types, up to highly ridged areas off Pietarsaari. The raw data (630 Gbytes) are stored, but the processing will require a plenty of labour resources.

3.3 Data sets and characterization

Buoys

The wind anemometer of buoy 1154 was destroyed on 24 February, 1998, but the air pressure and air temperature worked throughout the whole period. The sensors of buoys 5892 and 5893 functioned through the measurement period. The drift of buoys 1154 and 5893 was characterized by a period of fast drift towards southwest, followed by a drift back towards northeast. Time series of the drift speeds of the buoys 5893 and 1154 are shown in Figure 3.1, together with the wind speed. The results indicate an overall response of ice drift to the local wind, an item to be studied further in detail.

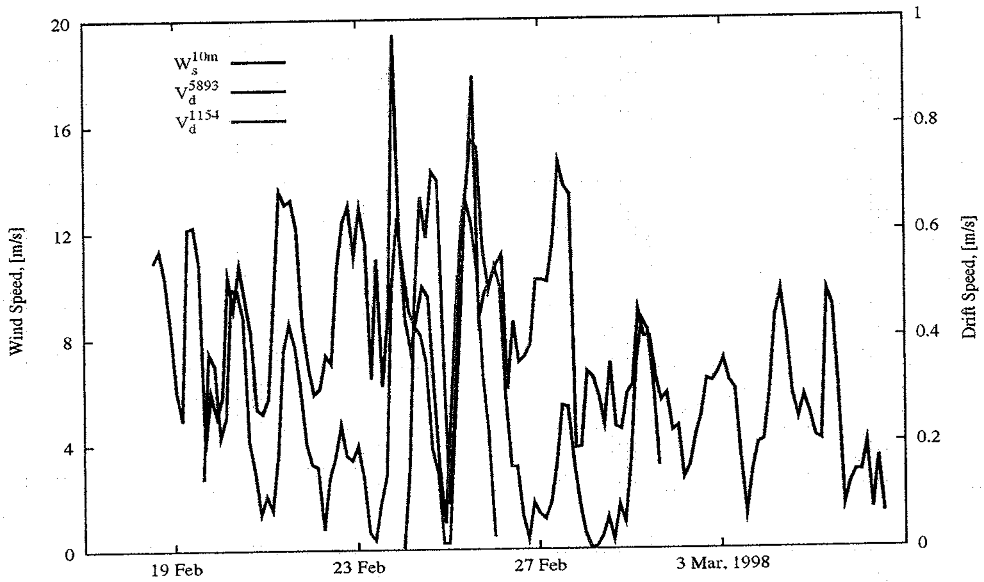


Figure 3.1. Time series of the drift speeds (V_d) of the buoys 5893 and 1154, and the 10-m wind speed (W_s) measured at the meteorological mast.

(b) Surface layer wind, air temperature and humidity

The vertical near-surface profiles of the wind speed and air temperature depended on the synoptic weather condition and wind direction (Figure 3.2). The winds were strongest during conditions of warm advection, and the vertical air temperature gradient was then small, except in a very shallow layer of some 0.4 m. The air temperature gradient was largest during temperatures below -5°C.

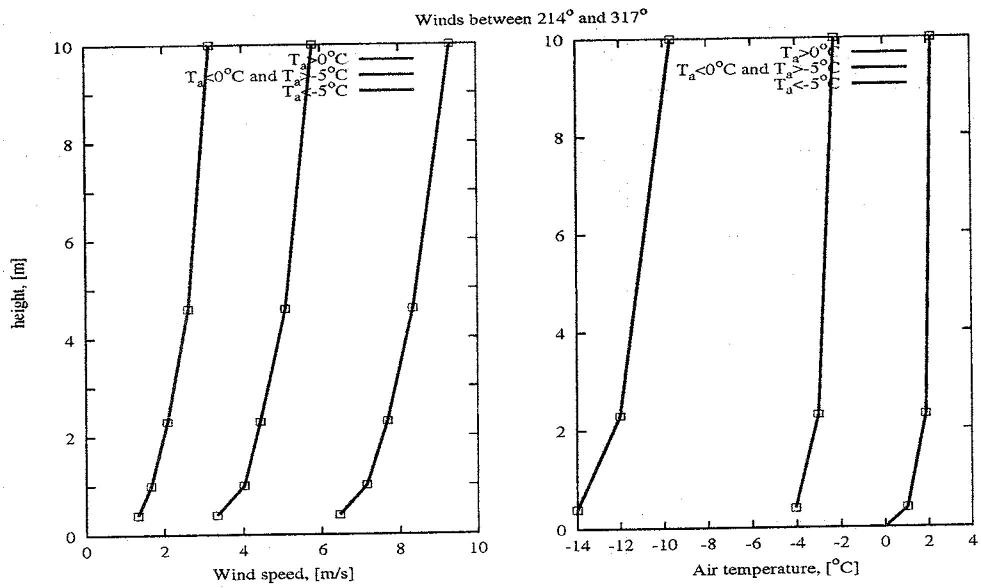


Figure 3.2. Vertical profiles of (a) the wind speed and (b) the air temperature for cases of wind from the sea. The cases are classified according to the air temperature.

(c) Atmospheric turbulence

The sonic anemometer data suffer from interruptions due to technical problems caused by bad weather conditions. The data are corrected by making axial calibrations and corrections for potential alignment errors due to deviations of equipment axes from vertical and horizontal orientation. The time series of the data are shown in Figure 3.3. A characteristic feature is the prevalence of downward sensible heat flux over the ice. During cold periods the downward flux is associated to the negative radiation balance of the surface, and during warm periods to the advection of air with temperatures exceeding 0°C.

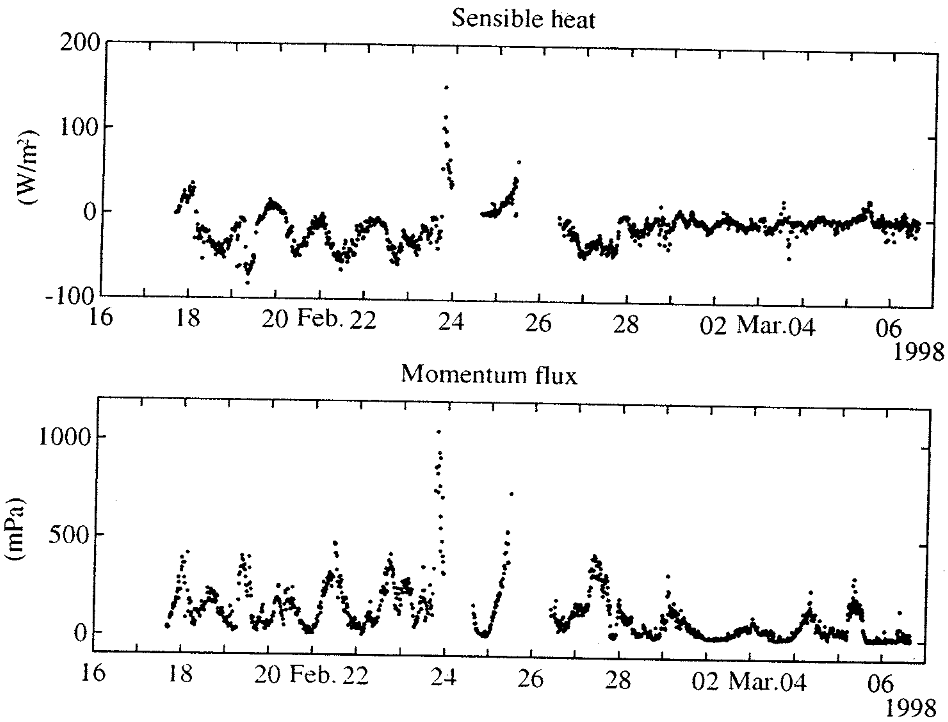


Figure 3.3. Time series of the surface sensible heat and momentum fluxes measured by the sonic anemometer.

(d) Radiation measurements

Time series of the net radiation, surface radiation temperature, and the upward and downward components of the shortwave and longwave radiation are shown in Figure 3.4. The downward longwave radiation was not directly measured, but calculated as a residual from the measurements of the other components. The net radiation is shown as an average of the two sensors, which agreed well, and the radiation balance of the surface, averaged over the whole observation period, was slightly negative (-6 W m^{-2}). The upward longwave radiation showed fairly constant values around 200-300 W m^{-2}, but the downward component varied a lot depending on the cloudiness and air temperature and humidity profiles. The reflected part of the solar radiation suggested a mean surface albedo of 0.73. It varied, however, strongly depending on the state of the surface and the altitude of the sun. The downward solar radiation reached occasionally values much larger than those predicted by standard theoretical formulae. We believe these have resulted from multiple scattering between the snow surface and clouds.

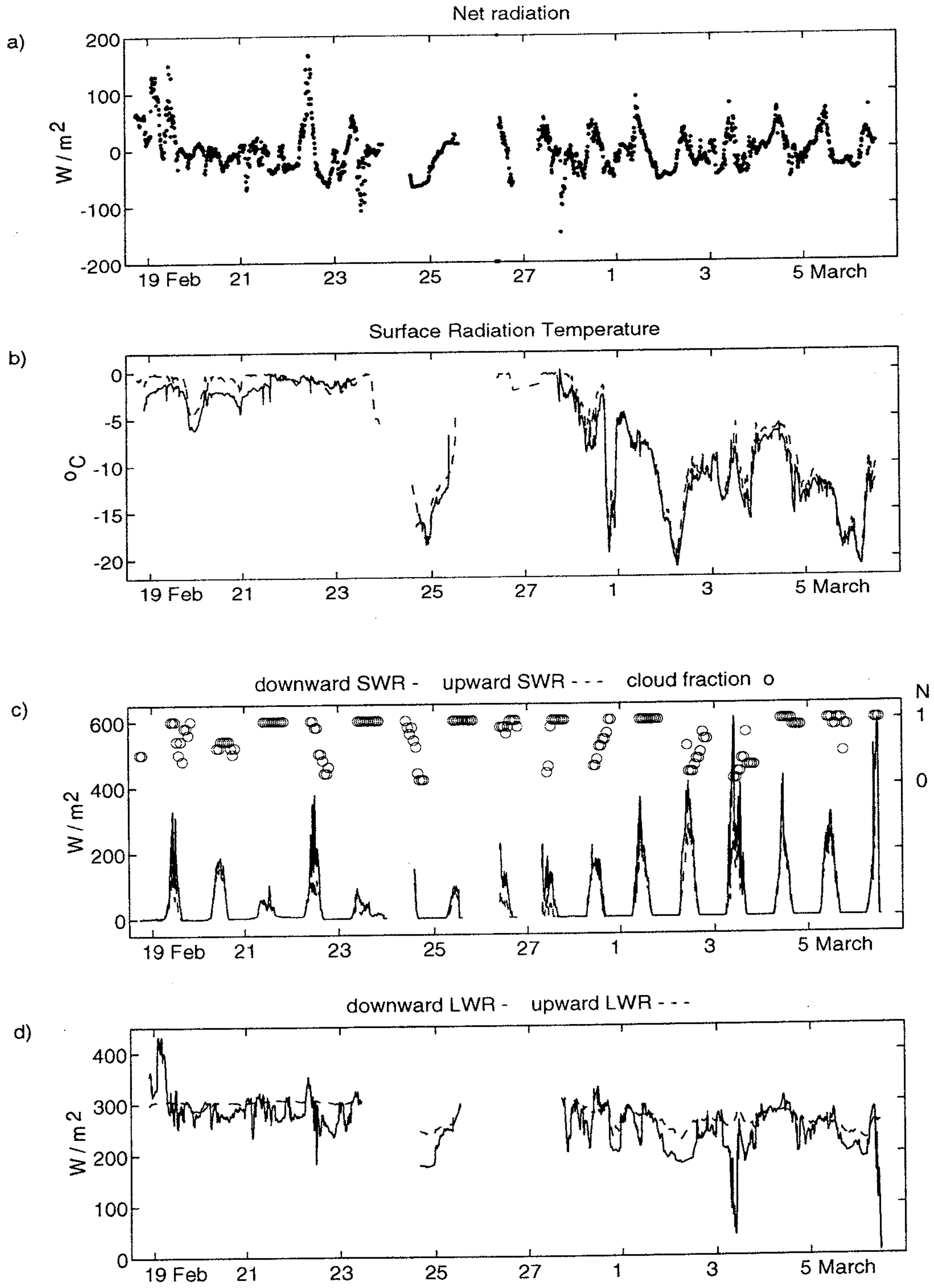


Figure 3.4. Time series of the (a) surface net radiation, (b) surface radiation temperature (two sensors), and (c) cloud fraction (N) and downward and reflected shortwave radiation, and (d) downward and upward longwave radiation.

(e) Meteorological soundings

The wind, temperature, and humidity profiles above the site of *R/V Aranda* showed an overall structure and temporal evolution comparable to those presented in Figure 4.8 of the UHAM sounding site in Kokkola. The ABL was ofter characterized by the presence of temperature inversions and low-level jets (a wind speed maximum exceeding the speeds both above and below it by at least 2 m/s). A total of 90 inversion layers and 64 low-level jets were detected from the 71 soundings made. The basic properties of these are summarized in Table 3.2.

Table 3.2. Properties of the temperature inversions and low-level jets as detected by the rawinsonde soundings from *R/V Aranda.*

Quantity	Mean	Median	Max.	Min.	Std
Inversion base (m)	580	370	1740	0	600
Inversion top (m)	750	490	2220	20	650
Base temperature (°C)	-6.8	-8.1	5.1	-20.1	7.0
Inversion strength (°C)	2.1	1.4	7.8	0.3	1.8
Jet core height (m)	670	590	1560	60	430
Jet core wind speed (m/s)	15.0	13.0	32.3	3.6	6.8

(f) Current measurements

The under-ice ADCP and Aanderaa current meter recordings showed rather good compatibility during cases of current speeds exceeding 5 cm/s, but for much of the time the current speed was below the threshold value of the Aanderaa current meter (2 to 3 cm/s). An example of the data during a windy period in the middle of calm periods is shown in Figure 3.5. The wind effect is felt in the under-ice currents after a delay of 1-2 hours. In addition to the wind, the under-ice currents were related to the variations in the water level.

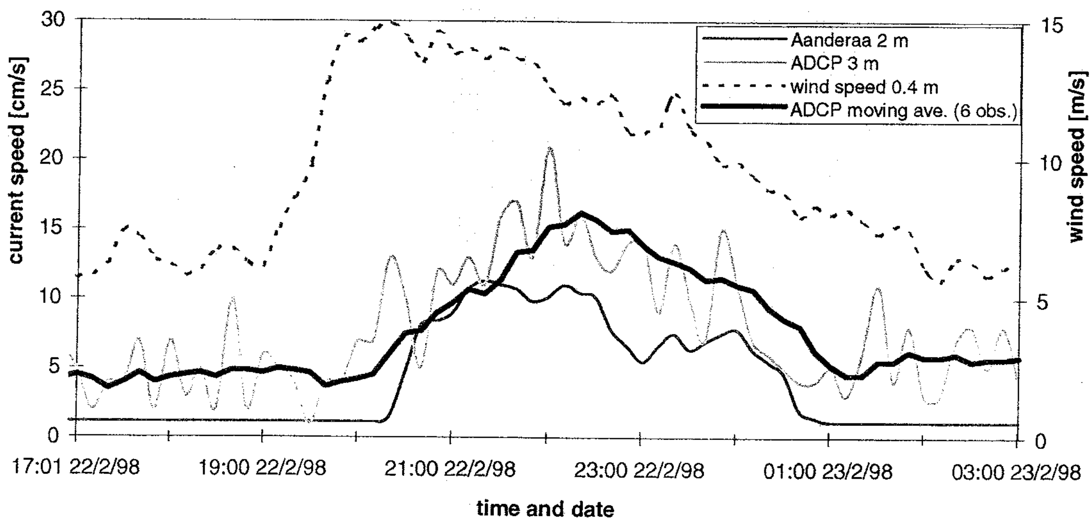


Figure 3.5. Time series of the current speed below the ice as measured by the ADCP (3 m below the ice) and Aanderaa current meter (2 m below the ice). The wind speed at the height of 0.4 m is drawn by dashed line.

(g) Water temperature and salinity profiles

Characteristics of the hydrographic conditions below the ice are shown in Figure 3.6. The salinity shows a stratified distribution in the beginning and the end of the observational period. These stratified conditions are interrupted by a pronounced unstratified period from 24 February up to 26 February, which suggests a saline convection. The temperature show an overall decrease for the observational period which is overlaid by a patchy small scale structure with local temperature maxims in the water column. The evolution of the temperature and salinity profiles will be further compared with the ice growth and melt, currents and water level fluctuations.

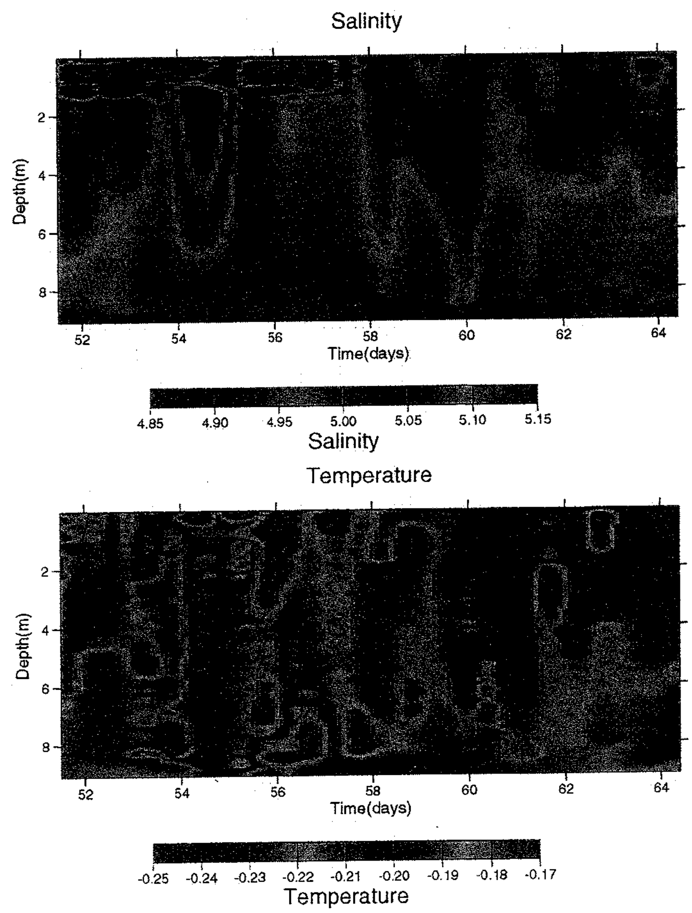


Figure 3.6. Salinity and temperature below the ice during BASIS-98.

(h) Ice thickness, temperature, salinity and structural properties

The temperature profiles in the ice and snow showed large variations (Figure 3.7). The generally warm conditions were interrupted by a cold period from 23 to 25 February, and from 28 February onward the temperatures decreased again.

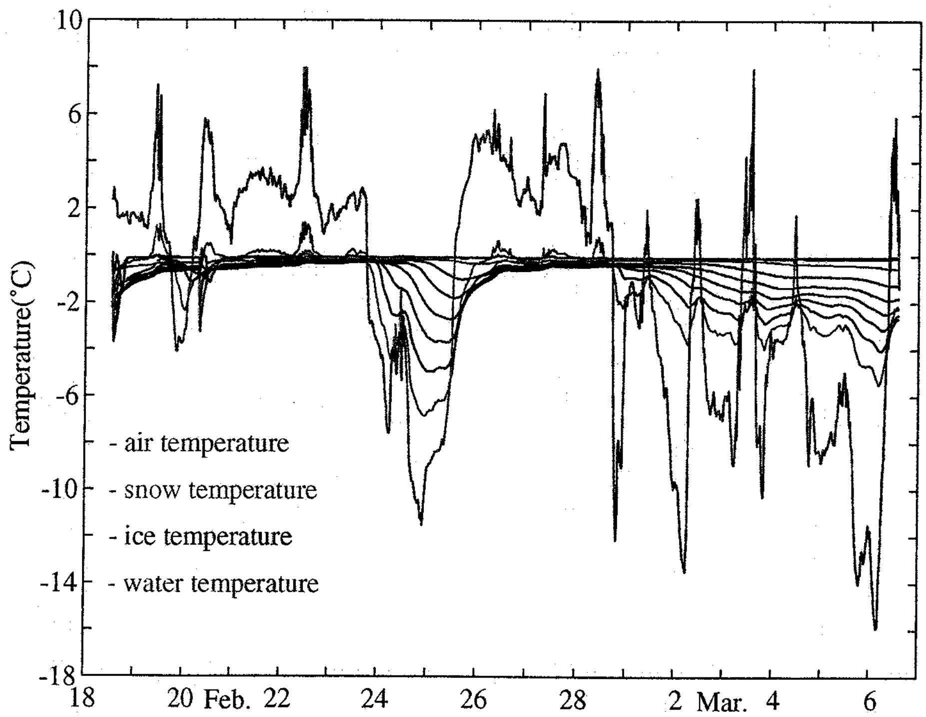


Figure 3.7. Time series of the air temperature (red), snow temperature (blue), in-ice temperature (black; at various depths) and near-ice water temperature (green; as close to 0 °C).

Because of mild and freezing weather alternating, the changes in the net ice thickness were moderate. Figure 3.8 gives the ice thickness variation in the area of the ice temperature profile stick. Due to the weather characterized, the thickness of snow cover was very variable, and the state of the surface varied between a level snow cover, low snow dynes, snow ice, and water layer on the ice. An areal mapping of the ice thickness in the Ice Station area was made on 17 and 19 February, 1998. The ice sampling sites are described in Table 3.3. The minimum observed salinity in the samples was 0.2 - 0.3‰ and the maximum 1.2 - 1.3‰. Figure 3.9 shows the vertical ice salinity profiles at the various sites.

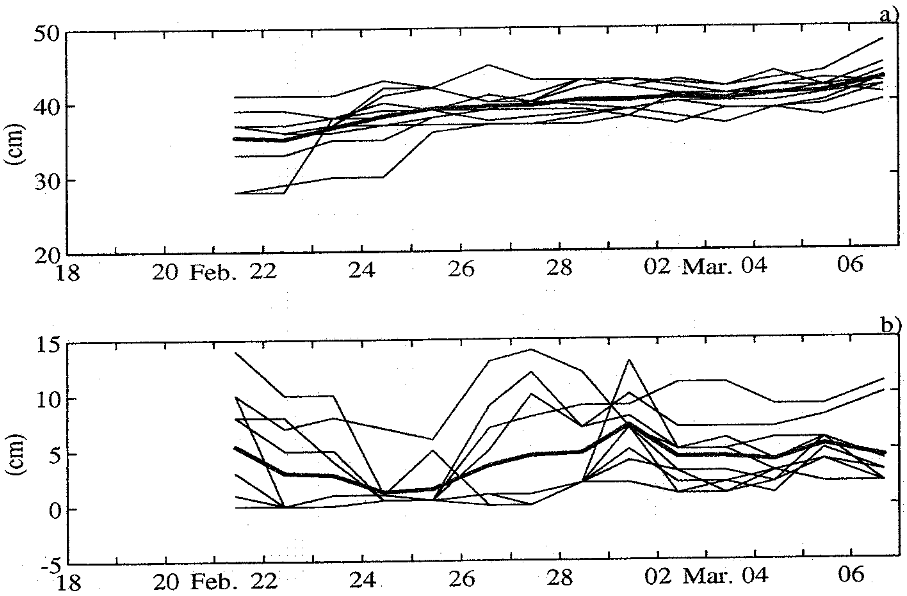


Figure. 3.8. a) Ice thickness at the Ice Station. The black graphs give the time variation in various points in a L-shape line 30 + 20 m in the area of the ice temperature profile stick. The red line gives the algebraic mean.
b) Snow thickness at the points above.

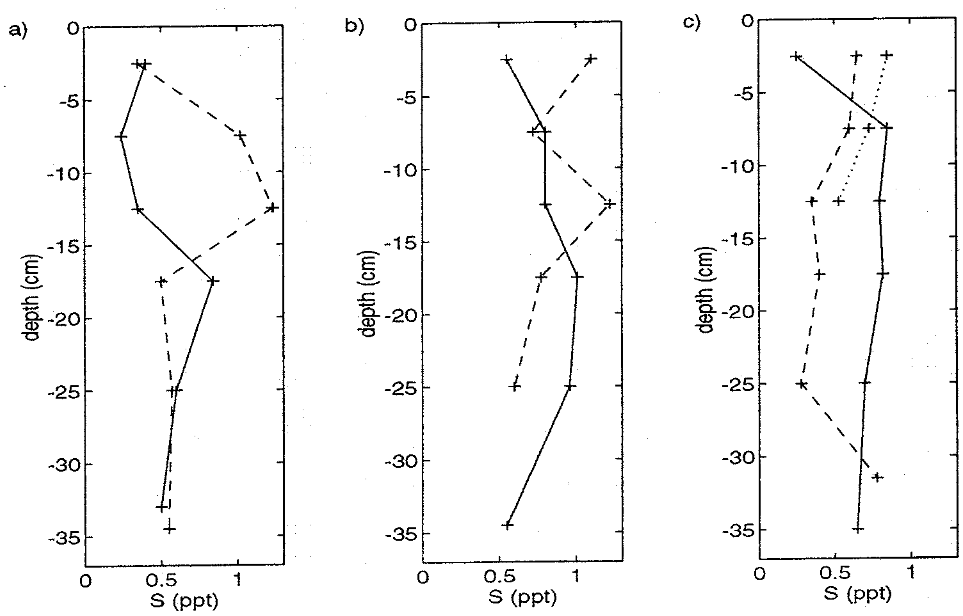


Figure 3.9. Vertical profiles of ice salinity at (a) sites 1 (continuous line) and 2 (dashed line), (b) sites 3 (continuous line) and 4 (dashed line), and (c) sites 5 (continuous line), 6 (dashed line), and 7 (dotted line). See Table 3.3 for the locations of the sites.

Table 3.3. Ice samples. The site is given as a distance and direction from *R/V Aranda*. h_s is the snow thickness, h_i the ice thickness, h_d the height of snow drifts, S the mean ice salinity, and T the ice temperature.

	Site	Date	h_s (m)	h_i (m)	h_d (m)	S (‰)	T(5 cm)	T(10cm)	T(15cm)
1	*R/V Aranda*	28 Feb.	0.03	0.37	-	0.49	-0.4	-0.2	-0.3
2	2.3 km W	28 Feb.	0.03	0.39	0.15	0.70	-0.7	-0.4	-0.5
3	1.9 km E	28 Feb.	0.03	0.40	0.10	0.78	-0.4	-0.5	-0.5
4	2.8 km N	1 Mar.	0.02	0.31	0.10	0.88	-2.2	-1.4	-0.2
5	6.8 km NW	2 Mar.	0.02	0.35	-	0.68	-3.9	-3.2	-2.1
6	104 km NE*	3 Mar.	0.02	0.33	-	0.51	-3.8	-3.6	-3.0
7	55 km NE+	3 Mar.	0.02	0.18	-	0.70	-1.2	-0.7	-0.2

*location 63°53.108 N, 22°29.282 E

+location 63°35.476 N, 21°46.273 E

3.4 Field personnel and acknowledgments

Scientists: Jouko Launiainen, Timo Vihma, Juha Uotila, Pekka Kosloff, Bin Cheng, Tero Purokoski, Corinna Schrum (UHAM)
Technical assistants: Henry Söderman, Hannu Vuori

We are grateful for the captain and crew of *R/V Aranda*.

4. Aircraft and surface-based observations by the University of Hamburg (UHAM), Meteorological Institute

The contribution of UHAM concentrated on three kinds of observing systems:

- the Falcon research aircraft (section 4.1),
- two meteorological ice buoys (section 4.2),
- the surface and upper air station at Kokkola (section 4.3).

Accordingly, this section is subdivided into three chapters.

4.1 Boundary layer measurements with research aircraft FALCON

Burghard Brümmer and Gerd Müller

4.1.1 Objectives

The scientific objectives of the flight measurements with the research aircraft FALCON were to measure:

- the vertical structure of the atmospheric boundary layer,
- the vertical fluxes of heat, moisture and momentum in the boundary layer,
- the energy balance (radiation fluxes and heat and moisture fluxes) near the surface

over water as well as over ice in the vicinity of the ice edge zone under different large-scale weather conditions. Flight missions were aimed to be flown along a trajectory following the mean boundary layer flow.

4.1.2 Measurements and methods

The equipment of the research aircraft FALCON is listed in Table 4.1. The FALCON measured temperature, humidity, the three-dimensional velocity vector and pressure. Turbulent fluxes of momentum, of temperature and of humidity can be calculated from these data. Furthermore, the aircraft was equipped with an infrared thermometer to measure the surface temperature and with upward and downward facing sensors to measure the longwave and shortwave radiation fluxes. Cloud parameters (liquid and ice water content, spectrum of particle sizes) were measured by two probes installed below the aircraft. FALCON's typical research flight speed is about 100 m/s. Turbulence parameters are sampled at rates of 100 Hz and the others with 10 Hz resulting in horizontal resolutions of about 1 m and 10 m, respectively.

The operation center for the flight missions was the airfield at Kokkola (Finland). In total six flight missions with a total duration of about 11.5 hours were flown in the region of the marginal ice zone on

27 February 1998 : strong on-ice air flow,
28 February 1998 : ice-parallel air flow,
02 March 1998 : on-ice/ice-parallel air flow,
03 March 1998 : weak variable air flow,
05 March 1998 : off-ice air flow,
06 March 1998 : off-ice/ice-parallel air flow.

Except for the first flight, wind speeds were mostly moderate in the boundary layer. Due to geographical limitations and due to inhomogeneous weather conditions not all flights could be flown exactly along an air-flow trajectory.

The flight pattern during each mission was composed of vertical profiles and horizontal flight legs. Two to four so-called "stacks" composed of several horizontal flight legs located one upon the other at different altitudes have been flown during each mission. Except in the case of the first flight, the lowest legs were at levels from 10 m to 40 m to obtain the turbulent fluxes at the sea/ice interface. Due to safety reasons, the aircraft was not allowed to fly below 80 m during the first mission, since the turbulence was relatively strong on 22 February 1998.

The FALCON flight patterns and locations of the low-level flight legs, stacks, vertical profiles, as well as wind information encountered along the low-level legs during the six missions are shown in Figures 4.1 a-b. Details of the six flight missions as altitudes/height intervals, locations, times, and headings of all horizontal flight legs (called runs) and vertical profiles are summarized in flight reports (Tables 4.2 a-f). Visual observations made by the aircraft scientist (cloud situation, sea-ice situation, etc.) needed for the interpretation of the data are also listed.

4.1.3 Data sets and characterization

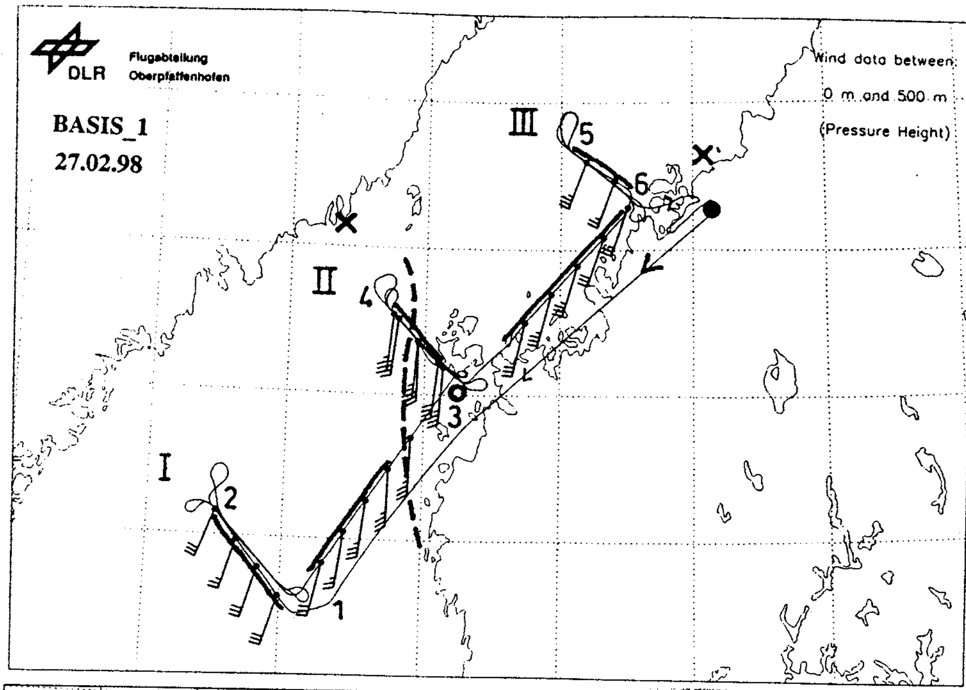
Data were sampled continuously during the entire flight mission. Therefrom profiles and horizontal runs are extracted in separate files. The profile data sets identified by the date, flight number and profile number will contain the following parameters at 1 s time intervals: time, latitude, longitude, height, pressure, temperature, water vapour mixing ratio, horizontal velocity components. The data sets of the horizontal flight legs (identified as the profile data sets) contain at 0.01 s and 0.1 s intervals, respectively: time, latitude, longitude, height, pressure, temperature, water vapour mixing ratio, horizontal and vertical velocity components, upward and downward long- and shortwave radiation fluxes and surface temperature. The data processing is currently performed but not finished until yet. Plots of the measured data are instantaneously available.

Examples of profiles of temperature, water vapour mixing ratio, wind speed and wind direction characterizing the atmospheric boundary layer conditions during each aircraft mission are shown in Figure 4.2 a-b.

Table 4.1: Instrumentation of the FALCON.

Parameter	Accuracy	Resolution	Sampling rate (Hz)	Sampling dist. (m)	Sensor type, hardware, manufacturer
Wind					
u,v	± 1.0 m/s	± 0.02 m/s	100	1	5-Hole probe (Rose-mount 858J) and Honey-well IRS 1761
w	± 0.5 m/s	± 0.02 m/s	100	1	
Temperature					
T	± 0.5 K	± 0.006 K	100	1	Pt-100 (Rosem.102 BM/BV)
T	± 0.5 K	± 0.006 K	10	10	Pt-500 (Rosem.102 AU2AG)
Humidity					
ϱ_v	± 0.5 g/m^3	± 0.002 g/m^3	100	1	Lyman-α-Humidometer (El. Res. Corp. BLR)
RH	± 2 %	± 0.007 %	10	10	Vaisala Humicap HMP 11
T_D	± 1.0 K	± 0.006 K	10	10	Dewpoint sensor (General Eastern 1011B)
Pressure					
p	± 1 hPa	± 0.07 hPa	100	1	Pitot-tube (Rosem.)
Altitude					
z	± 5 m±	0.5 m	10	10	Radioaltimeter
Position					
Lat., long.	(~ 400 m/h)	± 0.0003"	10	10	Honeywell IRS 1761
Lat., long.	± 10 m	± 1 m	10	10	GPS
Surface temp.					
T_S	± 1.0 K	± 0.01 K	10	10	Infrared radiation thermometer KT-19
Radiation					
K↓, K↑	± 4 W/m^2	± 0.1 W/m^2	10	10	Pyranometer (Epply PSR)
L↓, L↑	± 10 W/m^2	± 0.2 W/m^2	10	10	Pyrgeometer (Epply PIR)
Cloud particles					
1D-Probe	± 0.2 % of total amount	± 1	10	10	FSSP-100 (2-32 μm)
2D-Probe		± 1	10	10	OAP-2DC (25-800 μm)

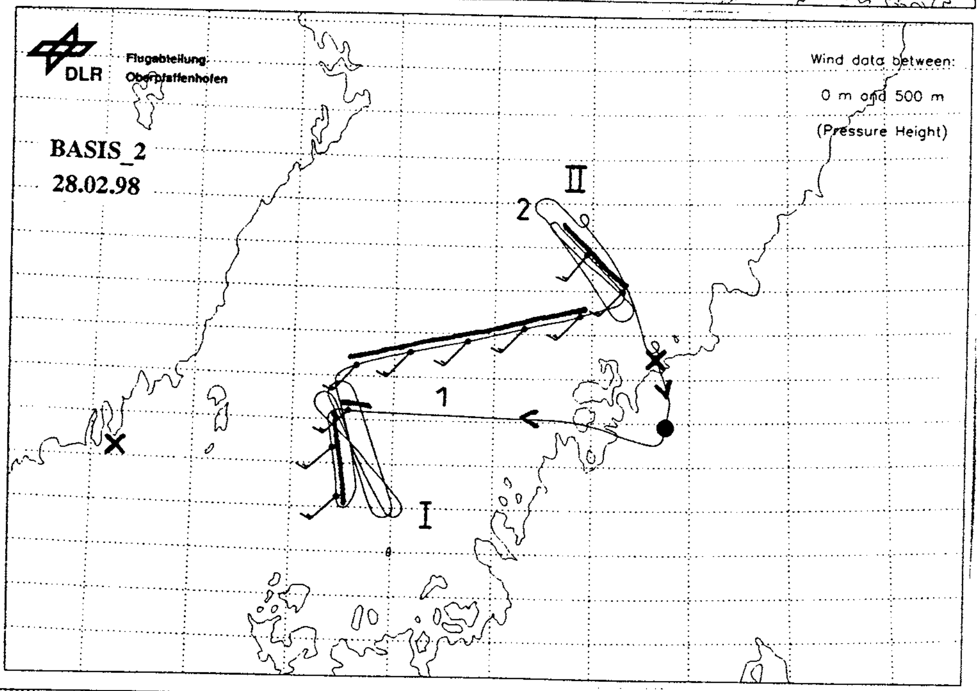
Figure 4.1 a-b (next page): The FALCON flight patterns during the six missions. In addition, these Figures indicate locations of the low-level flight legs (full lines), stacks (Roman numbers), vertical profile soundings (Arabic numbers), wind information encountered along the low-level legs, the research vessel Aranda (open circle), meteorological radiosonde/surface stations (crosses), Kokkola airfield (filled circle) and ice edge (dashed line). On the right-hand side of each Figure the flight levels within the stacks are listed. The meanings of the abbreviations are: "CB": near cloud base, "CT: near cloud top, "CL" inside cloud layer, "BT": near boundary-layer top, "IB": near inversion base, "Inv": inside inversion. Capital letters indicate the corner points of the stacks.



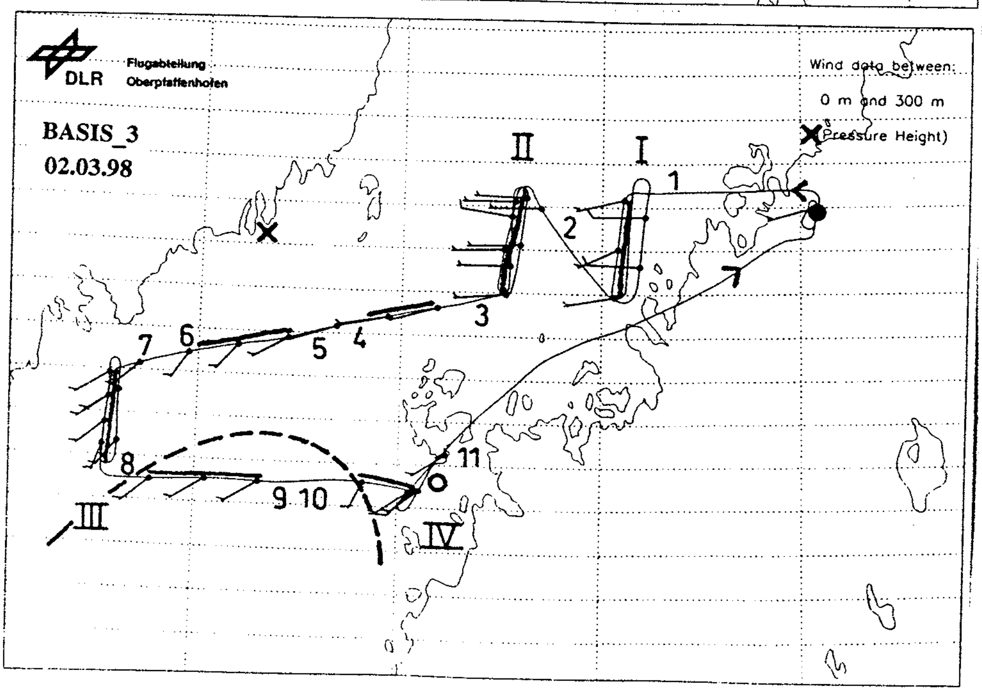
Flight levels in stacks:

I	II
A - B	C - D
80-101 m	60 m
200 m BT	110 m BT
580 m	580 m CL
1230 m CB	1200 m CT

III
E - F
85 m
175 m BT
350 m
580 m CL



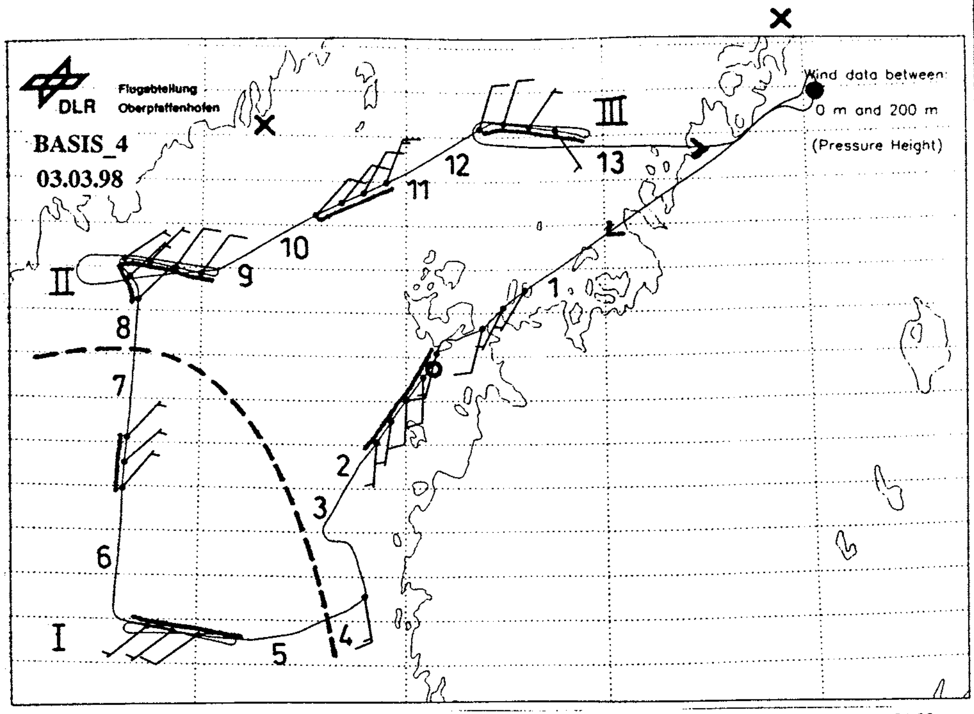
I	II
A - B	C - D
11-25 m	10 m
150 m	140-180 m
290 m CB	290 m IB
360 m CL	430 m Inv
430 m IB	
570 m Inv	



I	II
A - B	C - D
10-15 m	10-15 m
150 m Inv	95 m
575 m	150 m Inv

III	IV
E - F	G - H
10 m	15 m
90 m	90-110 m
150 m BT	135-155 m BT

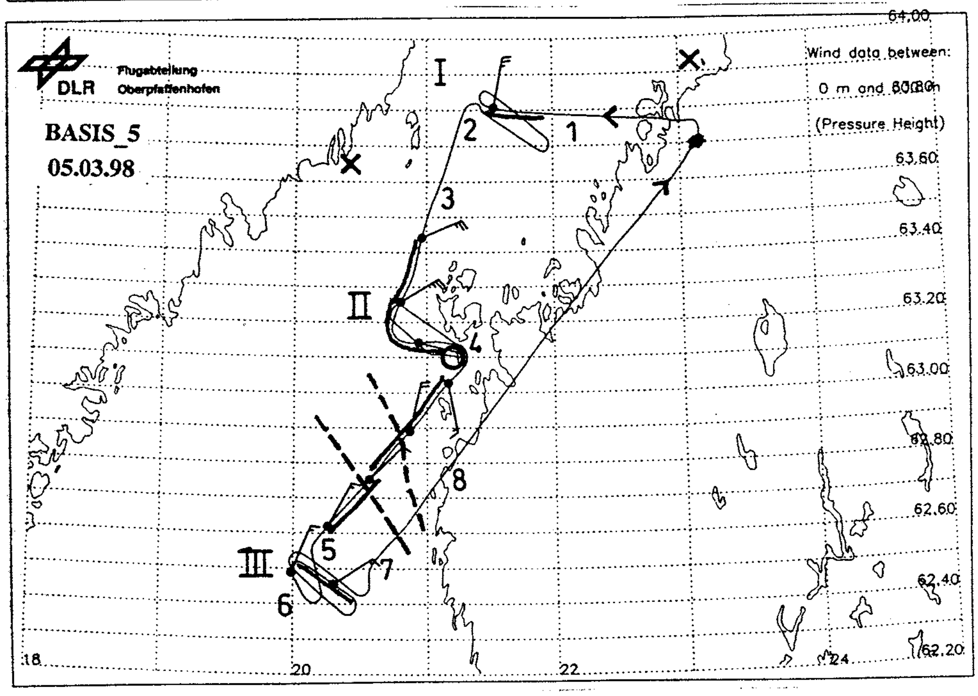
Figure 4.1 a: Flight patterns.



Flight levels in stacks:

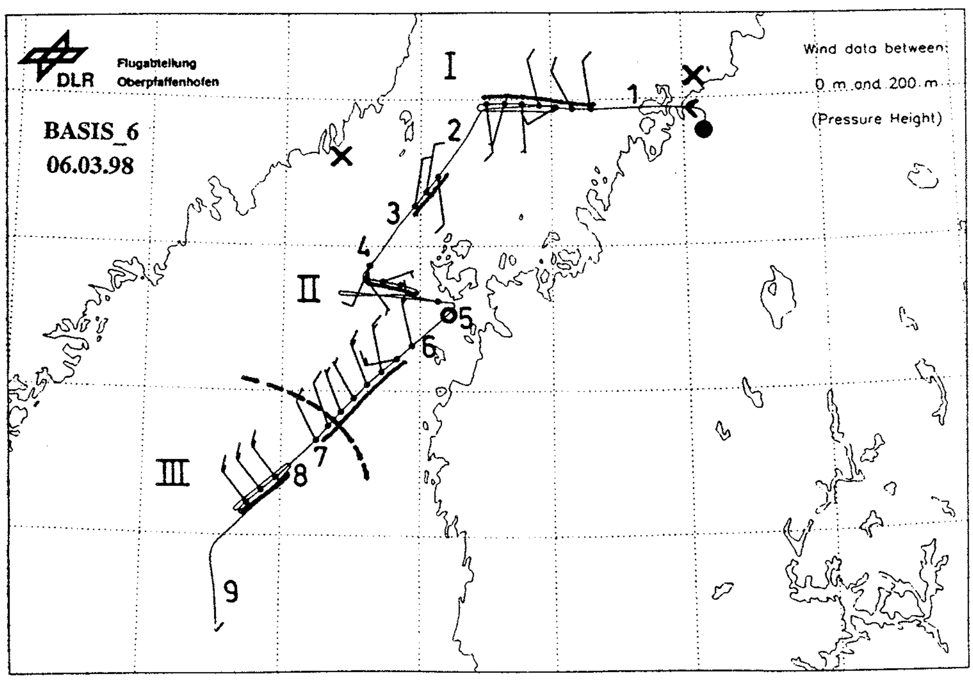
I	II
B - C	D - E
15 m	15 m
650 m CB	120 m
1030 m CL	235 m BT

III
F - G
15 m
200 m CB
390 m CL



I	II
A - B	C - D
15 m	10-45 m
190 m	195-207 m
320-360 m BT	390 m CL

III
E - F
20-40 m
555 m CL
1090 m CL



I	II
A - B	C - D
10-15 m	10-20 m
150-165 m IB	160-181 m IB
330-360 m	340 m

III
E - F
19-28 m
284-321 m CB
596 m CL

Figure 4.1 b: Flight patterns.

Table 4.2 a-f: Flight reports of research aircraft FALCON missions during BASIS-98. (CB indicates cloud base and CT cloud top. Capiteal letters (A,...) indicate corner points of stacks.)

BASIS 1998 No. 1	**Date:** 27.02.1998, **FALCON-flight No.:** 3069, **T/O:** 08:45:55 UT, **T/D:** 11:44:41 UT.
Mission:	On-ice air flow with measurements over open water and ice.
Synoptic situation:	Strong low over North Norway (960 hPa). South-westerly flow over the experimental area.
Coordinates of flight patterns:	**A:** 62° 25'N 20° 00'E, **B:** 62° 40'N 19° 30' E, **C (Aranda):** 63° 08'N 21° 12'E, **D:** 63° 22'N 20° 45'E, **E:** 63° 45'N 22° 30'E, **F:** 63° 55'N 22° 05' E

Time (UT)	Patterns and Heights	Hdg.	Remarks (Weather etc.)
08:45:55	Start at Kokkola		
08:45:55-08:49:11	Profile: 0-2555 m		Ascent Kokkola to transit level.
09:12:43-09:16:19	Prof.1: 2000-83 m at A		CT 1465 m, CB 1310 m.
09:17:02-09:24:06	Run at 80-101 m A-B	310°	Below 4 - 6/8 As. Open water with white crests. Wind: 36 kts 209°.
09:24:06-09:26:33	Prof.2a: 102-1512 m at B		4/8 As/Sc, CB 1220 m, CT 1525 m. Turbulence ends above 400 m. Sharp cloud-top.
09:28:30-09:30:59	Prof.2b: 1520-175 m at B		Two inversions: 200 m and 1525 m.
09:31:12-09:35:31	Run at 200 m B-A	148°	Just at base of the lower inversion. Inversion base increases towards east.
09:37:51-09:46:02	Run at 580 m A-B	305°	4/8 As. Between the two inversions. Wind: 41 kts 240°.
09:49:33-09:55:31	Run at1230 m B-A	145°	In clouds. 60 m above cloud base. Sometimes in cloud gaps.
09:57:14-10:06:38	Run at 100 m A-C	35°	10:04:45 aircraft crosses ice edge. 10:06:25 100% ice coverage.
10:06:50-10:08:38	Prof.3a: 81-1191 m at C		
10:08:38-10:11:55	Prof.3b: 1191-67 m at C		
10:12:47-10:16:14	Run at 60m C-D	310°	Below 6 - 7/8 As. Ice: 95%, 10:14:05 ice edge. Completely open water.
10:16:14-10:18:44	Prof.4a: 63-1763 m at D		
10:18:44-10:21:39	Prof.4b: 1763-96 m at D		CB 1763 m. No clouds below this level.
10:21:39-10:27:42	Run at 110 m D-C	145°	Just below inversion, 10:23:36 ice edge. Ice: 95% -100% east of ice edge. Run ends above Aranda.
10:30:55-10:36:56	Run at 580 m C-D	305°	Clouds at 610 m. 10:35:00 ice edge. Turbulence: 10:34:29 to 10:35:50.
10:39:56-10:45:18	Run at 1200 m D-C	140°	No turbulence. 10:41:58 ice edge. 10:42:33 aircraft reaches CB of 6/8 - 8/8 As.
10:56:59-10:50:06	Run at 180 m C-E	50°-35°	Above Islands. Extremely strong turbulence.
10:50:39-10:57:20	Run at 95 m C-E	43°	Wind: 30 kts 215°, ice: 100%, 10:53:05-10:54:14 above open water (ice 0%). Then ice floes (90% - 95%) with leads. Snow/rain after 10:55:10.
10:59:09-11:02:59	Run at 85 m E-F	295°	Ice: 95% white to grey. Strong turbulence.
11:03:04-11:04:54	Prof.5a: 83-1323 m at F		Turbulence ends above 245 m. Clouds: 8/8 As, CB 1310 m.
11:04:54-11:07:35	Prof5b: 1323-163 m at F		
11:08:05-11:13:25	Run at 175 m F-E	175°	Intermittent turbulence. Turbulence generally weaker than at 85 m.
11:16:51-11:21:41	Run at 580 m E-F	295°	In clouds. Near CB. After 11:17:10 no turbulence.
11:21:41-11:24:47	Prof.5c: 569-2610 m at F		Clouds: CB 1372 m, CT 2530 m. West of F large open-water ponds.
11:24:47-11:27:21	Prof.5d: 2610-308 m at F		CB 1615 m.
11:27:43-11:31:35	Run at 350 m F-E	142°	Inside the lowest inversion or just above it.
11:44:41	Landing at Kokkola		

Commentary: A strong south-westerly flow transports relatively warm air into the experimental area. Air temperature is everywhere warmer than water and ice temperature. The wind velocities detected along the low-level runs range from 25 kts to 35 kts. The temperature profiles exhibit two inversions at the experimental area: one at about 200 m and one at about 1500 m.

BASIS 1998 No. 2 **Date:** 28.02.1998, **FALCON-flight No.:** 3070, **T/O:** 10:56:34 UT, **T/D:** 12:19:28 UT

Mission: Ice-parallel air flow. Boundary-layer development over ice between Kokkola, Umea and Aranda.

Synoptic situation: Behind the cold front of a strong low (960 hPa) centred over Northern Finland with a westerly flow moderately cold air is advected into the experimental area.

Coordinates of flight patterns: **A:** 63° 45'N 21° 30'E, **B:** 63° 30'N 21° 45' E, **C:** 64° 01'N 22° 53'E, **D:** 64° 12'N 23° 30'E

Time (UT)	Patterns and Heights	Hdg.	Remarks (Weather etc.)
10:56:34	Start at Kokkola		
10:56:34-11:01:43	Profile: 0-665 m		Ascent Kokkola - transit level.
11:02:17-11:05:50	Prof.1: 2670-26 m Kokk.-A		0 - 1/8 Cu fr: CT 700 m (max.), CB 365 m. Increased turbulence above 305 m. Profile outside of clouds. Ice: 80% -90%, fissures and leads, grey ice west of position.
11:05:50-11:06:48	Run at 25 m Kokk.-A	270°	Large ponds of open water west of aircraft.
11:07:49-11:10:39	Run at 11-25 m A-B	175°	Ice: 50%-90%. Small ice floes organized in fields.
11:12:57-11:15:13	Run at 150 m B-A	330°-345°	Ice: mostly 50%. Run ends over white ice. Grey ice west of A.
11:17:07-11:21:11	Run at 290 m A-B	135°-145°	Just below CB of 0 - 1/8 Cu fr.
11:22:58-11:27:13	Run at 430 m B-A	329°	Partly inside inversion, partly at CT of 0 - 1/8 Cu fr. Ice: 50% at A.
11:28:52-11:33:09	Run at 570 m A-B	165°	Inside inversion, no turbulence.
11:34:26-11:38:37	Run at 360 m B-A	336°	Just below/inside/just above Cu fr cloud layer.
11:40:08-11:49:50	Run at 10-30 m A-C	75°	Ice towards NE increasingly compact and rough (ice ridges). Large open water ponds east of C.
11:50:48-11:54:02	Run at 10 m C-D	310°	Ice: 100%. Firstly ice ridges, later smooth ice (partially freshly frozen).
11:56:08-11:58:52	Run at 140-180m D-C	135°	Large open water ponds near C.
12:00:20-12:04:27	Run at 290 m C-D	318°	No clouds inside the PBL. Occasionally turbulence.
12:05:12-12:07:10	Prof.2: 22-1620 m at D		Cloudless conditions.
12:08:42-12:12:26	Run at 430 m D-C	144°-163°	Cloudless conditions, but Cu bands with CB > 450 m south-east of C.
12:14:02-12:14:55	Profile: 559-44 m		Profile near German radiosonde station Trullevi/Kokkola.
12:19:28	Landing at Kokkola		

Commentary: An inversion with base ranging from 395 m to 455 m is present over the experimental area. Below the inversion, spurious condensation (about 0 - 1/8 Cu fr) occurs inside a very thin layer. From W/SW a cloud layer approaches and starts to shadow the experimental area, while clear sky is visible north of the experimental area. Inside a strong extended low the mean surface pressure amounts to 964 hPa at the experimental area.
Inside the PBL the turbulence is weak, because the wind blowing from 240°/220° is below 15 kts. From A-B to C-D the ice coverage increases considerably. In the vicinity of C, especially SW of C, ice ridges dominate the appearance of the ice field.

Instrument report: FSSP break down during the whole flight. KT19 very noisy because average time (0.1 sec) is too short.

BASIS 1998 No. 3 **Date:** 02.03.1998, **FALCON-flight No.:** 3071, **T/O:** 08:39:40 UT, **T/D:** 10:32:59 UT

Mission: On-ice/ice-parallel flow. Boundary-layer structure and fluxes over ice (north of Vaasa) and over open water (south of Vaasa).

Synoptic situation: Weak and small high-pressure system is located over the experimental area. Weak westerly wind (0 - 3 m/s) and cloudless conditions.

Coordinates of flight patterns: **A:** 63° 48'N 22° 15'E, **B:** 63° 30'N 22° 15' E, **C:** 63° 46'N 21° 40'E, **D:** 63° 32'N 21° 35'E, **E:** 63° 21'N 19° 42'E, **F:** 63° 05'N 19° 42' E, **G (Aranda):** 63° 10'N 21° 15'E, **H:** 63°01'N 21° 05'E.

Time (UT)	Patterns and Heights	Hdg.	Remarks (Weather etc.)
08:39:40	Start at Kokkola		
08:39:40-08:42:55	Profile: 0-2600 m		Ascent Kokkola - transit level.
08:42:55-08:46:41	Prof.1: 2600-11 m towards A	270°	Cloudless conditions. Ice: 100% white/grey. Two inversions: 60 m and 365 m.
08:47:45-08:51:12	Run at 10-15 m A-B	185°	Cloudless conditions. Ice: very rough near A, freshly frozen black spots, smooth ice near B. Wind: 3 - 5 kts 220°.
08:52:56-08:56:42	Run at 150 m B-A	2°	Cloudless conditions, inside inversion, no turbulence.
08:57:53-09:02:08	Run at 575 m A-B	185°	No turbulence.
09:02:08-09:04:09	Prof.2a: 580-2190 m B-C		Ice: 100%. Two inversions at 30-45 m and about 395 m.
09:04:09-09:07:48	Prof.-2b: 2190-13 m at C		
09:07:48-09:08:29	Run at 10 m towards C	330°	
09:09:29-09:13:01	Run at 10-15 m C-D	192°	Weak turbulence. Wind: 6 kts 270°. 09:10:10 open-water pond. 09:10:30-09:11:30 smooth ice. Increased turbulence above thin ice/open-water spots near D. Ice generally smoother than along A-B.
09:13:56-09:17:36	Run at 95 m D-C	5°	Weak turbulence, white ice with leads (partially open, partially frozen), large ice floes with smooth surfaces.
09:18:44-09:22:36	Run at 150 m C-D	173°	Below inversion. Reduced turbulence.
09:23:43-09:25:07	Prof.3: 427-13 m at D		Inversion at 200 m marked by temperature jump of 1 K, by wind veering (230° to 260°) and by increase of wind speed (3 to 6 m/s.). Profile ends over grey ice.
09:25:07-09:29:39	Run at 10-15 m D-E	257°	First grey ice, later white ice with prominent gobbets. After 09:28:07 open water. Wind: 8 kts215°.
09:29:39-09:30:32	Prof.4: 15-470 m D-E		Turbulence ends above 250-300 m.
09:30:32-09:31:55	Prof.5: 470-11 m D-E		
09:31:55-09:36:32	Run at 10 m D-E	255°	Above grey ice. 09:32:18 white ice (95% -98%) of varying roughness and black spots. 09:33:25 new ice. 09:33:55 ice plates embedded in new ice, 09:34:16 rough pancake ice. Wind: 10 kts 180°.
09:36:32-09:37:16	Prof.6: 12-437 m at E		Turbulence above 60 m.
09:37:16-09:38:11	Prof.7: 437-26 m at E		
09:38:55-09:42:04	Run at 10 m E-F	185°	Moderate turbulence. Grey, thin and smooth new ice. 09:41:30 pancake ice 100%. Open water starts at F.
09:43:14-09:46:37	Run at 90 m F-E	359°	Weak turbulence.
09:47:25-09:51:38	Run at 150 m E-F	183°	Weak turbulence.
09:52:27-09:53:47	Prof.8: 456-10 m at F		Above stripes of ice in 80% open water.
09:53:47-09:57:39	Run at 10-25 m F-H	90°	First above open water, 09:54:35-09:55:12 grit ice, then open water and increased turbulence, wind 5 kts 250.
09:57:48-09:59:13	Prof.9: 32-930 m F-H		2 inversions between surface and 100 m (first) and at 900 m.
09:59:13-10:01:05	Prof.10: 930-37 m F-H		0 - 1/8 Cu below second inversion.
10:01:05-10:03:32	Run at 30-40 m F-H	100°	Above land-fast ice.
10:04:11-10:05:17	Run at 15 m H-G	25°	Aranda passed at end of run.
10:06:56-10:08:23	Run at 90-110 m G-H	205°	
10:09:22-10:11:16	Run at 135-155 m H-G	38°	
10:11:33-10:14:58	Prof.11: 80-2685 m at G		Cloudless, above grey new-ice and white old ice.
10:32:59	Landing at Kokkola		

Commentary: A weak westerly flow and relatively low temperatures dominate the experimental area. The temperature profiles exhibit two inversions: one at about 100 - 200 m and one at about 900 m. Almost cloudless conditions are found at the experimental area. Only at the southern part spurious condensation occurs below the second inversion.

BASIS 1998 No. 4 **Date:** 03.03.1998, **FALCON-flight No.:** 3072, **T/O:** 09:10:48 UT, **T/D:** 10:55:38 UT

Mission: Weak variable air flow. Boundary-layer structure and fluxes over open water, smooth new ice and rough old ice.

Synoptic situation: Weak pressure gradients over Finland and Sweden in front of a low approaching from SW. Small, weakly pronounced low pressure centres over Scandinavia. One of these low pressure centres is located near the experimental area.

Coordinates of flight patterns: **A (Aranda):** 63° 08'N 21° 14'E, **B:** 62° 29'N 20° 10'E, **C:** 62° 30'N 19° 42'E, **D:** 63° 20'N 19° 40'E, **E:** 63° 19'N 20° 09'E, **F:** 63° 40'N 21° 30'E, **G:** 62° 40,N 22° 00'E.

Time (UT)	Patterns and heights	Hdg.	Remarks (weather etc.)
09:10:48	Start at Kokkola		
09:10:48-09:13:41	Profile: 0-1790 m		Ascent Kokkola - transit level.
09:17:22-09:21:49	Prof.1 2690-9 m tow. A	230°	Descent through cloud gap ending above islands. Turbulence below 120 m.
09:22:21-09:24:35	Run at 80 m Kokk.-A	225°-245°	Above islands and land-fast ice towards Aranda.
09:26:24-09:30:05	Run at 15m A-B	210°	Above white, smooth land-fast ice.
09:30:05-09:31:27	Prof.2: 17-860 m A-B	210°	Above land-fast ice. CB 150 m, CT 215 m.
09:31:27-09:32:47	Prof.3: 860-90 m A-B		Sounding has been aborted because of dense Sc layer reaching down to the ice. Turbulence starts at 152 m.
09:36:27-09:39:40	Prof.4: 15-1930 m A-B	249°	Ice 100%. 8/8 St, CB 61 m.
09:39:40-09:42:21	Prof.5: 1930-20 m at B	270°	Descent through cloud gap above open water.
09:42:21-09:45:10	Run at 15 m B-C	275°	Above open water.
09:46:46-09:49:09	Run at 650 m C-B	90°	Below CB of 2/8 - 4/8 Cu. More clouds north of than south of C-B.
09:50:42-09:53:42	Run at 1030 m B-C	275°	Inside cloud layer. Finally above clouds inside inversion.
09:55:10-09:58:19	Prof.6: 1880-22 m C-D	360°	Sometimes inside clouds. CB 702 m.
09:58:25-10:01:32	Run at 10 m C-D	5°	Above open water.
10:01:32-10:03:52	Prof.7: 14-1410 m C-D	360°	Ice edge crossed at time 10:03:50, altitude 1220 m and position 63° 18' 18"N 19° 27' 18"E.
10:03:52-10:05:50	Prof.8: 1410-25 m at D	360°	Profile ends above pancake ice with numerous black spots.
10:07:59-10:11:06	Run at 15 m D-E	100°	Thin, grey new-ice. Later rough white ice with open spots.
10:12:11-10:16:12	Run at 120 m E-D	270°	Inside turbulent layer. Predominantly thin new ice. West of position: smooth, black/grey new-ice with leads.
10:17:45-10:22:35	Run at 235 m D-E	80°	Close to the upper boundary of the PBL. Turbulence is as strong as at 15 m.
10:24:12-10:25:52	Prof.10: 1130-26 m E-F	60°	CT 365 m. Turbulence ends at 610 m. Profile ends above rough white ice.
10:25:52-10:28:59	Run at 15 m E-F	60°	First open water and grey ice. Then rough white ice. Finally smooth white ice with black spots.
10:28:59-10:30:42	Prof.11: 14-1250 m E-F	60°	2/8 - 4/8 Cu, CB 275 m, CT 762 m.
10:30:42-10:33:06	Prof.12: 1250-11 m E-F	60°	CB 245 m, CT 762 m. A second CT is located at 305 m. CT increases from west to east.
10:33:31-10:36:38	Run at 15 m F-G	95°	Ice: 100%, rough, white, sometimes leads, finally sharp-edged and very rough.
10:38:05-10:41:15	Run at 200 m G-F	275°	Just below CB of 0/8 - 2/8 Cu fr.
10:43:13-10:45:44	Run at 390 m F-G	90°	Inside clouds with CB 275/300 m. 10:45:15 inside 8/8 St/Cu.
10:46:34-10:48:52	Prof.13: 15-1420 m G-Kokk.	90°	8/8 St, CB 305 m, CT 580. A second cloud layer is located at higher levels. North of position, the two layers are grown together.
10:48:52-10:51:08	Profile: 1420-195 m		Descent towards transit level. CT's at 762 m and 610 m, CB 425 m.
10:55:38	Landing at Kokkola		

Commentary: Meteorological conditions are relatively inhomogeneous in the experimental area. Southerly wind is found at the southern part near B-C, while a north-easterly wind shows up at the northern area around D-E and F-G. The south-eastern part of the experimental area is characterized by intense convection with showers down to the ice/water surface. Above the open water no low-level inversion is present below 2 km. Almost cloudless conditions (0/8 - 1/8 Cu fr) and a low-level inversion at 200 m are found at the middle part of the flight pattern (around D-E as well as around the Aranda). Increasing cloud coverage is observed at the north-eastern area around F-G where an inversion shows up at 500 m. Below this level 4/8 Cu/St is present while additional cloud layers are present at higher levels. Heat fluxes are expected to be of small because wind velocity and air-surface temperature difference are relatively weak.

Instrument report: FSSP break down during the whole flight.

BASIS 1998 No. 5 **Date:** 05.03.1998, **FALCON-flight No.:** 3073, **T/O:** 08:57:23 UT, **T/D:** 10:45:39 UT.

Mission: E/NE off-ice air flow between Kokkola and Kaskinen with measurements over open water and ice.

Synoptic situation: Low over East Finland (975 hPa) moves eastward. Trough impacts the experimental area.

Coordinates of flight patterns: **A:** 63° 45'N 22° 00'E, **B:** 63° 48'N 21° 30' E, **C (Aranda):** 63° 08'N 21° 14'E, **D:** 63° 12'N 20° 45'E, **E:** 62° 24'N 20° 25'E, **F:** 62° 30'N 20° 00' E

Time (UT)	Patterns and Heights	Hdg.	Remarks (Weather etc.)
08:57:23	Start at Kokkola.		
08:57:23-09:00:25	Profile: 0-2335 m	275°	Ascent Kokk. - transit level. 3/8 Cu (streets), CB 425 m, CT 550 m.
09:00:25-09:08:13	Prof.1: 2335-20 m at B	270°	Firstly above 8/8 Sc. Then above 4/8 Sc. Through 0/8 - 2/8 Cu. CB 275 m, CT 365 m. Ice: partially (50%) free of snow.
09:08:13-09:09:52	Run at 15 m A-B	285°	Wind: 22kts 5°.
09:11:20-09:15:14	Run at 190 m B-A	114°	Ice: 100%, white, moderately rough (roughness increases towards east). Below 2/8 - 3/8 Cu.
09:16:14-09:20:08	Run at 320-360 m A-B	302°	Firstly inside condensation layer without clouds. Later inside/outside of clouds organized in stripes. Increased turbulence. Wind: 22 kts 8°.
09:20:08-09:22:53	Prof.2: 358-1389 m at B	190°	CT 490 m.
09:22:53-09:25:20	Prof.3: 1389-19 m at B		First above 8/8 Sc with smooth surface forming strong mountain/valley waves. Two cloud layers: 1. CB 670 m, CT 915 m; 2. CB 425-455 m, CT 610 m. Ice crystals below CB.
09:25:20-09:31:22	Run at 15-35 m B-D	205°	Wind:22 kts 20°. Sea smoke above open-water spots. Ice: 98%, intermittent white and grey. Strong turbulence. Bad visibility.
09:32:24-09:35:40	Run at 10-45m D-C	80°-90°	First 8/8 St. Visibility extremely bad. 09:33:30 sun. Increased visibility at C (Aranda).
09:35:40-09:37:03	Prof.4: 15-662 m at C		Ascent during turning. CT 548 m.
09:38:22-09:41:05	Run at 390 m C-D	310°	First just above clouds. 09:39:20 inside clouds. Ice: torn open by off-ice flow.
09:42:30-09:46:21	Run at 195-207 m D-C	115°	Wind: 25 kts 3°. Cloud coverage 8/8 at the western area, broken clouds at the eastern area.
09:47:54-09:58:11	Run at 30-40 m C-F	225°-230°	First above solid ice. 09:48:37 islands and increased turbulence. 09:49:44 white solid ice 100%. 09:51:12 ice edge (62° 53'N 20° 51'E) with open water ponds and large ice fields. Clouds: 8/8 Sc. 09:57:00 open water.
09:58:11-10:00:07	Prof.5: 23-1251 m at F		Two cloud layers almost completely grown together. Upper cloud layer: CT 1370 m, CB not defined.
10:00:07-10:02:47	Prof.6: 1251-25 m at F		
10:04:24-10:07:32	Run at 20-40 m F-E	118°-114°	7/8 - 8/8 St with snow. 10:06:10 shortly sunshine. Wind near E: 23 kts 2°.
10:09:06-10:12:57	Run at 555 m E-F	307°-314°	Inside 8/8 St/Sc (lower layer of 2). Open water occasionally visible.
10:14:22-10:17:16	Run at 1090 m F-E	117°	Inside clouds (upper layer of 2). Not as dark as at 555 m.
10:17:30-10:19:55	Prof.7: 1115-14 m at E		Clouds: CB (of lower cloud layer) 395 m, CT 855 m.
10:19:55-10:23:27	Prof.8: 15-2175m E-Kokk.		Ascent towards transit level above ice. Ice edge inhomogeneously torn up.
10:23:27-10:32:56	Run at 2175 m E-Kokk.	37°-44°	Inside St layer. Cloud structures oriented in N-S direction.
10:32:56-10:39:23	Profile: 2175-359 m		Descent towards Kokkola above land. 6/8 - 8/8 Sc/Cu, CB 455 m, CT 915-1070 m.
10:45:39	Landing at Kokkola		

Commentary: At the experimental area, the cloud coverage increases from N to S. The cloud field which impacts the experimental area extends from Sweden (between Umea and Sundsvall) to Finland (between Vaasa and Merikarvia). Ice crystals are present almost at the entire experimental area. The flow direction is N/NE. The air temperatures are the lowest than during all six BASIS-missions, and, in contrast to the preceding missions, sea smoke is present. As a result of the off-ice flow (20 - 25 kts), the ice edge is not sharp and reveals a broad transition zone.

BASIS 1998 No. 6 **Date:** 06.03.1998, **FALCON-flight No.:** 3074, **T/O:** 08:44:13 UT.

Mission: Boundary layer above ice and open water during weak off-ice/ice-parallel air flow from N/NW and low temperatures.

Synoptic situation: Small pressure gradients at experimental area between eastward moving low above the Barents Sea and small low above Denmark.

Coordinates of flight patterns: **A:** 63° 48'N 22° 00'E, **B:** 63° 48'N 21° 30' E, **C:** 63° 10'N 20° 30'E, **D (Aranda):** 63° 10'N 21° 05'E, **E:** 62° 24'N 19° 42'E, **F:** 62° 30'N 20° 00' E

Time (UT)	Patterns and Heights	Hdg.	Remarks (Weather etc.)
08:44:30			
08:44:30-08:47:09	Profile: 0-1830 m	270°	Ascent Kokkola - transit level. 2/8 Cu, CB 305 m, CT 395 m. No clouds above ice.
08:47:09-08:50:33	Prof.1: 1830-12 m at A	270°	Ice: firstly white land-fast, later black smooth. Turbulence below 670 m above black ice.
08:50:33-08:56:27	Run at 10-15 m A-B	270°-280°	Run start 8 nm east of A. Ice: extremely rough and white with smooth spots, near B increasingly smooth and grey to black. Wind: 8 kts 350°.
08:57:21-09:00:49	Run at 150-165 m B-A	87°	Weak turbulence.
09:01:52-09:05:24	Run at 330-360 m A-B	369°	Cloudless. Weak turbulence until 09:03:50. At 09:05:00 above large area of black ice.
09:05:24-09:07:09	Prof.2a: 356-1420 m at B		
09:07:09-09:09:21	Prof.2b: 1420-16 m B-C	215°	Cloudless. Above 100% ice. Turbulence below 365 m.
09:09:21-09:11:50	Run 15-20 m B-C	217°	Wind: 11 kts 20°. Leads are freshly frozen (black, smooth ice). After 09:10:18 a few open-water spots.
09:11:50-09:13:06	Prof.3: 21-915 m B-C	220°	Cloudless. Open-water spots/ponds, but ice coverage > 98%.
09:13:06-09:14:58	Prof.4: 915-26 m B-C	220°	Cloudless. Above white ice. Turbulence at 670 m and below 335 m.
09:14:58-09:15:43	Run at 22-28 m B-C	218°	
09:16:29-09:19:00	Run at 10-20 m C-D	93°-103°	Cloudless. Wind: 15 kts 360°. Ice: almost 100%, white, towards east increasingly rough.
09:20:17-09:23:29	Run at 160-181 m D-C	272°	Cloudless. Turbulence. Above white and grey ice.
09:24:29-09:28:20	Run at 340 m C-D	93°	Cloudless. Only sporadic turbulence.
09:29:27-09:31:13	Prof.5: 18-870 m at D	220°	Near Aranda. Clouds with CB 600 m east of position.
09:31:13-09:33:31	Prof.6: 870-9 m at D		0/8 - 2/8 Cu/St, CB 395 m, CT 520 m.
09:33:31-09:40:15	Run at 9-22 m D-F	220°-231°	Below 6/8 Cu/St. Wind: 6 kts 340°. Good visibility. Grey and white ice 100%. Ice edge at time 09:38:00, position 62° 46'N 20°27'E.
09:40:15-09:41:21	Prof.7: 21-885 n D-F		8/8 St, CB 395 m, CT 792 m. A second cloud layer (8/8 St) is present at higher altitude.
09:41:21-09:42:55	Prof.8: 885-20 m at F		8/8 St, CB 395 m.
09:42:55-09:45:46	Run at 19-28 m F-E	230°	Below 8/8 clouds. Wind: 13 kts 280-300°.
09:46:47-09:49:53	Run at 284-321 m E-F	43°	Clearly below CB of cloud layer. Turbulence.
09:51:08-09:55:55	Run at 596 m F-E	222°-229°	Inside of 6/8 Cu/Sc. Cloud coverage decreases from NE to SW down to 2/8. Near E: south-west border of cloud field.
09:56:17-10:00:00	Profile: 598-3070 m at E	190°	Cloudless conditions south of experimental area.
10:00:00			End of mission.

Commentary: The experimental area is influenced by a N/NE cold-air flow. Clouds are only present over the open water at the southern part of the experimental area. These clouds seem to be advected into that area and not to be the result of local processes.

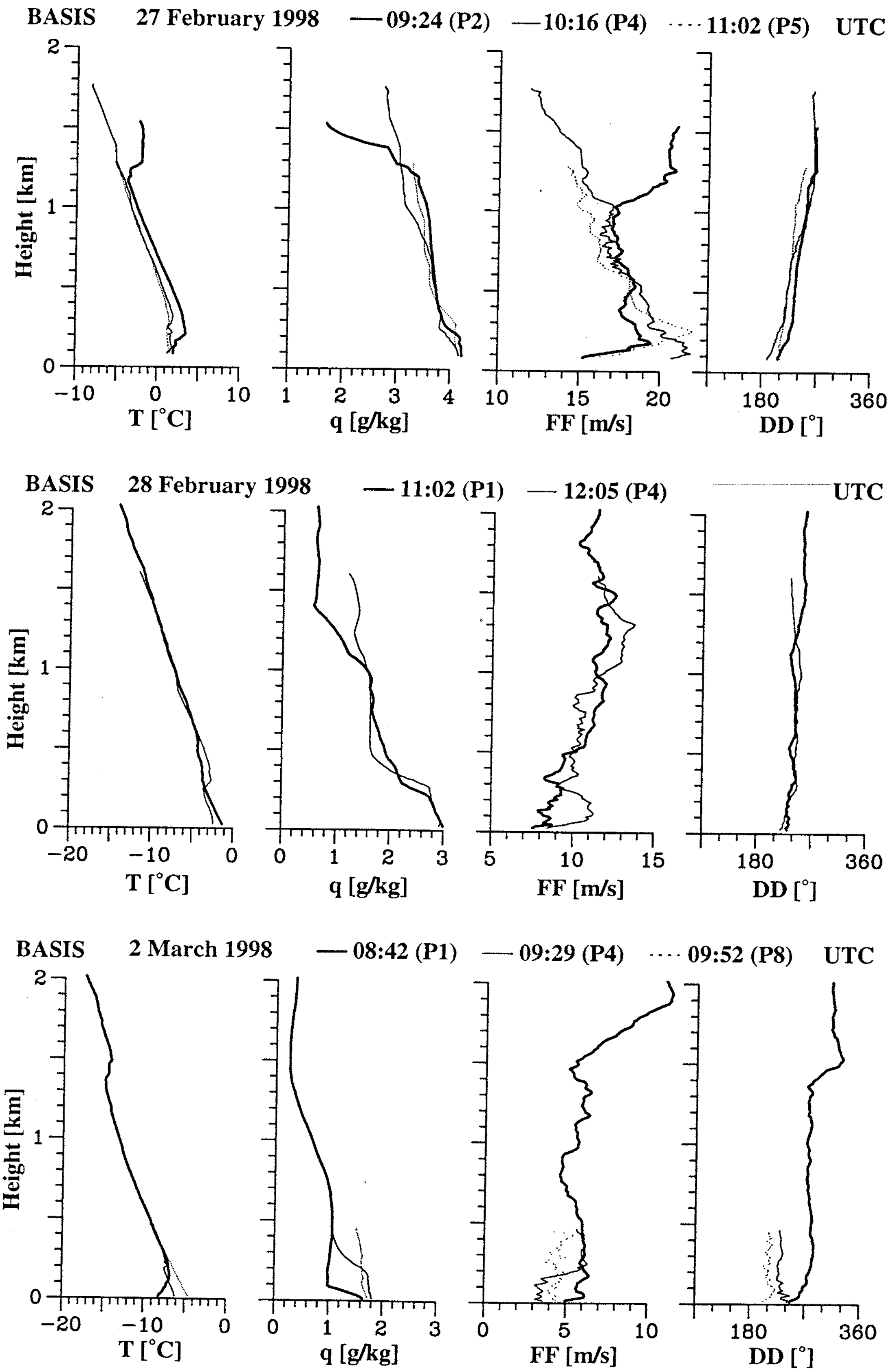


Figure 4.2 a: Examples of temperature, water vapour mixing ratio, wind speed and wind direction profiles characterizing the meteorological boundary-layer conditions during each mission of research aircraft FALCON.

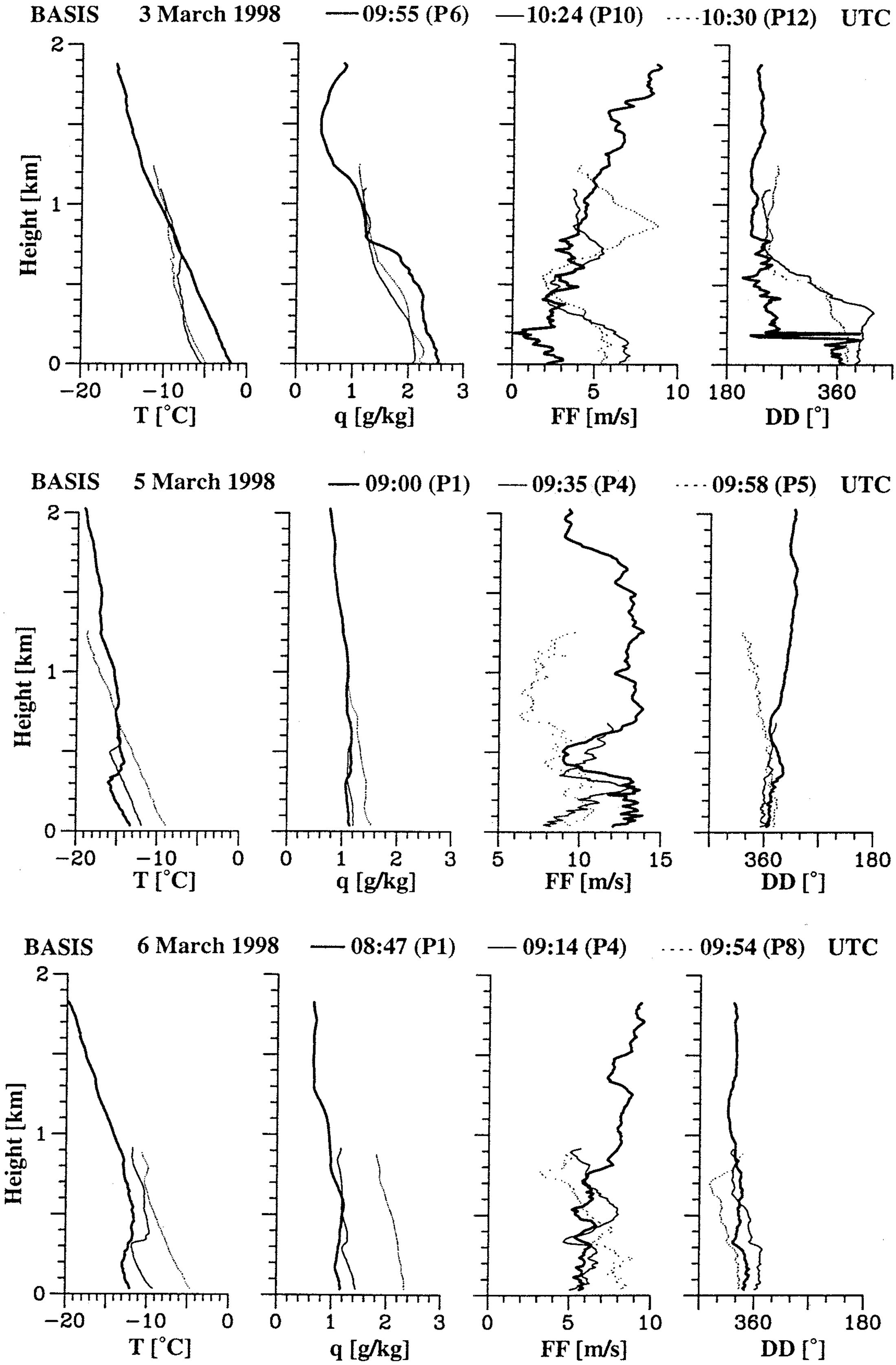


Figure 4.2 b: Examples of temperature, water vapour mixing ratio, wind speed and wind direction profiles characterizing the meteorological boundary-layer conditions during each mission of research aircraft FALCON.

4.2 Meteorological Measurements with two Argos ice buoys

Heinrich Hoeber

4.2.1 Objectives

The scientific objectives were twofold:

- to define the ice drift by following the track of the drifting buoys, and to provide information about drift velocity and its spatial derivatives,
- to contribute to the array of surface layer observing stations in order to define the surface forcing fields for ice drift and boundary layer processes.

Due to the poor ice conditions in the area at the time of the experiment, the first objective was dropped, and the stations were installed on land-fast ice and on the ground near the shore, respectively.

4.2.2 Measurements and methods

Two Argos ice stations were employed which were equipped with sensors for

- air surface pressure: Paroscientific Digiquartz Pressure Transducer
- air temperature: Thermistor mounted on the top of the beacon
- ice surface temperature: Thermistor mounted on the bottom of the beacon
- humidity: Vaisala humidity (Humicap) and temperature (Pt 100) probe
- wind vector: Young Wind Monitor (propeller type anemometer and vane) at 2.1 m
- time (hour of the observation)

The data were sampled once per hour and transmitted to the Argos system whenever a satellite was passing. The Argos system determined the position of the station by means of a Doppler frequency shift method. The positions and the times of observations are summarized in the following table:

Table 4.3: Positions and times of observations of the ARGOS ice stations.

Station ID	Latitude N	Longitude E	Time of First Observation	Time of Last Observation	Events
3333	63° 13.9'	20° 40.3'	17 Feb 1998 09 UTC	06 Mar 1998 06 UTC	Loss of wind sensor, humidity sensor on 23 Feb/ 4UTC
3335^{I}	63° 23,9'	21° 20.1'	17 Feb 1998 13 UTC	27 Feb 1998 12 UTC	Shift of position on 27 Feb, 12-13 UTC (see next row)
3335^{II}	63° 23.3'	21° 18.1'	27 Feb 1998 13 UTC	06 Mar 1998 08 UTC	

An analysis of the position accuracy shows an RMS error of between ±200 m and ±330 m (different for the east-west and the north-south coordinates) for the two stations.

4.2.3 Data sets and characterization

The data is available in two files, one for the relevant days of February 1998 and one for March 1998. The files are written in plain text; their volume is 345 Kb and 167 Kb, respectively. The files contain the raw data from both stations as received from the Argos System without any further processing. As such, they contain particulars of the transmission, e.g. the identification of the two NOAA satellites, the time of the satellite overpass, the position, the number of messages during the overpass (ranging from 1 to 10, approximately), and the number of identical messages during a given overpass. These housekeeping data are followed by the meteorological information, i.e., the actual data in physical units. Data outside a predefined range of the respective quantity are flagged in order to facilitate recognition of instrumental failure. A format description and some information on the necessary steps for further processing is provided in a separate Readme file.

An intercomparison of the pressure transducers, in particular, of the two Hamburg stations, three stations of the Swedish and Finnish groups, and the RV Aranda's met station was performed at the beginning of the period onboard the Aranda. The data of this intercomparison was evaluated by Timo Vihma of FIMR. He recommends the following corrections for the UHAM stations:

station 3333: +0.17 hPa
station 3335: -0.10 hPa

The data availability and quality can be inspected in Figure 4.3 which provides the time series of pressure, temperature, humidity and the wind vector.

4.3 Rawinsonde and surface station at Kokkola

Gottfried Kruspe

4.3.1 Objectives

The scientific objectives were:

- to contribute by means of radiosoundings to the large-scale heat and moisture-budget investigations for the determination of the regional evaporation,
- to study the energy balance by means of micrometeorological measurements within the Prandtl-layer above the ice-covered sea for energy balance studies.

4.3.2 Measurements and methods

The measurements at Trullevi/Kokkola, geographically located at 63.95°N, 23.08°E at the coast of the Gulf of Bottnia encompassed

- micrometeorological measurements (standard meteorological parameters, eddy fluxes of heat and momentum) over land-fast sea ice,
- radiation budget measurements over land-fast sea ice.
- regular upper air soundings at least every 6 hours,
- cloud-base measurements up to 7.5 km height.

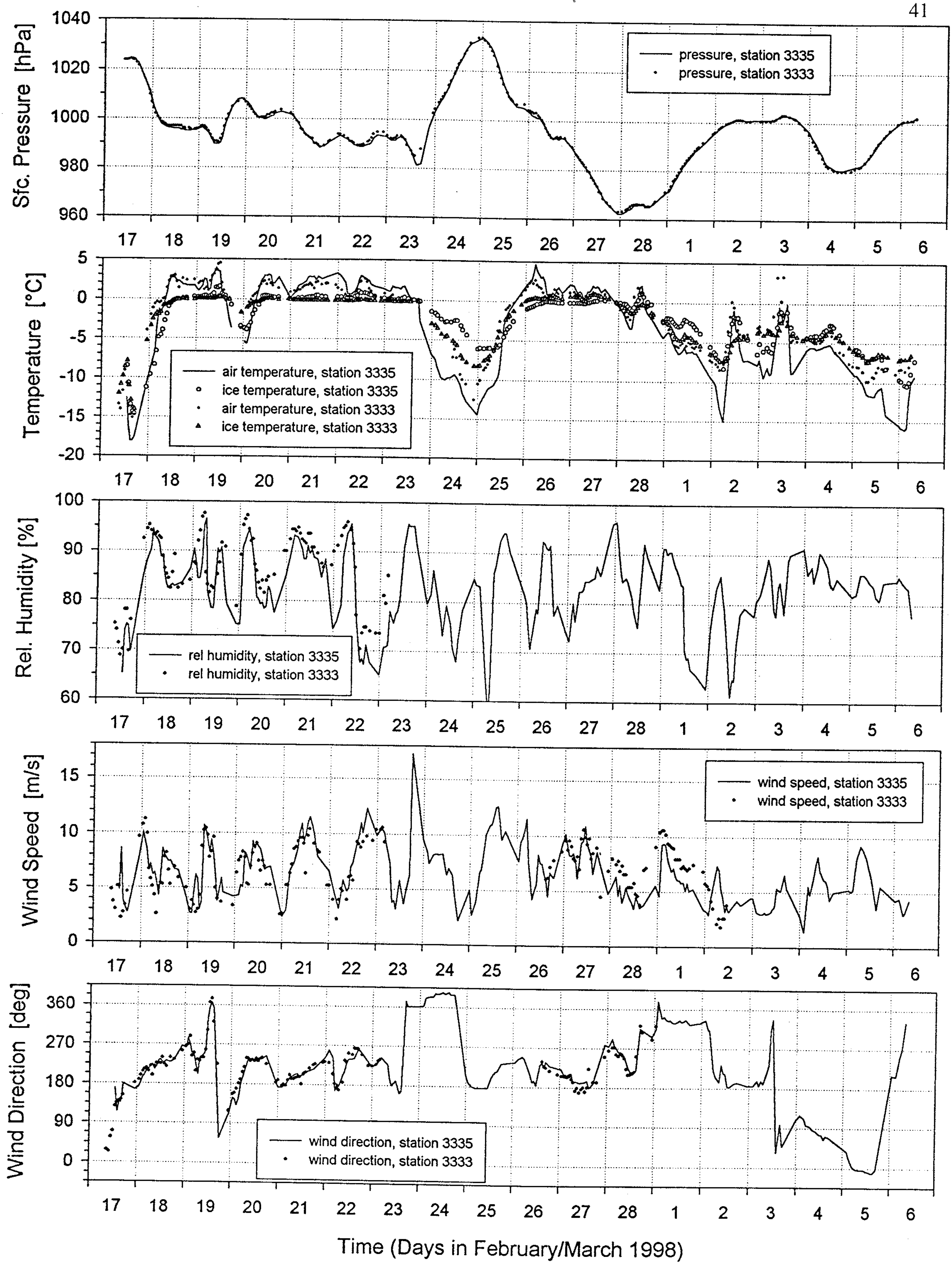


Figure 4.3: Time series of observations from two automatic meteorological Argos stations of Hamburg University. From top to bottom: surface air pressure, air temperature at 0.6 m and ice surface temperature, relative humidity at 0.8 m, wind speed at 2.1 m and wind direction at 2.1 m. For position see Table 4.3.

Details of the instrumentation are summarized in Table 4.4.

Surface data: The various sensors for measurements of the standard parameters (System Minerva) and eddy fluxes (System USA-T) were mounted on four different short masts which were arranged within an area of 10 m x 10 m over the ice-covered sea about 125 m south of the east-west oriented coast-line. Power supply and signal-transfer were maintained by cables which allowed for distances of maximal 140 m between the temporary Lab and the experimental site.

Aerology: The radiosondes of the type Vaisala RS80-GPS were launched from the frozen sea from about 1 m height. The 200 g balloons were inflated with 0.7 m^3 helium to provide a mean ascent rate of 4-5 m/s as a compromise between meteorological and telecommunicational aspects. The radiosondes were monitored by the DIGI-CORA system in the sounding mode „Research“ which allows for flexible launching and flight conditions of the radiosondes. The reception of the radiosonde signals became obviously better after the antennas for the remote UHF-signals and the local GPS-signals were elevated so that they exceeded the trees of the forest surrounding the temporary Lab.

4.3.3 Data sets and characterization

Surface station: Disregarding the episodes of minor data losses due to technical malfunctions and instrumental disturbances caused by the maintenance staff, surface data from all systems installed and cloud-base measurements are available throughout, from 17 February 00 UT until 06 March 18 UT.

The micrometeorological data may be affected by the quite inhomogeneous terrain arround the instrumental site. Consequently, the resulting data quality and representativity are crucially linked with the wind direction and also with the surface conditions which changed from initially snow on sea-ice to water on sea-ice during the extended episodes of warm-air advection from 18 to 23 February, and 25 to 28 February. On the other hand, wintry scenarios occurred from 17 to 18, 24 to 25 February and from 4 March until the end of the campaign with air-temperatures below -10°C. Surface conditions with respect to the different wind directions can be qualified as follows: winds from 225° to 315° were featured by adequate wind fetches over open ice, winds from 315° to 135° originated from the winterly woodland of the 2 km broad spit of the peninsula Trullevi-Lomakylä, winds from 135° to 160° had afterall open-ice fetches of 5 km length, and winds from 160° to 225° had open ice fetches of 3 km but came from an industry area located south of the experimental site. Figures 4.4 - 4.6 present surface data and cloud base as averages over 10 minutes.

Aerology: A total of 72 successfully launched soundings form the aerological data set. The profiles were taken every 6 hours, centered around WMO-times 00, 06, 12, 18 UT. Eight additional soundings were launched around 09 UT in context with FALCON flight missions (see Table 4.2). The sondes reached usually heights of 17 - 19 km, thus exceeding the tropopause level between 8 to 12 km. Data were stored every 2 seconds in binary format, and in ASCII format too, applying the Vaisala-Metgraph software. The achieved quality of the thermodynamic profiles and of the kinematic profiles, data gaps implied, differs remarkably from each other, as can be seen in Table 4.5. Undisturbed wind profiles were preferably obtained between 23 UT and 08 UT (in more than 75 % of the total), but wind soundings at 18 UT reveal defects in 50 % of the time.

Time-height cross-sections of temperatures, relative humidity and wind speed are presented in Figures 4.7a - 4.7c for the lowest 0.5, 3 and 12.5 km. For this presentation, the profiles were gridded in steps of 10 m, 40 m and 200 m, depending on the vertical range displayed.

Phenomenological observations;
As background information for a better physical interpretation of the data sets, observations of cloud type, cloud coverage and weather type according to the WMO scheme were made every hour.

4.4 Field personnel and acknowledgements

The following persons were involved in the FALCON flights: Vogel, Welser, Meier, Schönbach from the FALCON crew of the DLR at Oberpfaffenhofen and Brümmer, Thiemann, Brecht from the University of Hamburg.

Ing. Rudolf Kapp of the UHAM was responsible onboard RV Aranda for the setting-up and the installation of the buoys. When he left the ship, Timo Vihma and his crew of FIMR took over, kept a watchful eye on the stations and recovered them at the end of the campaign. Their efforts are gratefully acknowledged.

The scientific (Gottfried Kruspe, Jutta Rost, David Schröder) and technical crew (Michael Offermann and temporarily Rudolf Kapp) arrived at the coastal holiday village Trullevi/Kokkola on 13 February , and returned from the campaign to Hamburg on 17 March. Trullevi offered the crew excellent working and living conditions. The crew gratefully acknowledges all the cooperative efforts of the warmhearted manager of the Holiday Village, Kari Liedes and his family.

Table 4.4: Instrumentation at station Trullevi/Kokkola

Parameter	Instrument	Height [m]	Continuous output (mean values)	sampling rate (sec^{-1})	Rms-accuracy
sfc-pressure	PTB-Aueroid[a)] (Vaisala)	9.5	60 s	1 s	0.1 hPa
wind vector	Wind vane, cup anemometer Metek-USA-T	2.0 3.5	60 s 300 s	1 s 50	2 deg, 0.1 m/s 0.4 deg, 0.01 m/s
air temperature	Metek-USA-T two PT 100	1.0 3.5	300 s 60 s	50 1 s	0.01 K 0.15 K
dew point	two mirrors (Fa. Kroneis)	1.0	60 s	1 s	0.1 K
snow temperature	two PT 100	-0.05 -0.10	60 s	1 s	0.1 K
sfc-radiation temp.	Heimann-KT19	0	60 s	1 s	0.3 K
global radiation	Kipp a. Zonen pyranometer	1.0 m	60 s	1 s	5 W/m^2
reflected short-wave radiation	Kipp a. Zonen pyranometer	1.0 m	60 s	1 s	5 W/m^2
atmosph. back radiation	Eppley pyrgeometer	1.0 m	60 s	1 s	5 W/m^2
terrestrial radiation	Eppley pyrgeometer	1.0 m	60 s	1 s	5 W/m^2
sensible heat flux	Metek-USA-T	3.5	300 s	50	0.1 W/m^2
wind stress	Metek-USA-T	3.5	300 s	50	0.01 N/m^2
Upper air: pressure, temperat., relative humidity	DIGI-CORA (Vaisala) RS80-15G Radiosonde with GPS-module	1.0 (start)	2 s 2 s	0.5 0.5	0.3 hPa, 0.2 K, 5% 1 m/s
cloud-base up to 7.5 km	Ceilometer CTK25 (Vaisala)	7.0	30 s	0.03	20 m

a) mounted in the LAB

Table 4.5: Aerological soundings at Trullevi/Kokkola.
Launch time, profile heights (in km) for PTU[a] and (^) wind, as well as assessed data qualitiy[b]

date 1998	06 UT	09 UT	12 UT	18 UT	24 UT
02-18	-	-	**11:24** 7.5 (1) ^ 7.3 (3)	**17:23:** 11.8 (1) ^ 11.8 (3)	**23:17:** 6.5 (1) ^ 6.5 (1)
02-19	**05:28:** 17.5 (1) ^ 17.5 (1)	-	**11:22:** 15.3 (1) ^ 15.3 (1)	**17:41:** 9.9 (1) ^ 9.9 (3)	**23:20:** 4.7 (2) ^ 4.7 (3)
02-20	**05:38:** 17.2 (1) ^ 17.2 (1)	-	**11:26:** 10.5 (1) ^ 10.5 (3)	**17:21:** 6.9 (1) ^ 0.0 (4)	**23:13:** 9.6 (1) ^ 9.6 (1)
02-21	**05:17:** 10.0 (1) ^ 10.0 (3)	-	**11:27:** 11.0 (1) ^ 11.0 (2)	**17:12:** 9.9 (1) ^ 0.0 (4)	**23:08:** 18.7 (1) ^ 18.7 (1)
02-22	**05:03:** 18.5 (1) ^ 18.5 (1)	-	**11:07:** 18.3 (1) ^ 18.3 (2)	**17:13:** 7.5 (2) ^ 0.0 (4)	**23:03:** 19.3 (1) ^ 19.3 (1)
02-23	**05:05:** 19.1 (1) ^ 19.1 (1)	-	**10:58:** 18.1 (1) ^ 18.1 (2)	**17:09:** 17.5 (1) ^ 17.5 (3)	**23:19:** 14.7 (1) ^ 14.7 (1)
02-24	**04:55:** 17.0 (1) ^ 17.0 (1).	-	**11:16:** 17:7 (1) ^ 17.7 (1)	**17:15:** 14.6 (1) ^ 14.5 (1)	**23:06:** 17.4 (1) ^ 17.4 (1)
02-25	**05:08:** 15.8 (1) ^ 15.8 (1)	-	**11:22:** 15.7 (1) ^ 15.7 (1)	**17:03:** 16.1 (1) ^ 16.1 (1)	**23:06:** 16.0 (1) ^ 16.0 (3)
02-26	**04:58:** 17.1 (1) ^ 17.1 (1)	-	**10:59:** 18.1 (1) ^ 18.1 (1)	**17:13:** 17.6 (1) ^ 17.6 (1)	**23:08:** 17.8 (1) ^ 17.8 (1)
02-27	**05:08:** 19.3 (1) ^ 19.3 (1)	**08:39:** 12.2 (1) ^ 12.2 (1)	**11:10:** 18.2 (1) ^ 18.1 (1)	**17:07:** 15.8 (1) ^ 15.8 (1)	**23:11:** 17.1 (1) ^ 17.1 (1)
02.28	**05:13:** 15.0 (1) ^ 15.0 (3)	**08:43:** 13.0 (1) ^ 13.0 (1)	**11:06:** 15.1 (1) ^ 15.1 (1)	**17:10:** 19.0 (1) ^ 19.0 (3)	**23:15:** 17.5 (1) ^ 17.5 (1)
03-01	**05:06:** 17.2 (1) ^ 17.2 (1)	**08:23:** 15.0 (1) ^ 15.0 (1)	**11:10:** 17.1 (1) ^ 17.1 (1)	**17:15:** 17.4 (1) ^ 17.4 (1)	**23:05:** 17.1 (1) ^ 17.1 (1)
03-02	**05:10:** 18.5 (1) ^ 18.5 (1)	**08:10:** 15.2 (1) ^ 15.2 (1)	**11:10:** 20.3 (1) ^ 20.3 (1)	**17:15:** 17.2 (1) ^ 17.2 (1)	**23:13:** 14.4 (1) ^ 14:4 (1)
03-03	**05:11:** 15.2 (1) ^ 15.2 (2)	**08:20:** 18.4 (1) ^ 18.4 (1)	**11:11:** 17.0 (1) ^ 17.0 (1)	**17:09:** 19.7 (1) ^ 19.7 (1)	**23:07:** 16.2 (1) ^ 16.2 (2)
03-04	**05:52:** 16.4 (1) ^ 16.4 (1)	-	**11:22:** 18.4 (1) ^ 18.4 (1)	**17:14:** 18.2 (1) ^ 18.2 (2)	**23:08:** 17.1 (1) ^ 17.1 (1)
03-05	**05:19:** 19.5 (1) ^ 19.5 (1)	**08:28:** 10.2 (1) ^ 10.2 (1)	**11:11:** 18.8 (2) ^ 18.5 (3) **13:31:** 18.6 (1) ^ 18.6 (1)	**17:08:** 17.7 (1) ^ 17.7 (1)	**23:13:** 18.1 (1) ^ 18.1 (1)
03-06	**05:07:** 15.8 (1) ^ 15.8 (2)	**09:02:** 10.0 (1) ^ 10.1 (2)	**11:13:** 18.2 (1) ^ 18.2 (1)	**17:17:** 8.5 (1) ^ 8.5 (2)	-

a. P=Pressure, T=Temperature, U=Relative humidity.
b. **Key for data quality:** 1: data-gaps in the profile < 20 % , 2: 20-40 % data gaps in the profile, 3: data gaps > 40 % 4: no data available.

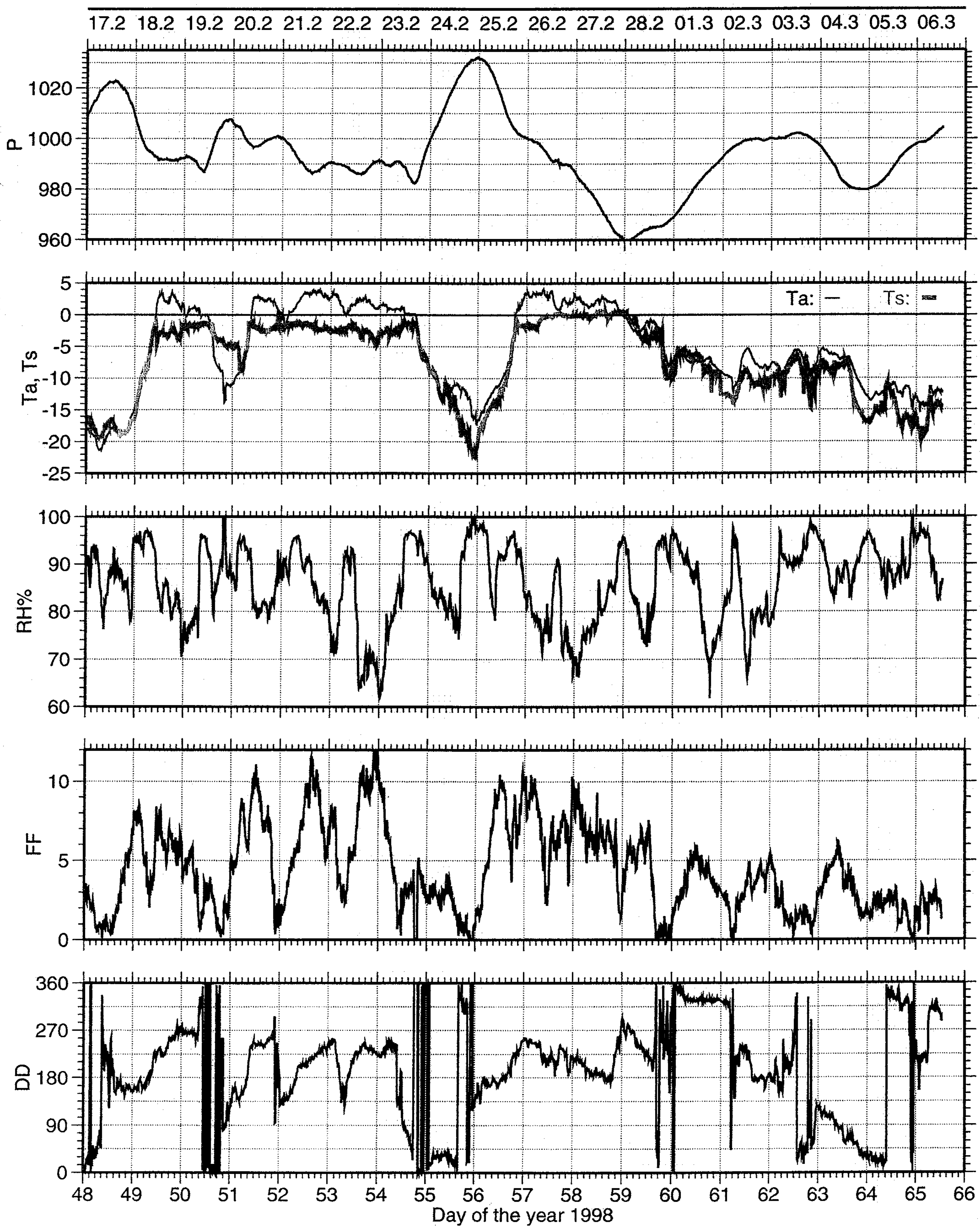


Fig.:4.4: Station Trullevi/ Kokkola: surface data

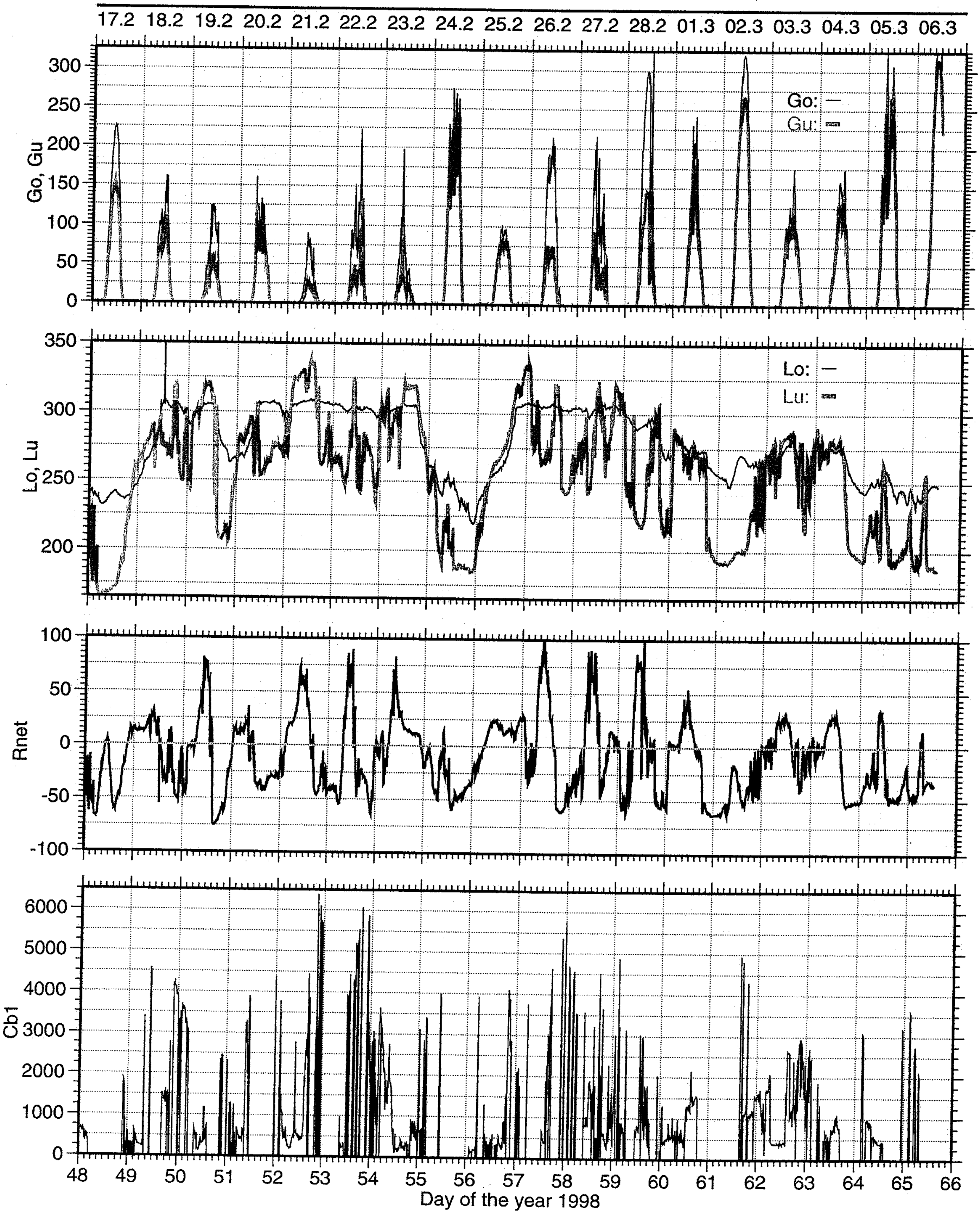


Fig.:4.5: Station Trullevi/ Kokkola: radiation, lowest cloud base

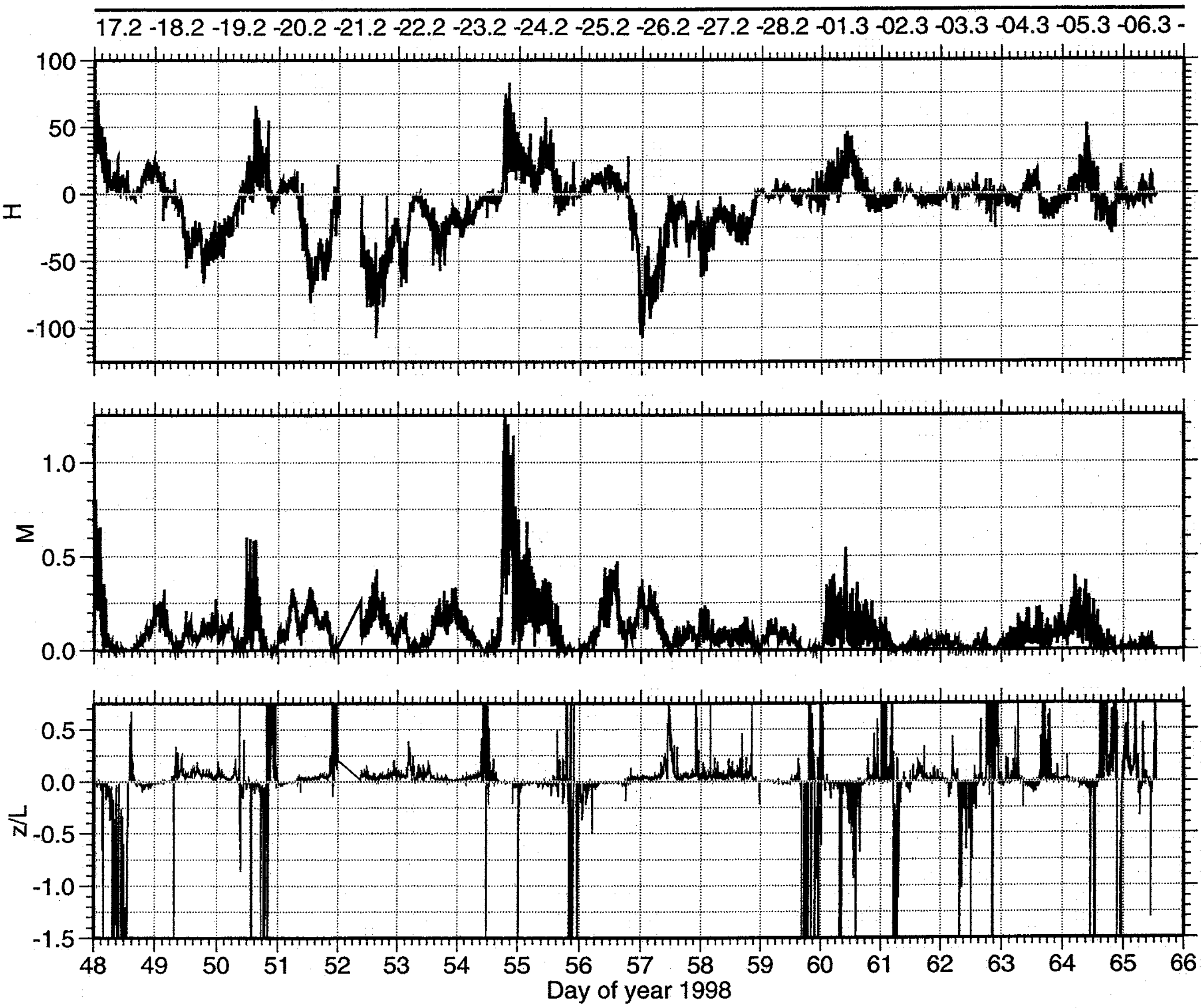


Fig:4.6: Station Trullevi/ Kokkola: eddy-fluxes (USA-T,h=3.5m)

Legend to figures 4.4-4.6

P : sfc-pressure at 9.5m height [hPa]
Ta: air temperature (Pt100-II- Minerva) [ºC]
Ts: blackbody radiation temperature of the surface [ºC]
RH%:relative humidity (MirrorII- Minerva) [%]
FF: total wind speed (Yawi-Minerva) [m/s]
DD: wind direction (vane-Minerva) [deg]
Go: global radiation Gu: reflected shortwave radiation [Wm^{-2}]
Lo: atmosph. back-radiation Lu: terrestrial radiation [Wm^{-2}]
Rnet: sfc netto radiation [Wm^{-2}]
Cb1: detected lowest cloud base up to 7.5km [m]
H: sensible heat flux [Wm^{-2}]
M: momentum flux [kg/ms^2]
z/L: Monin Obukhov stability measure ,z=3.5m
All the curves represent data averages over 10 minutes

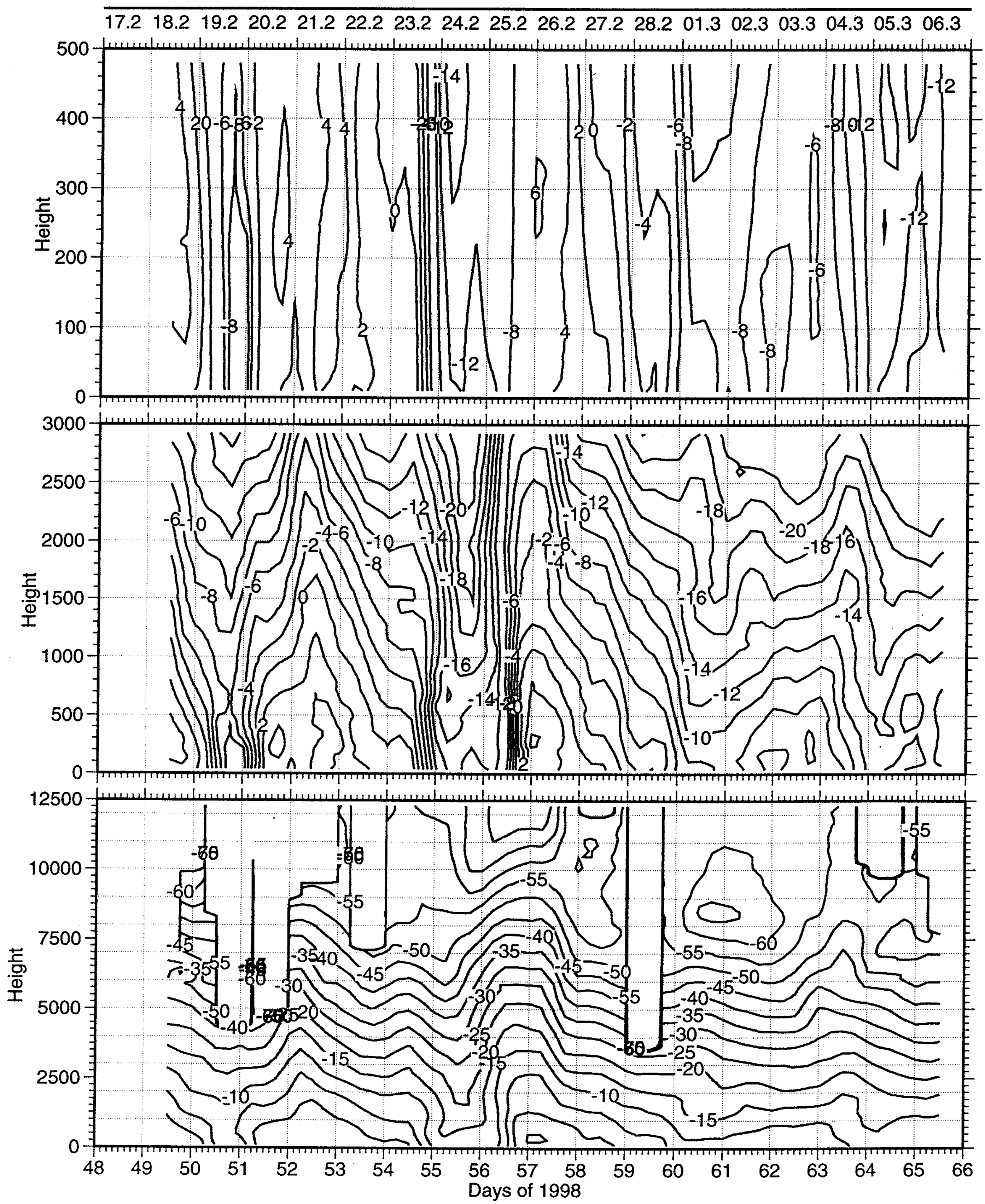


Fig.:4.7a: Radiosonde station Trullevi/ Kokkola: Time-height cross-section of temperature

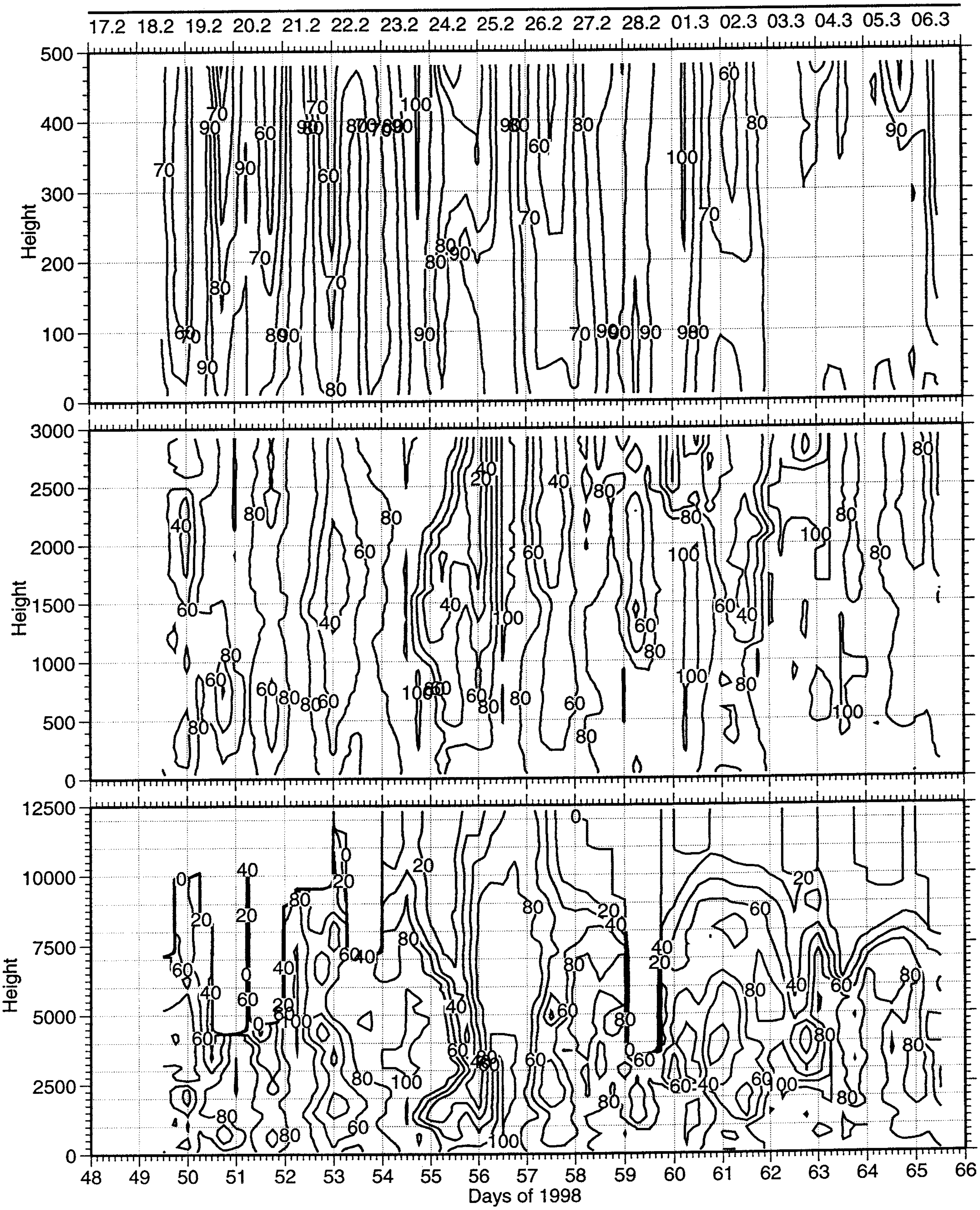


Fig.:4.7b: Radiosonde station Trullevi/ Kokkola:Time-height cross-section of relative humidity

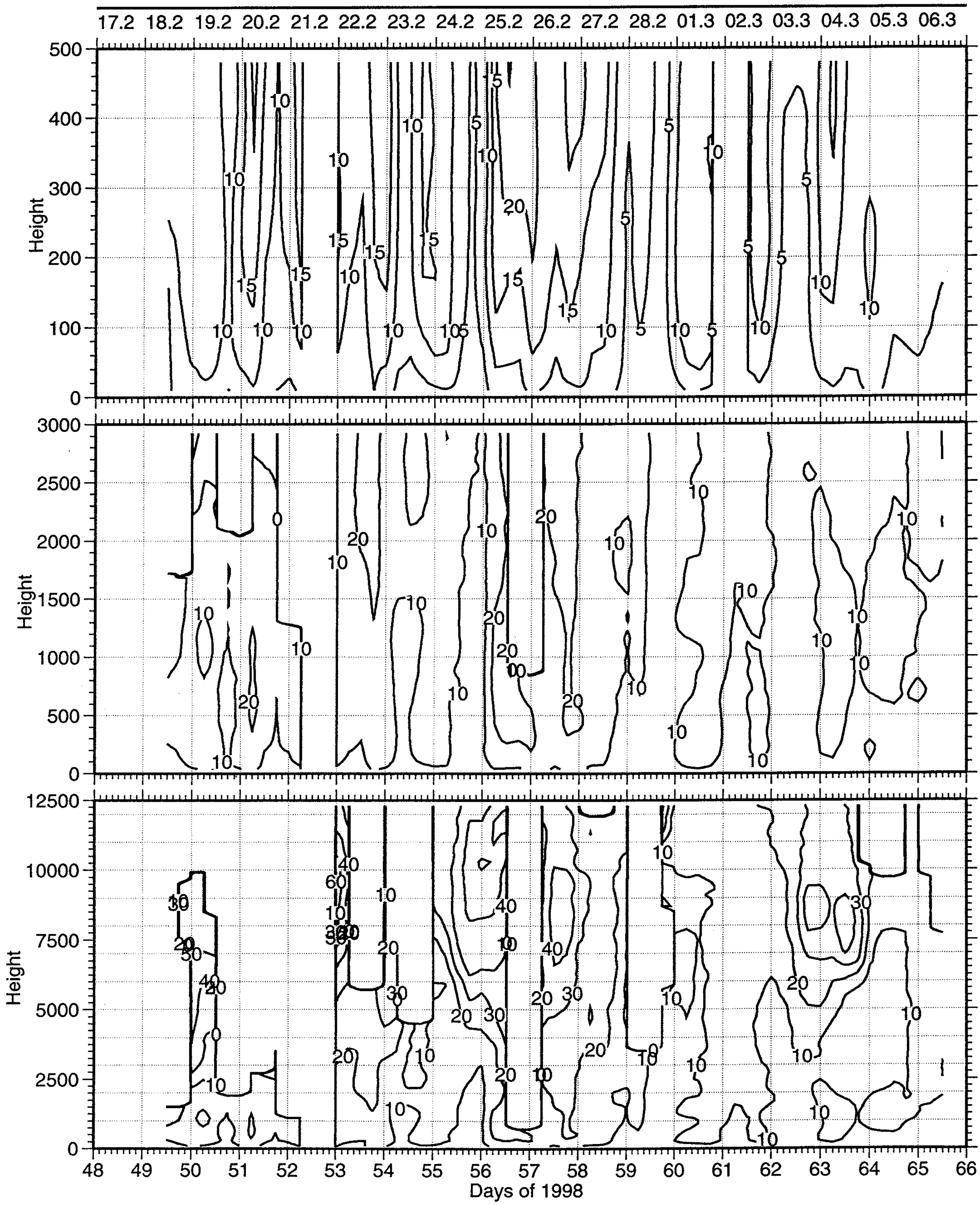


Fig.:4.7c: Radiosonde station Trullevi/ Kokkola: Time-height cross-section of wind speed

5. Helipod measurements and rawinsonde soundings by the University of Hannover, Institute for Meteorology and Klimatology

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5.1 Objectives

The tasks of the Department of Meteorology and Climatology of the University Hannover in BALTEX-BASIS were the performance of helicopter measurement flights with the helicopter carried measurement system Helipod, and rawinsonde soundings from the Merikarvia station.

The project BASIS aims at an improved understanding of the energy and water cycles during winter conditions by conducting a field experiment. The helicopter-borne turbulence measurement system Helipod provide data on a smaller scale than airplane measurements usually do. In contrast to mast measurements they supply a space-time average over an area instead of a time average measured at one point.

With Helipod it is possible to gather data even down to altitudes as low as approximately 10 m, which makes the system extremely useful for intercomparisons with mast measurements, for example. In order to investigate the exchange of momentum, sensible heat and latent heat between the ocean, sea-ice and the atmosphere, the planned flight patterns mainly covered the lower boundary layer. Special emphasis is laid down onto near surface flight legs at a height of 10 to 20 m agl (above ground level). These flights consist of box-shaped patterns in three different heights, which allow a direct intercomparison with mast measurements as well as an intercomparison with budget calculations of the airplane measurements.

At Merikarvia, the Department of Meteorology and Climatology from the University of Hannover performed rawinsonde soundings four times a day. With five other rawinsonde sounding stations (cf. sect. 2.1 and 2.3) these data are used for budget studies and for synoptic background information for the BASIS campaign.

5.2 Measurements and methods

Helipod measurements

Helipod is an autonomous measurement system projected by the Department of Meteorology and Climatology of the University Hannover and realized by the Aerodata Company in Braunschweig. The system consists of several instruments to measure the parameters of meteorological interest, see Table 5.1, with a high time resolution as well as with a long-term stability. For determining the wind velocity, the equipment has a five-hole probe and a highly accurate navigation system, containing two GPS receivers and one inertial platform. Height is measured both as barometric height and as height above ground level with a radar altimeter. The air temperature is measured by a long-term stable Rosemount PT-100 sensor and the high frequency temperature is sampled by a newly developed sensor unit Aerodata AD-STS, which has a Dantec open wire element of 0.005 mm diameter. For humidity measurements, three different instruments are used: a dewpoint mirror, a capacitive sensor and a Lyman-alpha sensor. The surface temperature is measured by a KT-19 infrared thermometer. More detailed information in particular with regard to the accuracy of the measurement system Helipod is given by Wode and Roth (1996), Wode et al. (1996), Hoff et al. (1998), Hofmann et al. (1998), and Wode et al. (1998).

Table 5.1. Sensors and time resolution of the Helipod measurement system.

Measurement Quantity	Sensor	Time Resolution
wind speed	five-hole probe	100 Hz
air temperature	Rosemount PT-100	20 Hz
	Aerodata AD-STS	100 Hz
air humidity	dewpoint mirror	20 Hz
	capacitive sensor	10 Hz
	Lyman-Alpha sensor	100 Hz
surface temperature	infrared thermometer	100 Hz
navigation	2 x GPS	1 Hz
	inertial platform	100 Hz

Unfortunately, the mean wind velocity during the expedition was rather high (Figure 5.1). As to the measurements made on board *R/V Aranda* the mean wind speed during daylight was 11.2 m/s with a standard deviation of 3.9 m/s. Since Helipod flights can only be conducted if the wind velocity is up to 10 m/s in ten-minute-average, only few time intervals had been suitable for Helipod measurements. Thus during the hole campaign only three flights could be done altogether. The mean wind velocity during the daylight on days without Helipod flights was even 12.3 +/- 3.7 m/s whereas during the days with Helipod flights this was 7.8 +/- 2.0 m/s. The three flights were carried out on 24 and 28 February and on the 1 March, 1998.

On each of these flights there were technical problems leading to a premature break-off before finishing of the pattern. All in all, there was roughly half an hour of meteorological usable Helipod measurement time during these three flights containing one vertical sounding on each flight and two horizontal legs of approximate 8 km length at a height of 20 m agl on the last flight. Because of a technical failure on 1 March, Helipod could not be used up to the end of the campaign.

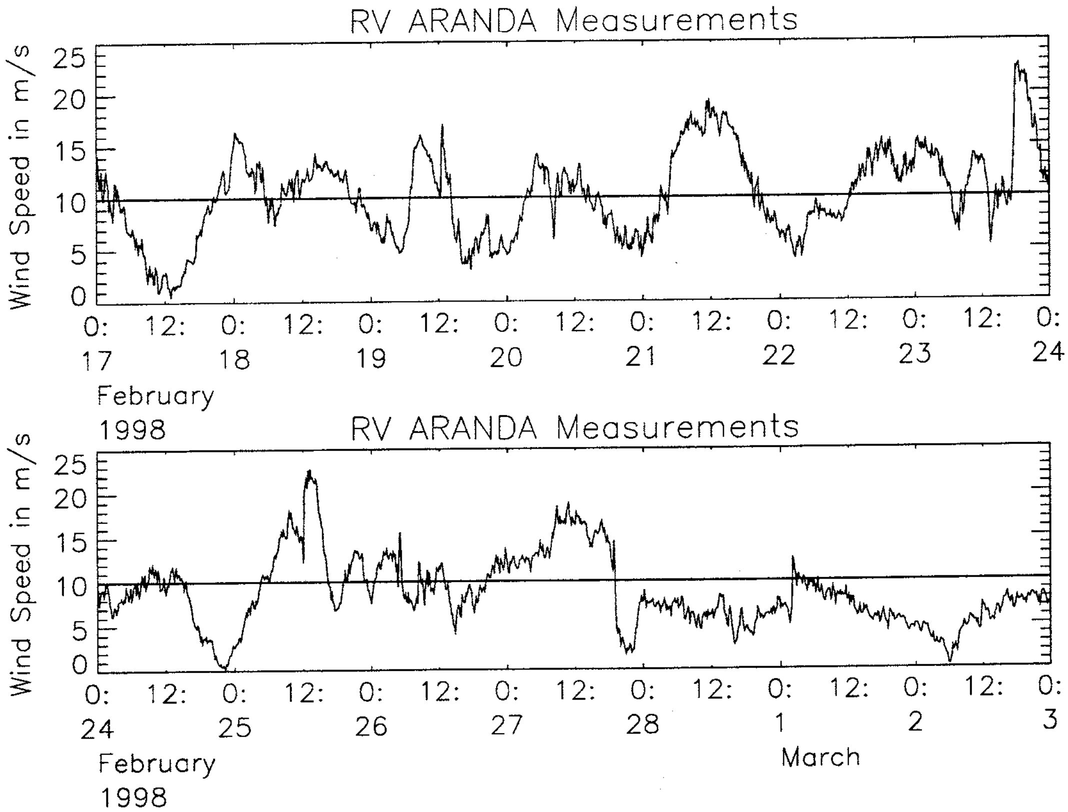

Figure 5.1. Wind speed (ten minute averages) measured on board of *R/V Aranda* (at 19m). The horizontal lines indicates an upper wind speed limit for Helipod flights.

The measurement flights were located in the marginal ice edge zone on the Finnish coast of the Gulf of Bothnia. The average flight velocity during the measurement flights was 40 m/s. The central position of the measurement flight on 24 February was 63° 15.9' N and 20° 49.2' E to northwest from *R/V Aranda*, on 28 February the central position was 63° 11.0' N and 20° 40.3' E to northwest from *R/V Aranda* and on 1 March the central position was 63° 7.1' N and 20° 58.7' E to southwest from *R/V Aranda*. On the 24 and 28 February, measurements could only be taken from the vertical soundings. On 1 March, 1998, measurements were taken from two vertical soundings and two horizontal legs. The figure of the horizontal flight pattern was a "L- form" at a height of 20 m agl. The length of the legs was 8 km approximately.

Rawinsonde soundings at Merikarvia Station
At Merikarvia, in a village at the Finnish coast located at 62° 51.0' N and 21° 28.2' E, GPS-based rawinsonde soundings were made by our rawinsonde sounding group. The soundings started on Tuesday 17th of February at 17:30 UTC and finished on Friday 6th of March, 1998, at 11:30 UTC. All in all there were 65 routinely soundings made with launch times of 05:30, 11:30, 17:30 and 23:30 UTC plus four additional soundings at the flight time of the Falcon research aircraft (University of Hamburg).

These soundings provide data of wind velocity, wind direction, humidity, temperature and pressure. The height of the rawinsonde soundings vary between 10 and 20 km with an average height of 16 km. The average ascend rate was 5 m/s, the time step of the measurements was two seconds. This results in a vertical resolution of 10 m.

Table 5.2 gives an overview of the instruments. For detailed information of the accuracy of the measurement system (with exception of GPS) see Vaisala (1986).

Together with the soundings at Sundsvall, Umea, Kokkola and the *R/V Aranda* these rawinsonde soundings supply a comprehensive data set for budget studies. Additional, they serve as a large-scale background information for intercomparison with the other gathered data.

Table 5.2. Sensors and time resolution of the rawinsonde.

Measurement quantity	Sensor	Time resolution
wind speed	GPS	0.5 Hz
wind direction	GPS	0.5 Hz
air temperature	Thermocap	0.5 Hz
air humidity	Humicap	0.5 Hz
pressure	Barocap	0.5 Hz

5.3 Data sets and characterization

Helipod data

The Helipod data contains the u-, v- and w-components of the wind, the air temperature, the air humidity, the surface temperature and the navigation data. The time resolution varied from 1 Hz (GPS-positioning) to 20 Hz or up to 100 Hz. The two latter ones cover the high frequency fluctuations for turbulence calculations. The three measurement flights cover:

24.02.1998: Takeoff at 08:09 UTC and landing at 08:52 UTC on *R/V Aranda*.
The measurements started at 08:19 UTC with a vertical sounding. Because the navigation system of Helipod did not work the measurement flight was stopped.

28.02.1998: Takeoff 12:12 UTC and landing 12:48 UTC on *R/V Aranda*.
The measurements started at 12:19 UTC with a vertical sounding. During the climbing flight the Helipod equipment started to swing seriously and the measurement flight had to be stopped.

01.03.1998: Takeoff 14:25 UTC and landing 15:07 UTC on *R/V Aranda*
The measurements started at 14:32 UTC with a vertical sounding up to 300 m. The beginning of leg 1 was at 14:41 UTC The height was 20 m agl and the leg length was 8 km. At 14:44 UTC leg 1 was finished and leg 2 was started. This leg has approximate the same length and height as leg 1. At 14:47 UTC leg 2 was finished. Because at 14:49 UTC a strong push was realized in the helicopter the measurement flight was stopped.

For calculation of the turbulent fluxes, only the six minutes from the measurement flight on 1 March could be used. Figures 5.2 to 5.5 show some results from this flight near the ice edge zone. Figure 5.2 gives the w-component and Figure 5.3 the air temperature of leg 1. Figure 5.4 gives the w-component of leg 2 and Figure 5.5 shows the mixing ratio for leg 2.

Rawinsonde sounding data

The rawinsonde sounding data contains the wind speed, wind direction, air temperature, air humidity and the pressure with a time resolution of 0.5 Hz. 65 soundings made with daily launch times of 05:30, 11:30, 17:30 and 23:30 UTC. Four additional soundings were performed at the flight time of the research aircraft.

The rawinsonde sounding data represents typical profiles for the area in the Bay of Bothnia, following the European large-scale weather conditions:

1. A high pressure area over central Europe for the time period from 18 to 21 February, 1998.
2. Anticyclonic northwest weather conditions for the time period from 22 to 26 February.
3. Cyclonic west weather conditions for the time period from 27 February to 6 March, 1998.

These large-scale weather conditions results in strong westerly winds and (exceptionally) high air temperature and humidity for the season in the area. Figures 5.6 and 5.7 show some typical sounding profiles of the time period 18 February 6 March, 1998, observed at the Merikarvia Station.

5.4 Field personnel

Scientist	Time	Activity
Michael Hofmann	14.02. - 07.03.	Helipod / Meteorologist
Merle Glandorf	14.02. - 07.03.	Helipod / Meteorologist
Christian Wode	14.02. - 16.02.	Helipod / Meteorologist
Maren Sasse	14.02. - 07.03.	Rawinsonde / Meteorologist
Jan-Mark Pilawa	14.02. - 07.03.	Rawinsonde / Meteorologist
Hagen Edeler	14.02. - 07.03.	Helipod / Engineer
Mathias Schuermann	14.02. - 16.02	Helipod / Engineer
Uwe Goehmann	14.02. - 07.03.	Helipod / Pilot
Heinrich Rutsch	14.02. - 28.02.	Helipod / Mechanician
Peter Soenksen	28.02. - 07.03.	Helipod /Mechanician

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Hofmann, M., Wode, C. and Roth, R. 1998: First field experiments in the Arctic with the helicopter-borne measurement system HELIPOD. Meteorol. Z., N. F., submitted.
Wode, C. and Roth, R. 1996: Helipod - ein hubschraubergestuetztes meteorologisches Messystem. Abschlussbericht BMBF Projekt Nr. 07KFT74, Institut fuer Meteorologie und Klimatologie der Universitaet Hannover, Germany.

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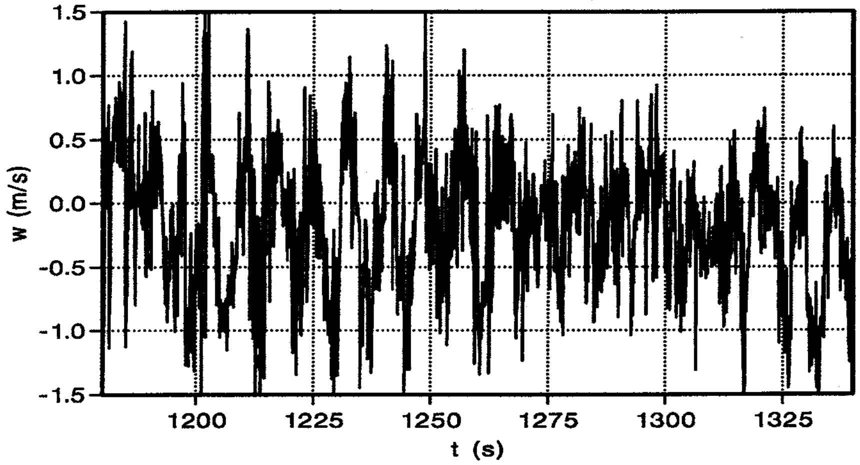

Figure. 5.2. w- wind component for leg 1.

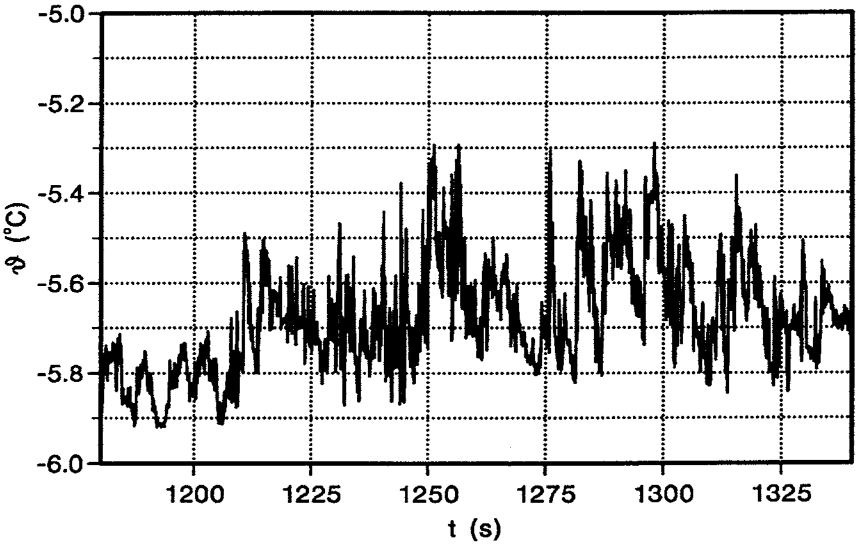

Figure 5.3. Air temperature of leg 1.

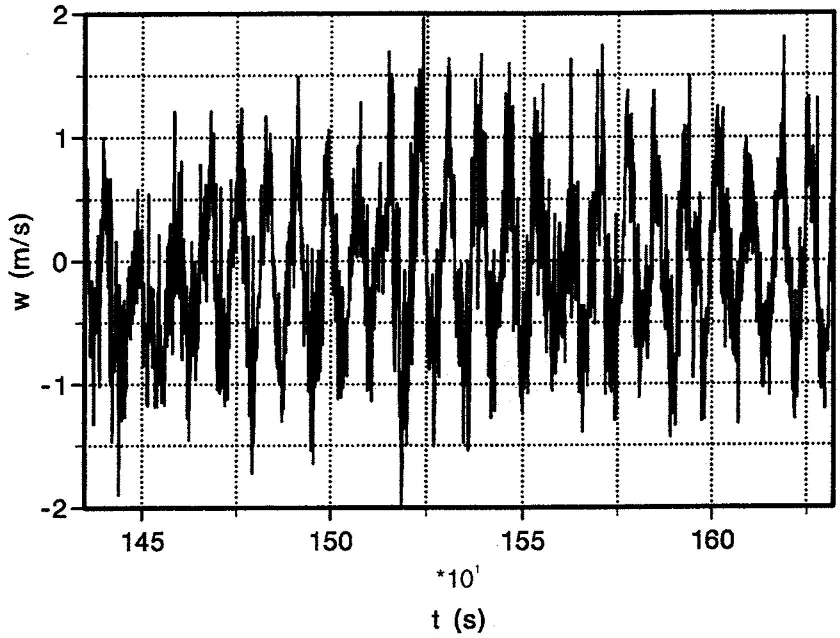

Figure 5.4. w- wind component for leg 2.

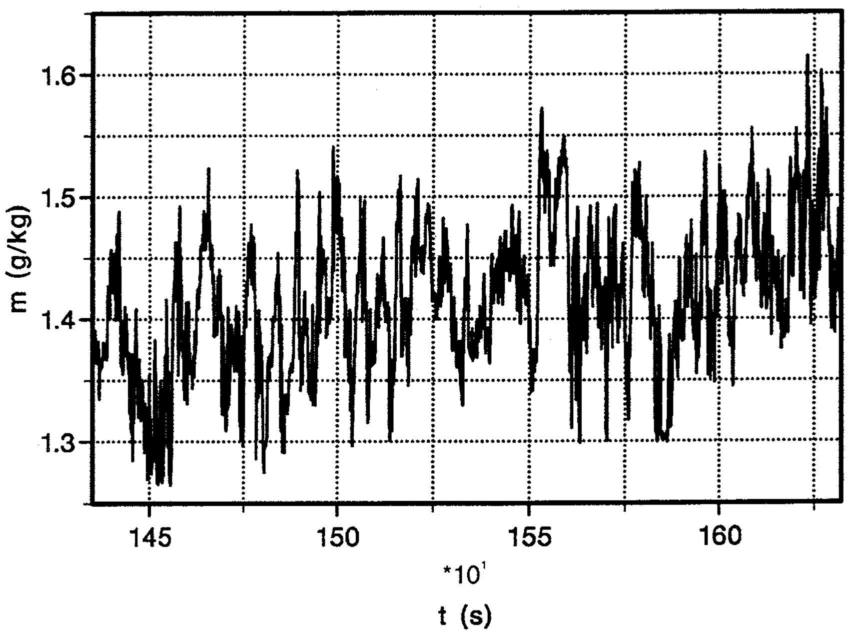

Figure 5.5. Mixing ratio for leg 2.

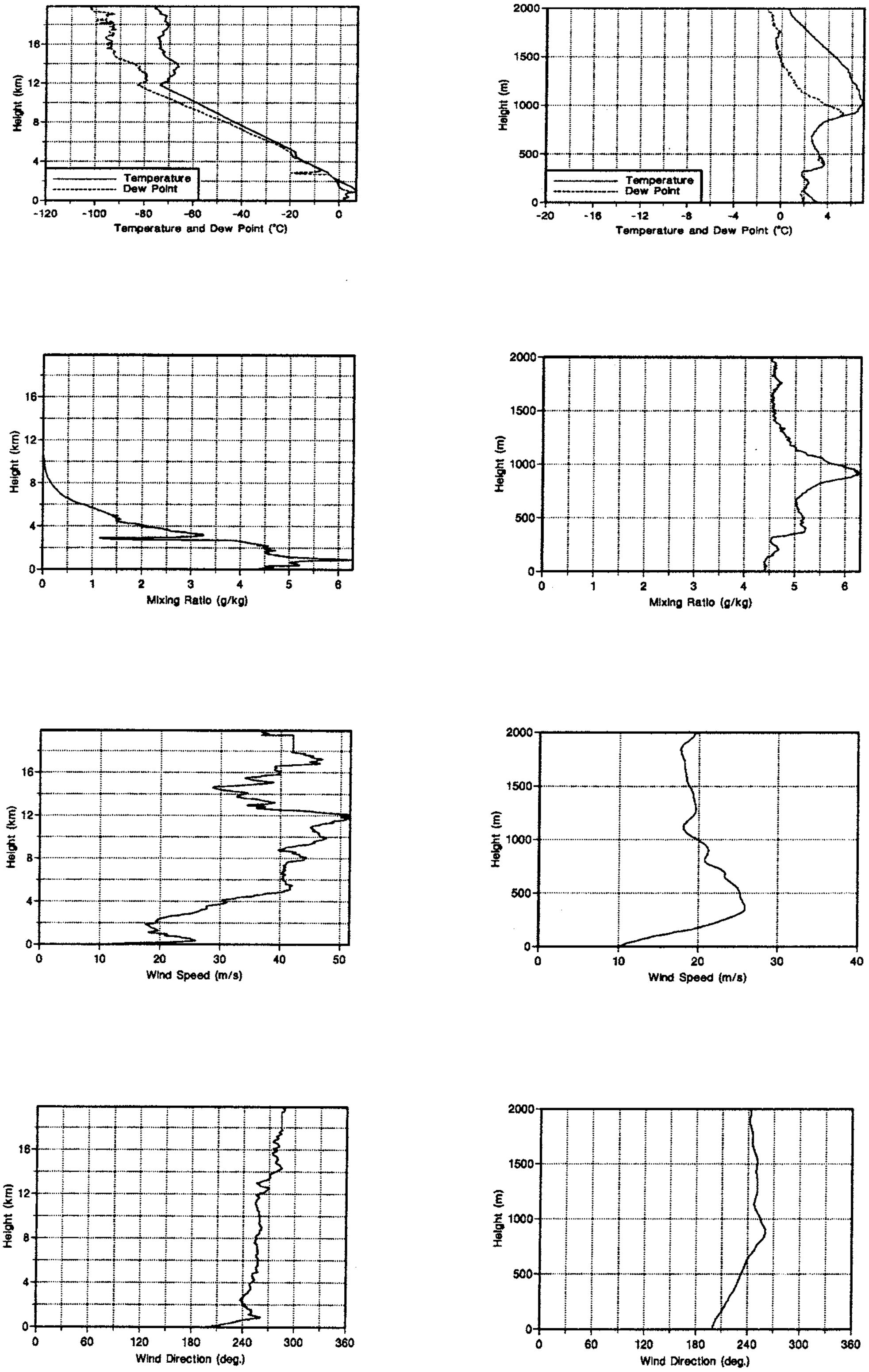

Figure 5.6. Sounding profiles as observed at the Merikarvia station on 21.02.98 , 11:30 UTC.

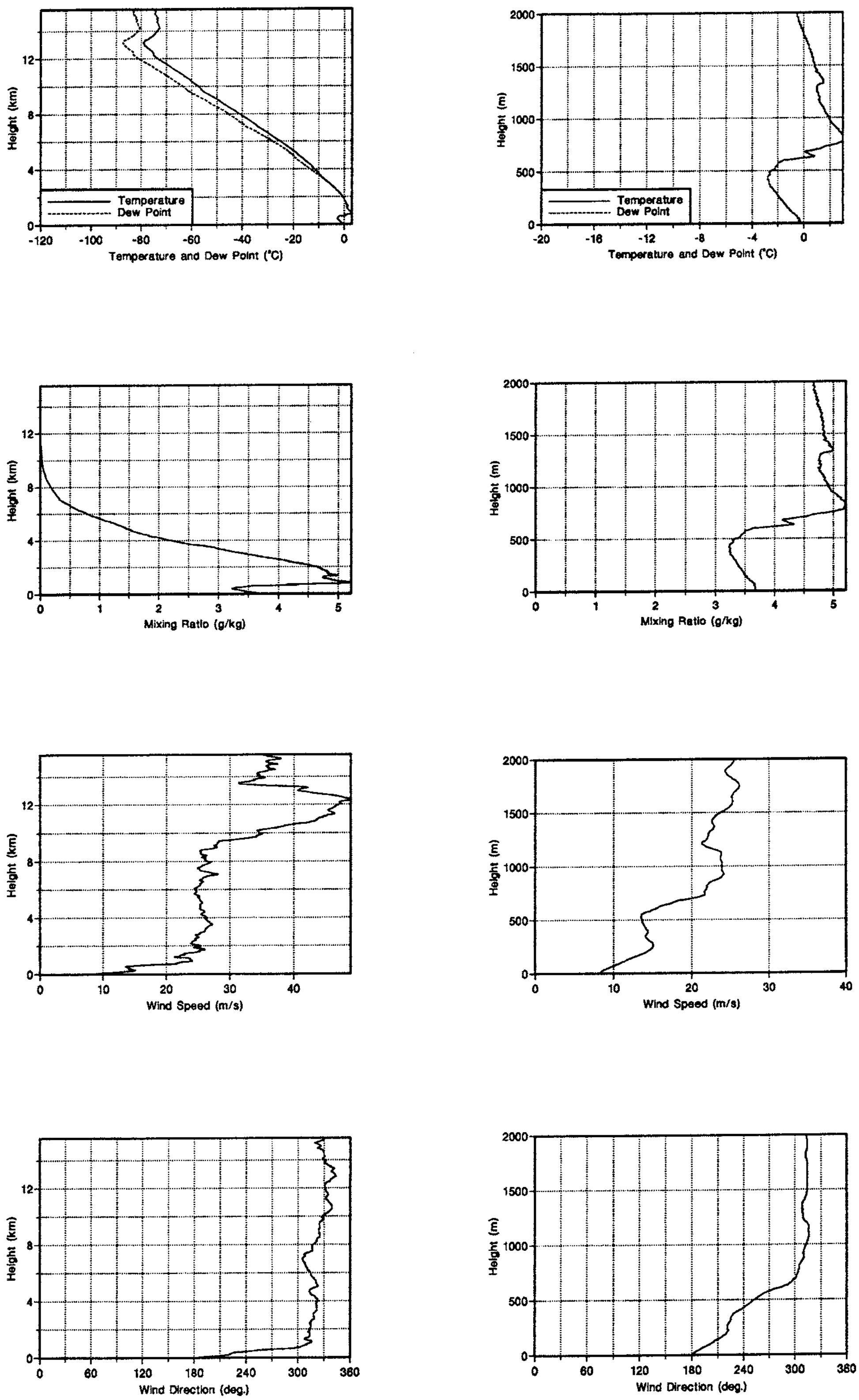

Figure 5.7. Sounding profiles as observed at the Merikarvia station on 25.02.98 , 17:30 UTC.

6. Meteorological measurements by the Uppsala University, Department of Earth Sciences - Meteorology (UUPP/MIUU)

Ann-Sofi Smedman, Mikael Magnusson and Ulf Andræ,

6.1 Objectives

The objective of the experiment was to measure temperature and humidity structure throughout the atmosphere together with wind speed and direction in the boundary layer. These measurements were performed by radiosonde soundings and pibal trackings. The site at Umeå (see below and Figure 6.1) was one of six sites, located as corners in a box where radiosonde soundings were performed. Data from these six stations will be used to determine the vertical budget of water, heat and momentum in the box. Another objective was to establish a fast ice reference station for surface flux measurements at the marginal ice zone. The reference measurements were performed on a tower, with profile and turbulence instruments. Measurements of incoming and outgoing longwave and shortwave radiation were performed in order to get reference data for the remote sensing data. In addition, an open water observation site, Östergarnsholm outside Gotland, was running during the experiment as a reference for open water conditions.

6.2 Measurements and methods

UUPP/MIUU was responsible for three different sites during the experiment. Measurements were performed at the main site outside Umeå and at an ice site on a small mast near the *R/V Aranda*, and at the reference site at Östergarnsholm, outside Gotland. The three sites and their locations are shown in Figure 6.1. Characteristics and instrumentation for the three different sites are presented in separate chapters below, and summarized in Table 6.1. The Umeå site was operated during the whole period by UUPP/MIUU. The ice mast was mounted and controlled by the SMHI staff from *R/V Aranda* and the Östergarnsholm station was checked through a modem connection.

6.2.1 Umeå

The main site was situated at Lövöudden (63^{o} 40,5' N, 20^{o} 24,0' E) at Holmsund 25 km outside the town of Umeå at the Swedish east coast (Figure 6.1). Lövöudden is small peninsula at the Umeå river mouth. The site has an open ice/water fetch in directions between 50^{o} and 230^{o}, disturbed by some small islands only. The tower measurements, pibal tracking and radiosonde soundings were performed there during the experiment.

Tower measurements

A 12-m tower was erected close to the ice at the shore at Lövöudden and equipped with wind and temperature sensors at three levels, 1, 3.5 and 11.5 m above the ice surface. The temperature was measured with Pt-500 resistance sensors placed in ventilated radiation shields. The wind speed was measured with Casella cup anemometers. Incoming and outgoing longwave and shortwave radiation over the snow/ice/water were measured with Eppley radiometers a few meters from the tower at the height of one meter. The profiles and radiation measurements were recorded every second and 10-minute averages were calculated and stored.
Turbulence was measured with a Solent 1012 R2 ultrasonic anemometer-thermometer at 10 m. The instrument was calibrated before mounted, in order to correct for flow distortion problems known for this instrument (Grelle and Lindroth, 1994). In addition, semi-continuous hot-wire measurements were performed at 2 m. The instrument was a wind-vane based on three-component hot-wire system (Högström, 1982). The turbulence was measured with a frequency up to 20 Hz and evaluated as 10-minute averages (20 Hz data available). The wind direction was measured with the sonic anemometer at 10 m. The tower instruments were running continuously, with some exceptions, from the 12 February to the 6 March, 1998.

Radiosonde soundings and pibal tracking

Radiosonde soundings and pibal tracking were performed every sixth hour from the 17 February, 17.30 UTC, to 6 March 11.30 UTC, 1998, with some exceptions due to bad weather and technical problems. Additional soundings were made during the research aircraft missions. For the radiosonde soundings the Vaisala RS80-15 sonde with receiver was used. The sonde measures temperature, humidity and pressure every 1.5 second throughout the atmosphere. The thermometer is a thermocap capacitive sensor with 0.1^{o}C accuracy. The hygrometer sensor is a humicap thin film capacitor with an accuracy of 2 % and the barometer sensor is a capacitive aneroid with an accuracy of 0.5 hPa.

Wind speed and direction were measured with a pibal tracking technique. A balloon, filled with hydrogen, was released and followed visually with a theodolite for about 10 minutes (~2000 m) or until the balloon was lost. The azimuth and elevation angle for the theodolite where stored every eight second on a Campbell logger and afterwards transmitted to a personal computer. From the angles and with the assumption that the balloon has got a constant ascending velocity of 4 m/s it is possible to calculate the wind speed and direction. Three balloons were released in connection to every radiosonde sounding in order to get a representative mean value of the wind. The pibal tracking technique is used frequently by UUPP/MIUU for wind measurements in the boundary layer.

6.2.2 Ice mast

A three meter high mast was erected on the sea ice at 63^{o} 24,025'N 21^{o} 9,940'E 15 nm northwest from *R/V Aranda*. The location of the mast is shown in Figure 6.1. The mast was equipped with ventilated and radiation shielded Pt-500 resistance temperature sensors at 1 and 3 m. The wind speed and direction were measured at 3 m with a combined cup anemometer and wind-vane, developed at UUPP/MIUU (Bergström and Lundin 1993). The ice mast's instruments run continuously between 20 February to 6 March, 1998.

6.2.3 Östergarnsholm

As a reference station for the atmospheric conditions over open water the Östergarnsholm site is used. The site Östergarnsholm (57^{O} 25,78' N 18^{O} 54.25' E; Figure 6.1) is a very low and flat island with no trees. A 30-m high tower is placed at the southernmost tip of the island with an undisturbed over-water fetch in sector from 50^{O} to 220^{O}. The tower is equipped with temperature and wind sensors at the heights of 6.7, 11.6, 14.1, 20.0 and 28.6 m. The system used is described by Bergström and Lundin (1993). In addition, turbulence is measured at 8.0 16.0 24.0 m with Solent 1012 R2 ultrasonic anemometer-thermometer. Humidity variations are measured with a fast response LI-COR 6262 (LI-COR 1991) at 9 m. The tower at Östergarnsholm is running continuously and a period from 14 February to 6 March, 1998, has been selected.

6.3 Data sets and characterization

The studied period was characterized by high variability in wind, temperature and ice distribution at the Umeå site. The synoptic situation varied rapidly during the period due to passages of intense lows. As a result the observed temperature varied between -22 ^{O}C and +10 ^{O}C. This affected both the surface conditions as well as the ice distribution and thickness. Several melting periods in combination with a high sea level (0.5 m above normal) gave flooding on the ice near the towers at Holmsund and the research vessel *R/V Aranda*. As a result, the surface changed between water and slush, fresh smooth ice, snow covered ice, etc. during the observation period and thus giving highly variable conditions.

Figure 6.2 shows that there were two rapid changes from -20^{O}C to above 0^{O}C at Holmsund and at the ice mast. The variation is less pronounced at Östergarnsholm due to the open sea surrounding. At the end of the experiment the temperature was generally colder. There are two peaks in the temperature distribution at Holmsund and at the ice mast, Figure 6.3. One concentrates with near the freezing point and one at ~-7 ^{O}C, the peaks are more pronounced for the ice mast.

In Figure 6.4 we can see the wind speed variation. We have one occasion, 25 February, with winds over 20 m/s at Holmsund and the ice mast. It is closely connected to the rapid increase in temperature (Figure 6.2). During the storm of 23-24 February, 1998, the winds were of the order of 25 m/s recorded at the ice mast. These high winds were not captured at Holmsund, since the tower was some shielded in that wind direction. Holmsund has got the highest amount of light winds due to influence of the local terrain, cf. Figure 6.5, though there are some cases with winds up to 20 m/s. The other two sites have their highest frequency at 7 m/s in the wind distribution (Figure 6.5). The mean wind for the whole period is highest at the ice mast site, 8 m/s, although it is measured at a height of 3 m and not at 10 m as for the other ones.

Figure 6.6 shows the high variability in the wind direction during the experiment, and in Figure 6.7 the distribution of the wind direction is shown. In Figure 6.7, the open sea/ice fetch sectors are marked with bars. It is important to have an open homogeneous fetch for studies of momentum and heat flux over the sea/ice. The wind distribution was not ideal for sea or ice fetch studies. However there are open water or ice fetch for about 30 % of the time at Holmsund and 40 % at Östergarnsholm.

Momentum and heat flux from Holmsund and Östergarnsholm are presented in Figure 6.8. The heat flux is generally low and we can see that there are larger heat fluxes from the surface at Östergarnsholm, as expected. The melting periods, however, should give more positive heat flux than if we have had a homogenous snow/ice surface during the whole period. The stability distribution, is shown in Figure 6.9 in terms of z/L, where L is the so-called Obukhov stability length and z is the measurement height.

At Holmsund, the stratification was stable during 70 % of the time, and as was discussed above, it is remarkable to get unstable stratification in the middle of winter over snow covered ground. It is interesting to note that also during wind from the open water the stratification in the marine boundary layer can be stable.

The measurements have resulted in a proper data set containing relatively continuous measurements of wind, temperature, turbulent fluxes and radiation in the surface layer. A summary of the data gained at the different sites is given in Table 6.2.

6.4 Field personnel and acknowledgments

The scientists participating in the Umeå site measurements during the BASIS-98 experiment were:

Ulf Andræ, Hans Bergström, Leif Hemström, Cecilia Johansson, Birgitta Källstrand, Mikael Magnusson, Anna Rutgersson, Anna Sjöblom and Ann-Sofi Smedman.

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Table 6.1. Instrumentation, measured quantities, levels, resolution and accuracy at the different UUPP/MIUU sites.

Holmsund			
Type of instrument	Measured quantities	Height (m)	Resolution/ Accuracy
Casella cup anemometer	Wind speed	1	4 m / 1%
Casella cup anemometer	Wind speed	3.5	4 m / 1%
Casella cup anemometer	Wind speed	11.5	4 m / 1%
MIUU Pt500	Temperature	1	30 s / 0.03°C
MIUU Pt500	Temperature	3.5	30 s / 0.03°C
MIUU Pt500	Temperature	11.5	30 s / 0.03°C
Solent ultra sonic anemometer	Turbulence, (u', v', w' Tv')	10	0.1 s / 1 %
MIUU Hot-wire	Turbulence, (u', v', w' T')	1	0.1 s / 5 %
Eppley long wave radiometer	Incoming long wave radiation	1	- / 2%
Eppley long wave radiometer	Outgoing long wave radiation	1	- / 2%
Eppley short wave radiometer	Incoming short wave radiation	1	- / 2%
Eppley short wave radiometer	Outgoing short wave radiation	1	- / 2%
Ice Tower			
Type of instrument	Measured quantities	Height (m)	Resolution/ Accuracy
MIUU wind instrument	Wind speed	3.0	3.5 m / 1 %
MIUU Pt500	Temperature	1.0	30 s / 0.03°C
MIUU Pt500	Temperature	3.0	30 s / 0.03°C
Östergarnsholm			
Type of instrument	Measured quantities	Height (m)	Resolution/ Accuracy
MIUU wind instrument	Wind speed and direction	6.7	3.5 m / 1 %
MIUU wind instrument	Wind speed and direction	11.6	3.5 m / 1 %
MIUU wind instrument	Wind speed and direction	14.1	3.5 m / 1 %
MIUU wind instrument	Wind speed and direction	20.0	3.5 m / 1 %
MIUU wind instrument	Wind speed and direction	28.6	3.5 m / 1 %
MIUU Pt500	Temperature	6.7	30 s / 0.03°C
MIUU Pt500	Temperature	11.6	30 s / 0.03°C
MIUU Pt500	Temperature	14.1	30 s / 0.03°C
MIUU Pt500	Temperature	20.0	30 s / 0.03°C
MIUU Pt500	Temperature	28.6	30 s / 0.03°c
LI-COR 6262	Humidity fluctuations	9	0.1 s / 10 %
Solent ultra sonic anemometer	Turbulence, (u', v', w', Tv')	8.0	0.1 s / 1 %
Solent ultra sonic anemometer	Turbulence, (u', v', w', Tv')	16.0	0.1 s / 1 %
Solent ultra sonic anemometer	Turbulence, (u', v', w', Tv')	24.0	0.1 s / 1 %

Table 6.2. Measured quantities, time period and comments for the different sites that UUPP/MIUU was responsible for.

Holmsund		
Measured quantities	Period	Comments
Temperature at three levels	11/2-6/3 1998	
Wind speed at three levels	11/2-26/2 26/2-6/3 two levels	The upper anemometer was damaged during the storm 25/2
Sonic ultra anemometer	11/2-6/3	
Radiation	17/2-26/2, 3/3-6/3	The gap is due to influence by atmospheric electricity
Radiosonde sounding	17/2-6/3	
Pibal tracking	17/2-28/2, 3/3-6/3	The gap is due to technical problem
MIUU Hot-wire	Approximately 60 hours	Measurements have only been made when fetch or weather have been suitable
Ice tower		
Measured quantities	Period	Comments
Temperature at two levels	20/2-5/3	
Wind speed and direction at one level (3 m)	20/2-5/3	
Östergarnsholm		
Measured quantities	Period	Comments
Temperature at six levels	14/2 -17/2, 22/2-6/3	Gap due to technical problems
Wind speed and direction at six levels	14/2 -17/2, 22/2-6/3	Gap due to technical problems
Humidity	14/2 -17/2, 22/2-6/3	Gap due to technical problems
Sonic ultra anemometer at three levels	14/2-6/3	

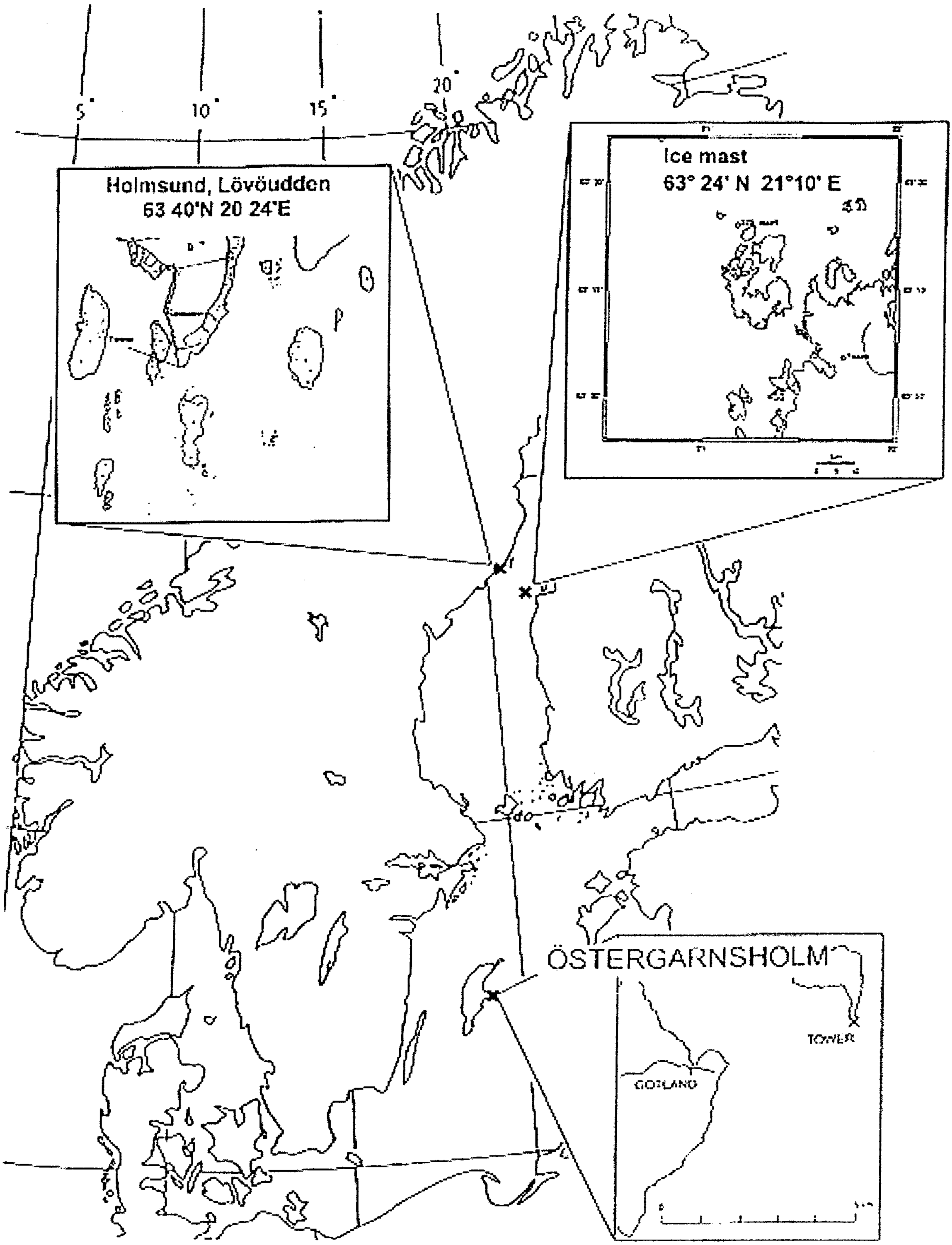

Figure 6.1. Map over the locations of the UUPP/MIUU sites and more detailed ones over the three different sites respectively.

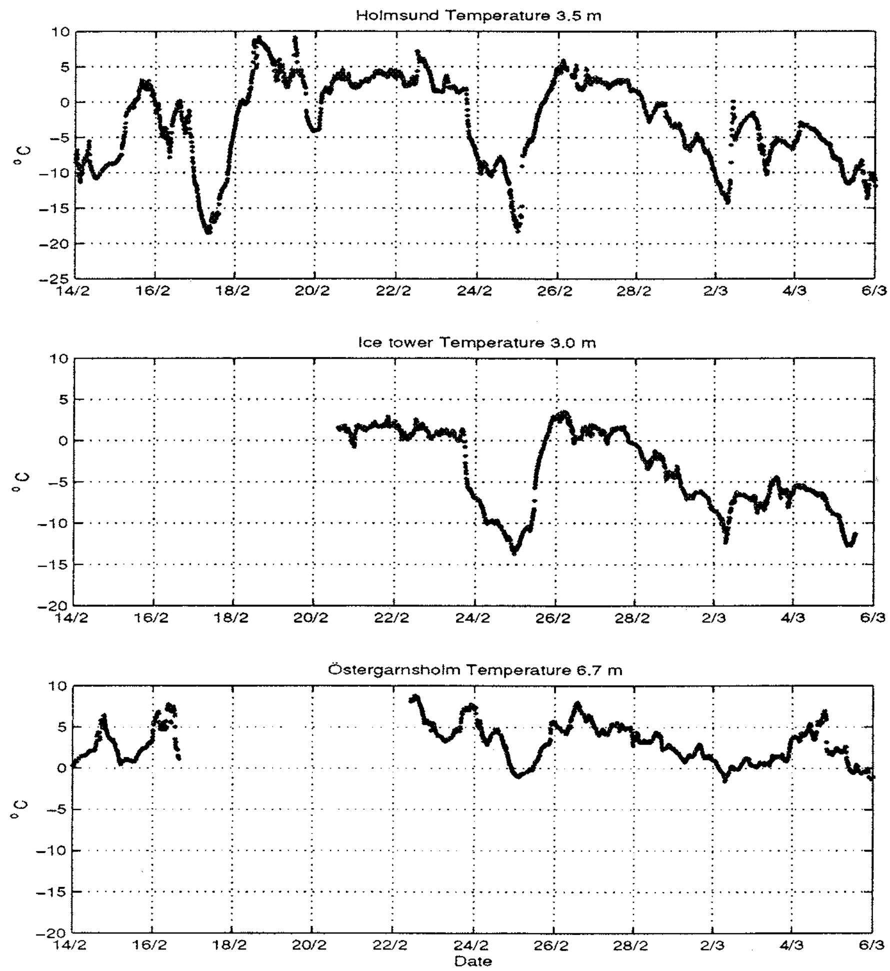

Figure 6.2. Temperature at the different measurement sites during 14 February to 6 March, 1998.

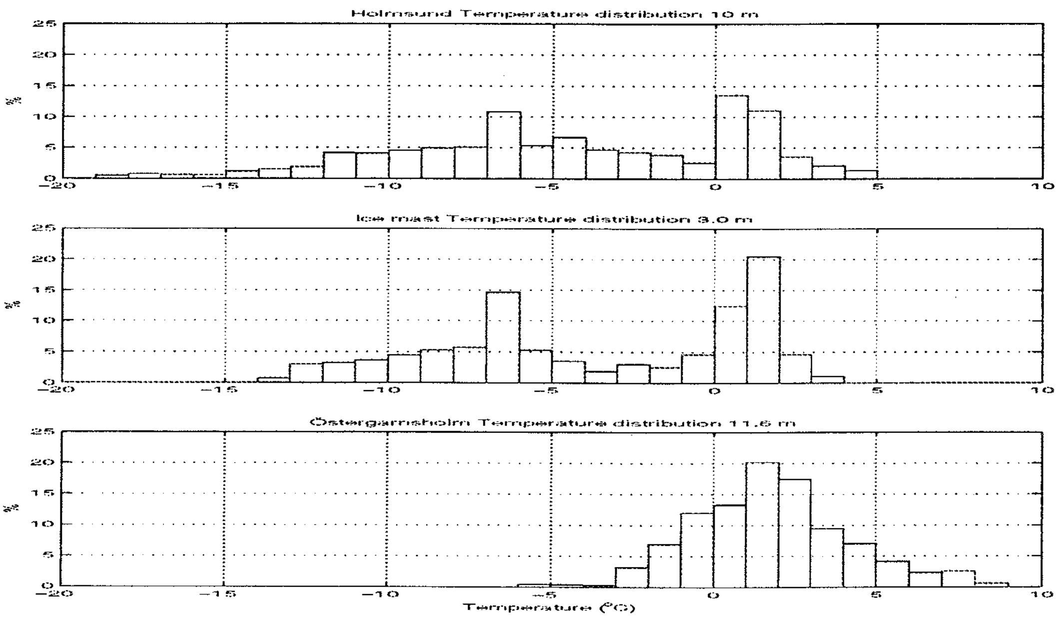

Figure 6.3. Temperature distribution at the different sites during 22 February to 5 March, 1998.

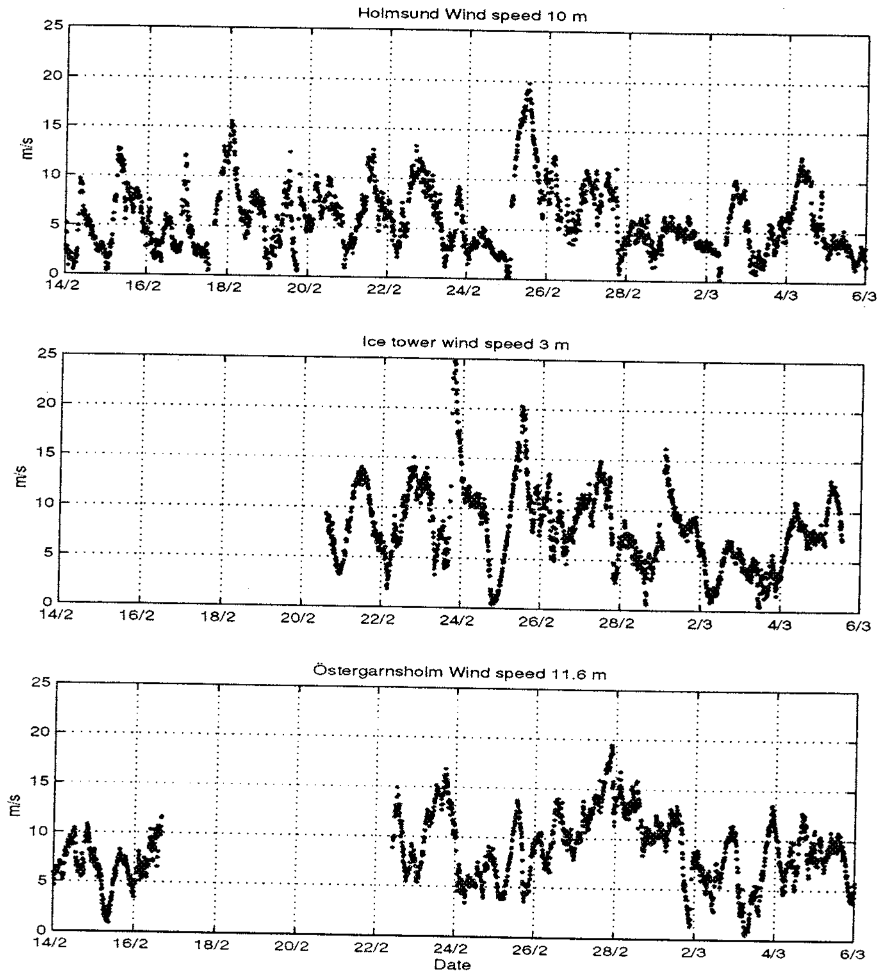

Figure 6.4. Wind speed at the different sites during 14 February to 6 March, 1998.

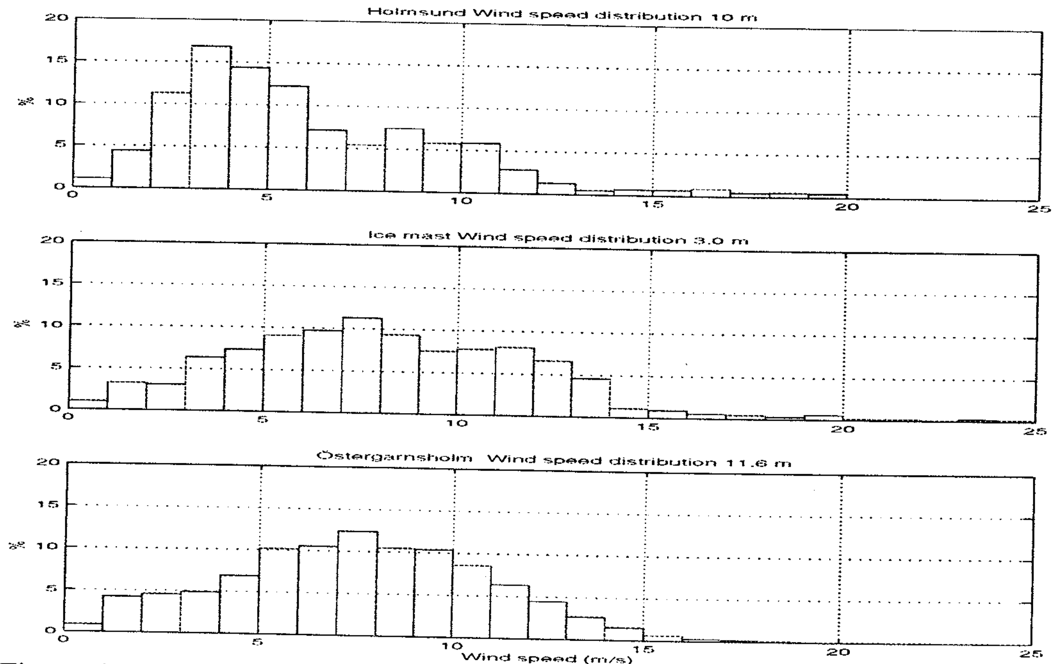

Figure 6.5. Distribution of the wind speed at the different sites during 22 February to 5 March, 1998.

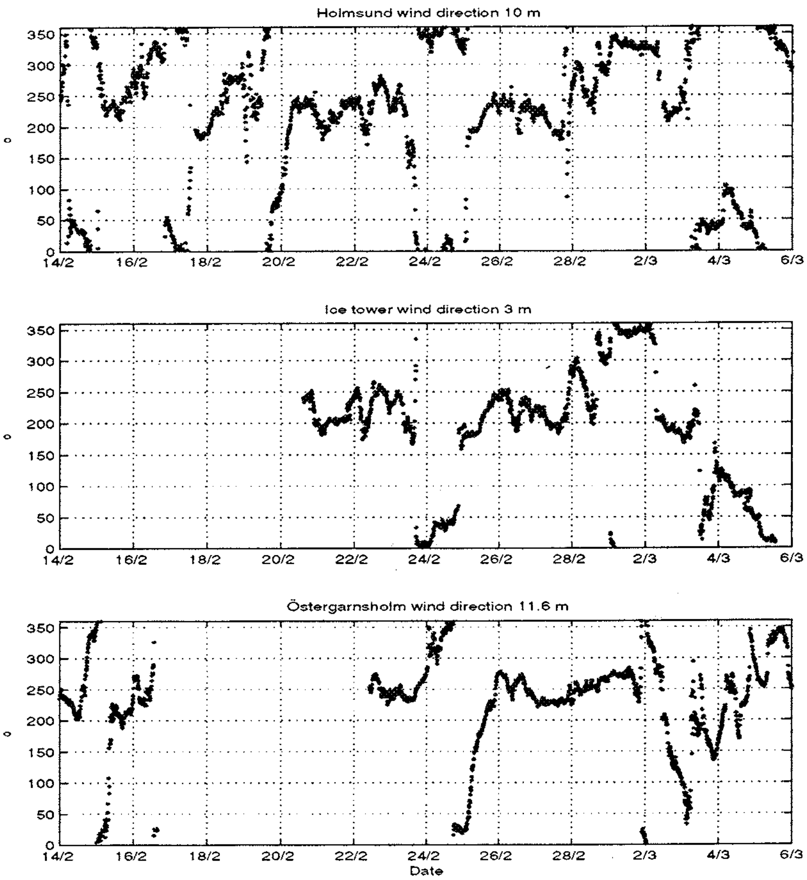

Figure 6.6. Wind direction at the different sites during 14 February to 6 March, 1998.

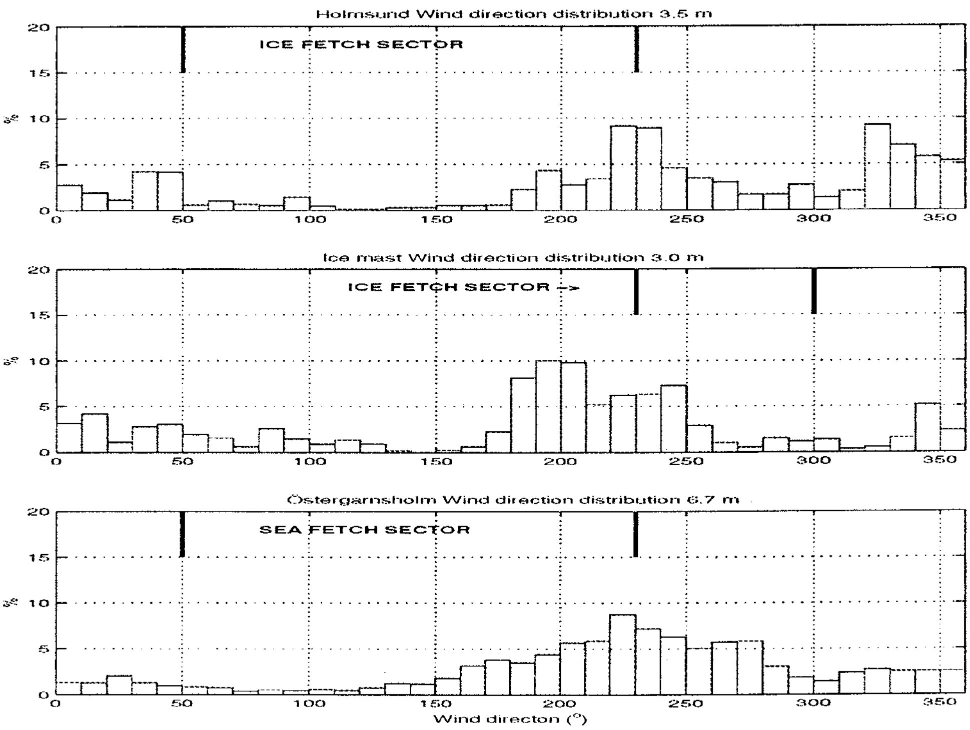

Figure 6.7. Distribution of wind direction at the different sites during 22 February to 5 March 1998.

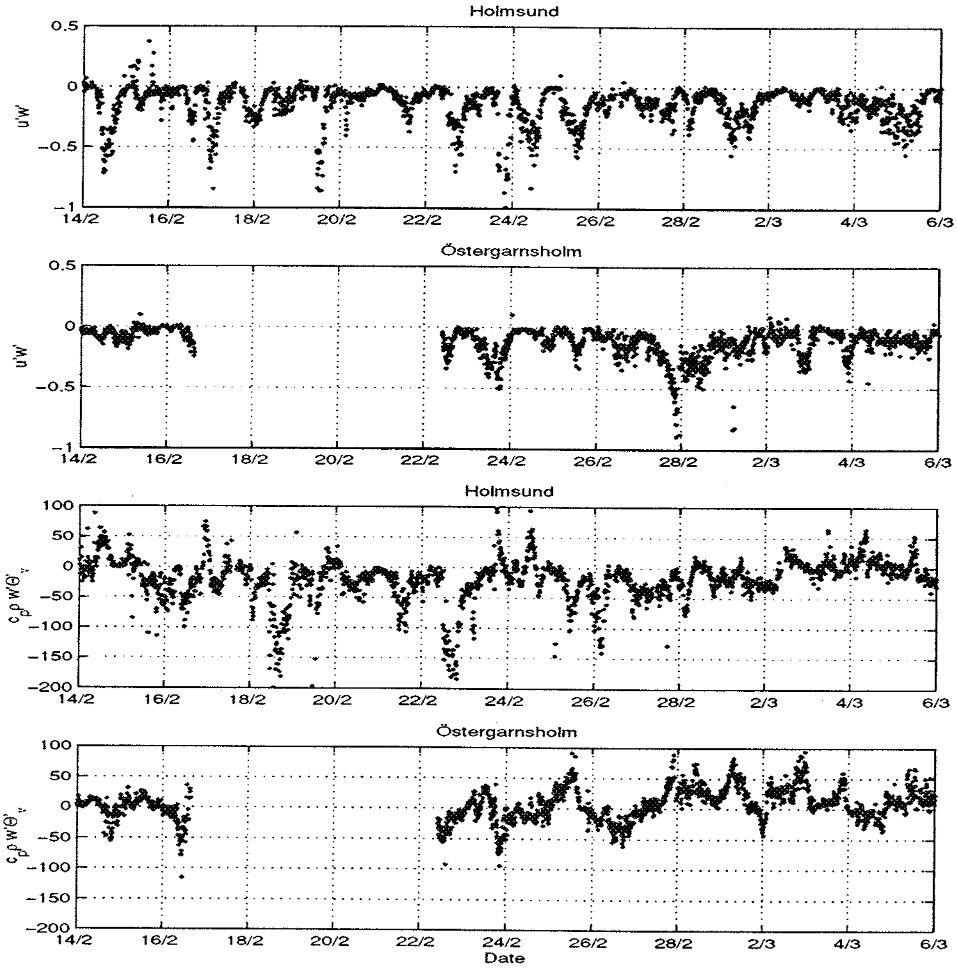

Figure 6.8. Momentum (u'w' in m^2/s^2) and heat flux ($c_p\rho$ w'θ ' in W/m^2) in the period 12 February to 6 March at Holmsund (at 10 m) and at Östergarnsholm (at 16 m).

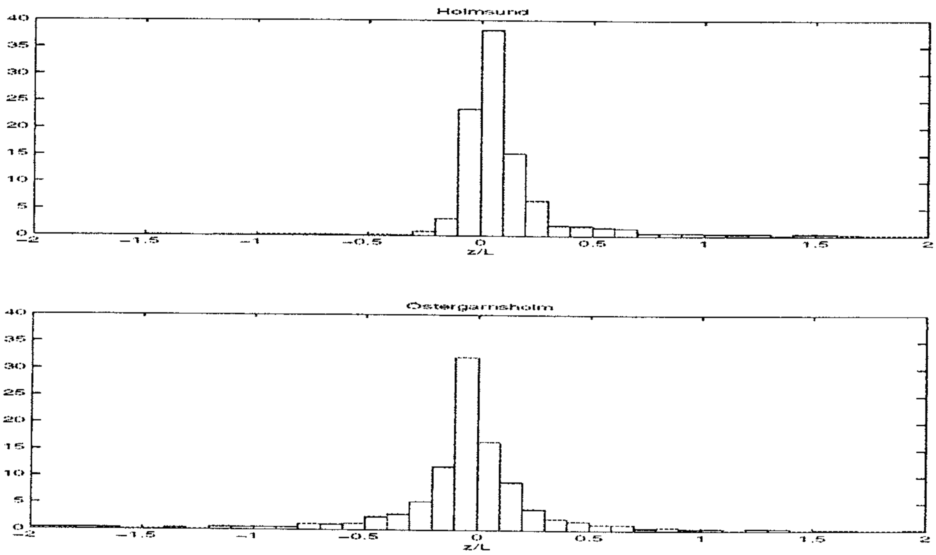

Figure 6.9. Distribution of the stability parameter z/L in the period 22 February to 6 March at Holmsund (at 10 m) and Östergarnsholm (at 16 m).

7. Ground, air and satellite data obtained during BASIS field experiment by the Swedish Meteorological and Hydrological Institute

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7.1. Objectives

The BASIS field campaign took place in northern Baltic Sea, during 18 February to 5 March, 1998. General weather and ice conditions during the campaign can be described as characteristic for a mild winter.

The overall objective of BASIS is to create and analyse an experimental data set for studies of water and energy exchange between the ocean and the atmospheric boundary layer during the cold season. BASIS aims to optimise and verify coupled atmosphere-ice-ocean models. The role of SMHI during the field phase was to collect data within following areas:

- *Physical properties of snow and ice* (Chapter 7.2.1)

Time series of snow and ice variables were sampled in level and deformed ice in the intensive study area close to *R/V Aranda.*

- *Vertical distribution of water temperature and salinity* (Chapter 7.2.2)

Pre-experiment CTD-sounding were carried out by R/V Argos during December, 1997. Time series of the vertical water temperature distribution have been measured with a thermistor chain in the Bay of Bothnia since January, 1998. The local vertical water temperature distribution was measured in the intensive study area during the experiment period. (Chapter 7.2.1)

- *Ice motion* (Chapter 7.2.3)

In order to calculate ice drift, buoys were deployed in the drifting ice to transmit their geographic positions.

- *Surface properties for SAR-data validation* (Chapter 7.2.4)

Ice reconnaissance were carried out for SAR validation purposes. Snow mobile were used for local scale observations, while the regional scale was covered by helicopter. Visual observations, such as video-filming, and surface roughness measurements were done to describe the areas covered.

7.2. Measurements, methods and data sets

The measured data collected during the BASIS field campaign are shown in Table 7.1. The table describes in what extent the parameters where measured, the horizontal, vertical and temporal resolution and accuracy of the parameters.

Besides the measured data, weather parameters from The Mesoscale Analysis System (MESAN) are available. MESAN is a gridded analysis system. It has been running operationally since April, 1997, providing science and consumers of weather information with spatially continuous fields of nine analysed meteorological parameters every hour. Data input to MESAN consists of surface observations from different observation systems, numerical weather prediction model fields, weather radar and satellite images and climate information. Each data source is quality controlled.

Table 7.1. Data summary.

	Measured properties	**Extension**	**Horiz. resol.**	**Vert. resol.**	**Temp. resol.**	**Accuracy (+/-)**
Ice Properties	Thickness	100 m	2 m	-	2 days	5 mm
	Temperature	100 m	50 m	0.05 m	2 days	0.1 deg C
Snow Properties	Thickness	100 m	2 m	-	2 days	5 mm
	Temperature	100 m	10 m	0.05 m	2 days	0.1 deg C
	Density	100 m	20 m	0.1 m	2 days	0.04 g/cm3
	Density (Snow fork)	100 m	20 m	0.1 m	2 days	0.08 g/cm3
	Wetness	100 m	20 m	0.1 m	2 days	
	Grain size	100 m	20 m	0.1 m	2 days	0.5 mm
Thermistor Stick	Temperature	2 m	-	0.1 m	0.5 h	0.1 deg C
Thermistor Chain	Temperature	10 m	-	1 m	0.5 h	0.1 deg C
CTD-sounding	Salinity	Gulf of Bothnia	-	< 0.1 m	8 profiles	0.01 psu
	Temperature	Gulf of Bothnia	-	< 0.1 m	8 profiles	0.02 deg C
Buoy Data	Argos-position	Northern Quark	-	-	1.5 h	150 - 350 m
	GPS-position	Northern Quark	-	-	10 min	100 m
SAR Images	Radarsat gray scale	300x300 km	50 m	-	1.5 day	1.0 dB
	ERS-2 gray scale	100x100 km	25 m	-	2 scenes	2.5 dB

Air temperature, relative humidity, mean wind, wind gust and totally cloud cover represented in an 11×11 km^2 grid, corresponding to the surroundings of *R/V Aranda*, are available. Air temperature and relative humidity represent the 2 m level while mean wind and wind gust are calculated at 10 m. Totally cloud cover are given in per cent. The parameters are available every third hour from 1 January to 31 March, 1998. In addition, precipitation and fresh snow cover accumulated during 3 hours are calculated between the same period in the grid of *R/V Aranda* and for the entire Bothnian Sea and Bothnian Bay. Bothnian Sea covers 477 11×11 km^2 grids and Bothnian Bay covers 254 11×11 km^2 grids.

7.2.1. Physical properties of snow and ice

Snow and ice measurements in fast ice - snow and ice line

Snow and ice properties were measured along 100 m lines within an area of 110 × 110 m^2 on a distance of about 500 m from *R/V Aranda*. The lines ran towards 325° which was perpendicular to the prevailing snow dunes. When the snow and ice line site was mounted, the snow dunes had a direction of approximately 045° but in the end of the field work period the direction was changed due to wind and snow fall.

A hundred metres long rope fasten in two sticks marked the snow/ice line. Before each new measuring line the rope was moved 5 metres to get undisturbed snow and ice. The measuring frequency was one line approximately every second day which gave 9 measured lines during the field campaign. The ice and snow lines were mainly measured on days of satellite passages.

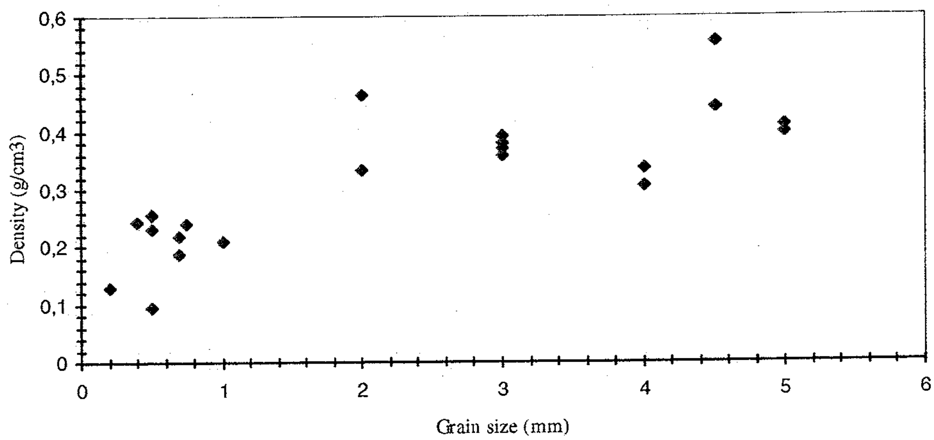

Figure 7.1. Grain size versus snow density measured 16 February – 6 March, 1998

Snow line

The snow thickness was measured every second metre with a folded rod and the different layers in the snow cover were described by type and thickness.

Temperature profiles were measured every 10 m with a PT100-probe. The vertical resolution of the temperature profiles is 50 mm or less, depending on the snow thickness. Due to the thaw in the beginning of the period, which decreased the snow cover thickness, the profiles often consist of only two levels - the snow and ice surfaces.

At every 20 m along the snow line, a more complete measurement program was done. The density, grain size and the liquid water content of the snow were measured. In addition, if slush-snow was present, the salinity of the bottom layer was measured.

The density of snow was measured by the so called volume and weight method, where a cylinder with a diameter of 110 mm and a height of 50 mm was gently pushed into the snow and then weighted. The density varied between 0.1 – 0.55 g/cm^3.

The grain size of the ice crystals was estimated with help from a plastic covered mm-paper and a magnifying glass. The sizes varied between less than 1 mm for cold fresh snow up to 5 mm grains which corresponds to consolidated grains. The grain size versus snow density can be seen in Figure 7.1. For small grains and densities the relation tends to be linear, while for grains larger than 2 mm the density does not seem to increase. The salinity of slush-snow was measured with a Beckman Solu Bridge, to get an estimation of whether the slush consisted of sea or melt water.

A snow fork was used to measure the wetness and density of the snow. The snow fork is a radio-wave sensor (Sihvola, A and Tiuri, M, 1986). The snow wetness varied mainly between 0 – 6 volume %, and in some single measurements up to 10 volume %. The density measured with the snow fork varied from very small densities (near zero) up to almost 600 kg/m^3.

Due to the hard and icy or very wet snow, it was not possible to measure all parameters at all occasions.

Ice line

Holes were drilled through the ice every second metre along the rope, so the ice thickness could be measured with a folded rod. The ice thickness varied between 20 and 55 cm during the measurement period.

Temperature- and salinity-profiles were measured from the ice cores at 20 and 80 metres along the ice line. Very small holes, to avoid air getting into the hole, were drilled every 50 mm in the ice core and a temperature probe of type T123-2 was used to measure the temperature of the ice. The ice core was then classified into columnar and granular ice.

About 100 mm thick pieces of the ice core were melted and the salinity was measured with the Beckman Solu Bridge.

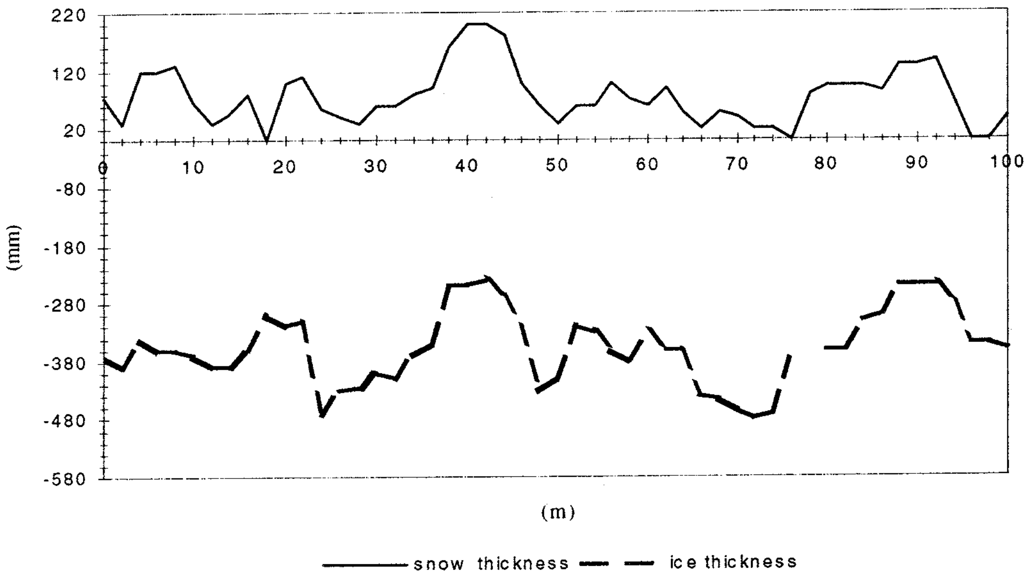

Figure 7.2. Snow and ice thickness distributions along a snow/ice line on 19 February. The snow and ice thicknesses are well correlated.

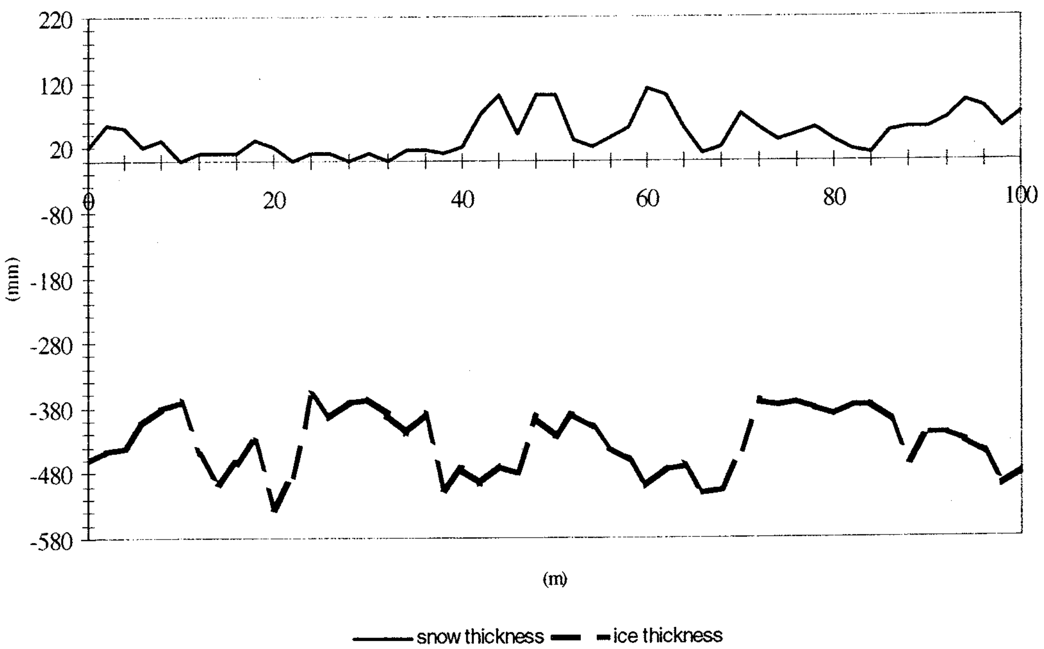

Figure 7.3: Snow and ice thickness distributions along a snow/ice line on 1 March. No correlation between snow and ice thicknesses.

Table 7.2. Statistics of snow and ice distributions along the nine snow/ice lines measured during the field campaign.

Date	*Snow thickness*				*Ice thickness*		
	mean (mm)	std (mm)	mean/std		mean (mm)	std (mm)	mean/std
980219	75	49	1,5		356	63	5,7
980221	69	45	1,5		386	61	6,3
980223	0	0	0	slush	411	60	6,9
980225	0	0	0	slush	431	49	8,8
980227	24	36	0,6		426	47	9,1
980301	39	31	1,3		433	48	9,0
980303	41	24	1,7		449	50	9,0
980304	33	23	1,4		437	44	9,9
980306	42	27	1,5		448	42	10,7

The variations of the ice and snow thicknesses along the snow/ice lines are shown in Table 7.2. The snow thickness has a high temporal variation due to a mild weather period in the middle of the field campaign. Note that the relation between the mean value and the standard deviation of the snow thickness was relatively constant before the melting period and after it, when the new snow cover was settled. On the other hand, the ice thickness increased through almost the entire period while the standard deviation of the ice thickness decreased.

Figures 7.2 and 7.3 show two examples of the snow and ice thickness distributions along the snow/ice lines measured before and after the mild weather period, 19 February and 1 March, respectively. In Figure 7.2 the snow and ice thicknesses show a high negative correlation, -0.69, which could be due to the isolating capacity of the snow preventing the heat conduction through the snow cover. During the snowless period thinner ice grows faster than thicker ice, leading to a decrease of the variation of the ice thickness. There is no correlation between the thickness of the ice and the new snow layer after the mild period in Figure 7.2.

Snow measurements in deformed ice

In order to get data from thicker snow layers, measurements were done in a ridged area nearby *R/V Aranda* at Enstensgrynnan. The ridge height in the area was about 1 metre. Same parameters as along the snow line were measured in two or three pits at four different occasions.

Because of the sheltered locations usually found in a ridge, the snow thickness is larger than on the level ice. Therefor the profiles had a different character compared with the snow lines.

Thermal profiling

A thermistor stick and a thermistor chain were deployed at the northernmost border of the snow/ice line site, to measure the temperature profile through air, snow, ice and water. The thermistor stick was deployed on 17 February, and the thermistor chain was deployed on 19 February. Both were recovered on 6 March.

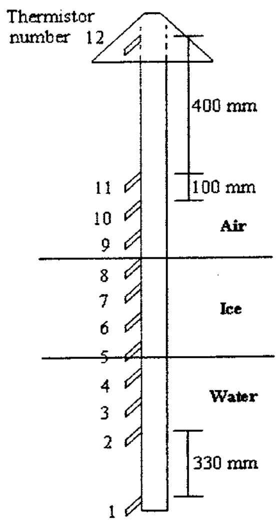

Figure 7.4. Thermistor stick.

Thermistor stick

The thermistor stick consists of a 2.0 m long plastic tube with 12 thermistors distributed according to Figure 7.4. The thermistors are of the type Campell 107 Temperature probe and have an accuracy of ±0,1°C. They are connected to a Campbell CR10 logger programmed to store temperature every hour. The logger was installed in a waterproof plastic box, type IP68.

On the top of the thermistor stick is a white-painted protection against direct sun radiation. Thus, the air temperature at the top of the thermistor is less disturbed by the sun radiation. Unfortunately there is no radiation protection downwards, which would be a great improvement since the snow reflects a greater part of the sun radiation upwards.

Photographs of the temperature stick were taken to observe changes in the snow layer around the stick.

The temperature evolution in the ice is presented in Figure 7.5. There are large variations due to the weather change during the period. The temperature near the ice surface is very sensitive to the changes in air temperature, while the lower thermistors show more inert temperature variations.

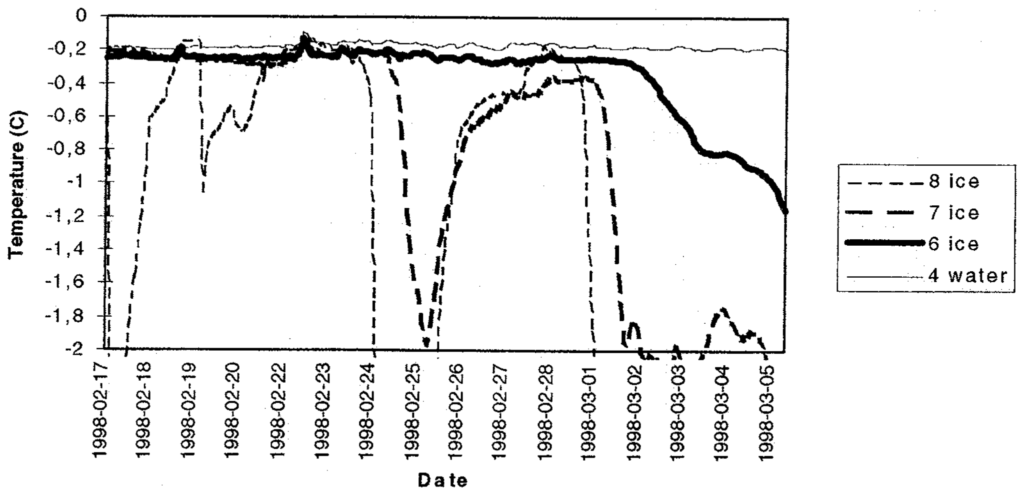

Figure 7.5: Temperature measured by thermistor 4, 6, 7 and 8 on the thermistor stick, during period 17 February to 6 March.

Thermistor chain

The thermistor chain is a 20 metres long chain with a thermistor, of type Fenwal 2K ISO curve thermistor, at every second metre. They are connected to an Aanderaa TR7 temperature logger with solid state memory, which logs the mean temperature every 30 minutes.

Since the water depth was 12 metres, the chain was folded and the temperature was measured with one metre interval from almost the entire water column.

7.2.2. Vertical distribution of water temperature and salinity

Pre-experiment CTD-soundings in the Gulf of Bothnia were made during 5-10 December, 1997. The soundings were done from the Swedish R/V Argos, using a Neil Brown Mark 5 CTD-instrument. In total, measurements were carried out at 22 sites in the Gulf of Bothnia, and eight of them were located in the northernmost part, the Bay of Bothnia. The temperature and salinity ranges from south to north were 4 to 2.5°C and 5.5 to 3.3 PSU, respectively. The water masses were well mixed between the surface and the depth of 30 metres, under which weak halocline and thermocline were observed.

The time evolution of the heat content in the Bay of Bothnia was also measured using a thermistor chain deployed at 64° 42.4'N, 22° 04'E. A same kind of a chain was deployed at the snow/ice line site, see Chapter 7.2.1. The chain measured at every second metre from 130 metres (the bottom) up to the mixed layer at 60 metres. The mean temperature was logged hourly. The deployment took place on 23 January, 1998.

7.2.3. Ice motion

To verify ice velocity fields retrieved from SAR images, seven buoys were deployed on ice floes north-west of Vallgrund, see Figure 7.6.

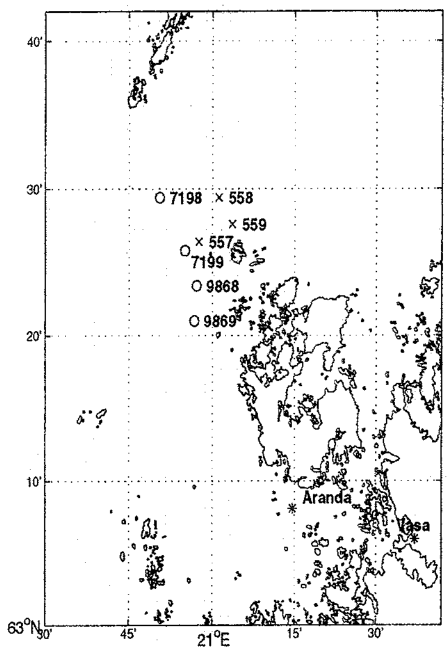

Figure 7.6. Location of the deployment sites of the drifters, Argos (o) and GPS (x). The Argos buoys were deployed on 18 February and the GPS buoys on 22 February.

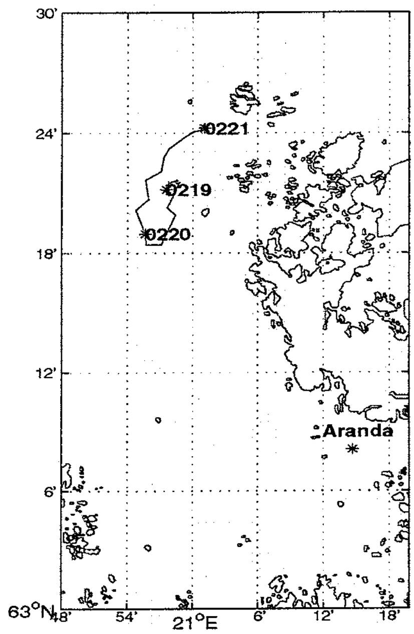

Figure 7.7. Argos buoy 9869. The dates refer to the location of drifter 9869 at approximately 0100.

Argos-buoys

Four Argos-buoys were deployed north-west of Vallgrund on 18 February. Buoy, number 9869, deployed closest to the fast ice edge, had a thermistor stick attached. The same kind of stick was deployed at the snow/ice line site, see Chapter 2.3.1. Beside the thermistor stick, 9869 also carried a GPS (Global Position System) which gave a more accurate position than the Argos system. The Argos system has an accuracy of 150-350 m while the GPS system has an accuracy of 100 m. Data from the thermistor stick and from the GPS were transferred to a floppy disk on 20 February. The day after, on 21 February, 9869 stopped sending its position probably because of damage on the antenna during a ridging event. Figure 7.7 shows the 3-day drift of buoy 9869. The buoy was later found at the coast without the thermistor stick.

The aim was to deploy the Argos buoys in a line perpendicular to the fast ice edge. That resulted in that the most westerly buoy, 7198, was dropped in open pack ice. It drifted across the Bay of Bothnia and was recovered by a Swedish icebreaker on 2 March, se Figure 7.8.

Buoy number 7199, in Figure 7.9, moved northwards and was recovered on 5 March near Kokkola.

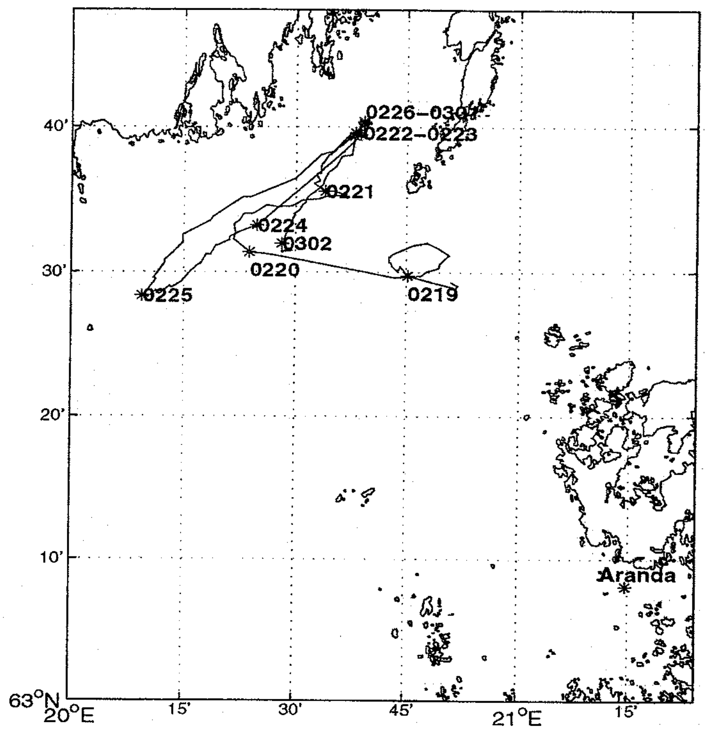

Figure 7.8. Argos buoy 7198. The dates refer to the location of drifter 7199 at approximately 0100.

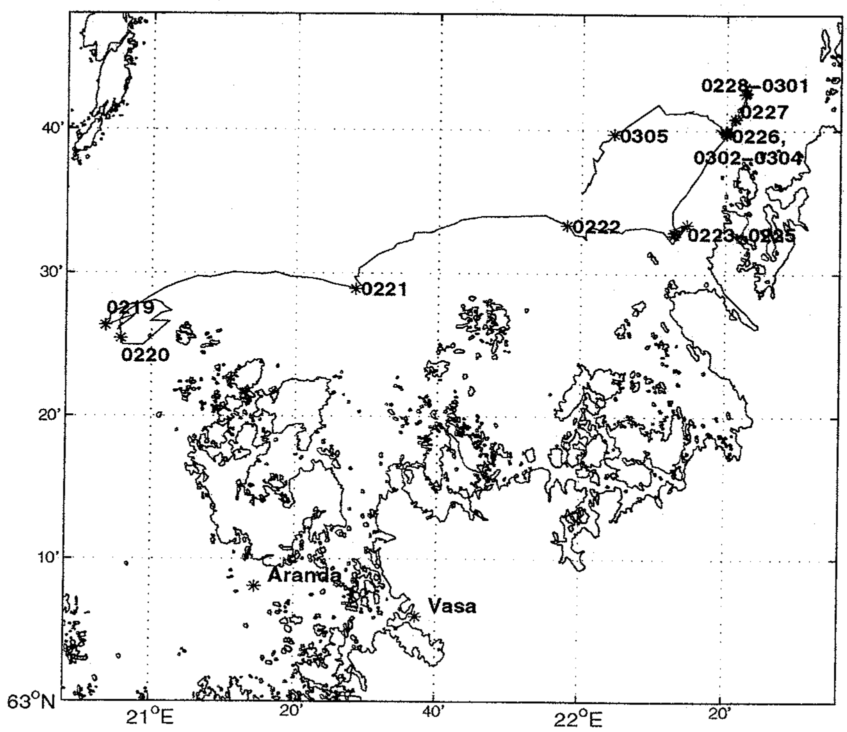

Figure 7.9. Argos buoys 7199. The dates refer to the location of drifter 7199 at approximately 0100.

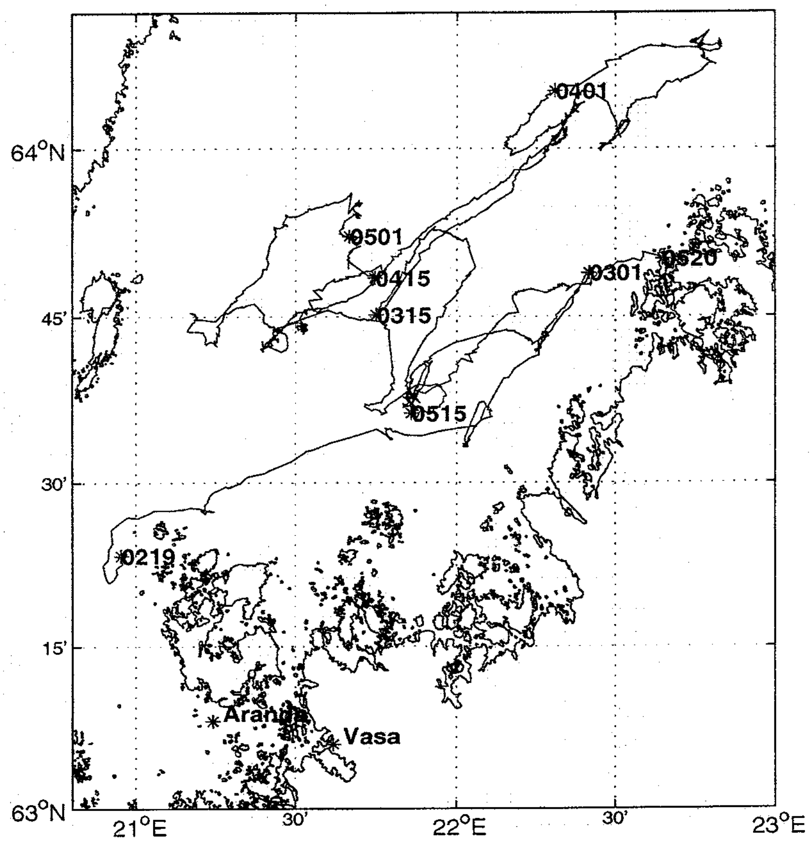

Figure 7.10. Argos buoy 9868. The dates refer to the location of drifter 9868 at approximately 0100.

Buoy number 9868 was sending its position for 3 months. On May 20 the drifter was stacked in the ice and recovered soon after. Figure 7.10 shows the drift of buoy number 9868 from 18 February to 20 May. The position is marked every 1st and 15th of the month including start and stop position.

The Argos system locates 400 MHz transmissions, with a Doppler technique, from buoys by using polar orbiting satellites (Håkansson and Rahm 1991). The position is received on the average 10 times every day.

GPS buoys

Three GPS drifters, developed at the Department of Geophysics, University of Helsinki (e.g. Haapala and Stipa, 1997), were used to collect data on basin-scale ice drift and to verify ice velocity fields retrieved from SAR images. In contrast to Argos buoys, the localisation of the drifters is made by GPS and data transmission by a radio modem network. This technique allows higher accuracy and higher data transmission rates in comparison to Argos drifters.

The data stream from the GPS receiver is transmitted every ten minutes via a network to a receiver located at the Department of Geophysics, University of Helsinki. After some transmission problems the drifters were deployed on ice floes in the drift ice zone, north-west of Storskär on 22 February. The deployment sites for the drifters are shown in Figure 7.4.

The weather was rather windy during the two first weeks of the BASIS field experiment. This and the relatively loosely compacted ice fields resulted in rather high ice drift during the measurement period. Figure 7.11 shows the drifter 557 track up to 17 March. Two of the drifters, 557 and 559 measured ice drift during the whole BASIS campaign, whereas one of the drifters, 558, probably was ice covered during the high northerly winds on 23 February, resulting in a broken antenna. Some gaps exist in the drifter data. Those can be explained by bad weather, tilting of the antenna or too long distance to a receiving station.

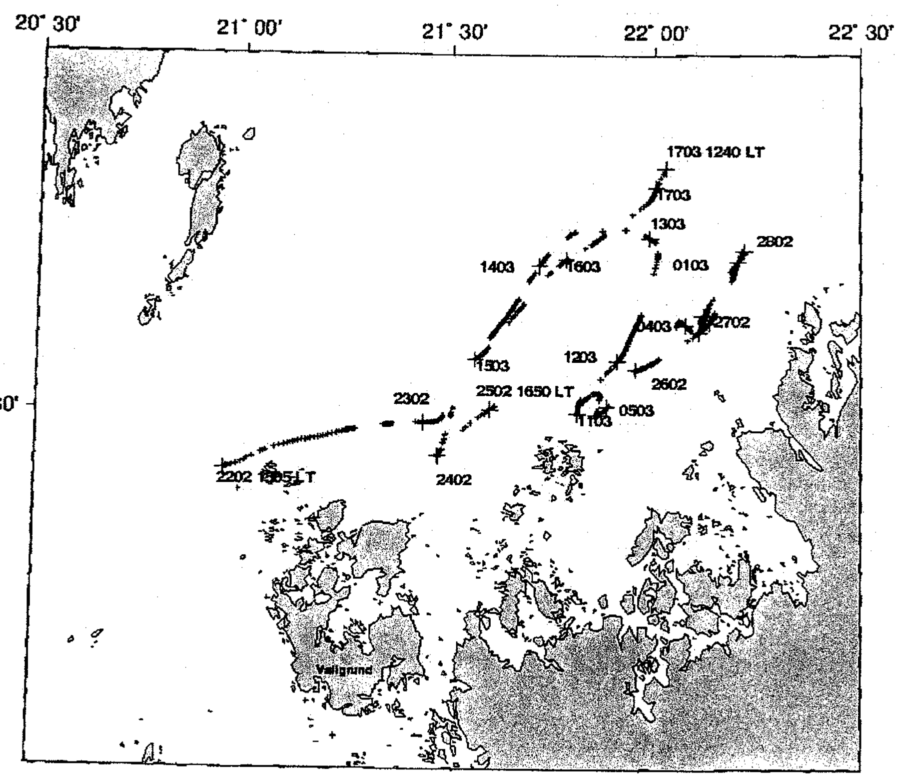

Figure 7.11. GPS buoy 557. The dates refer to the location of drifter 557 at approximately 0700 UTC, marked with big crosses (+). Drifter 557 was located almost at the same spot between 5 and 9 March. That is indicated by a cross at 0503.

Figure 7.12. Radarsat image 21 February.

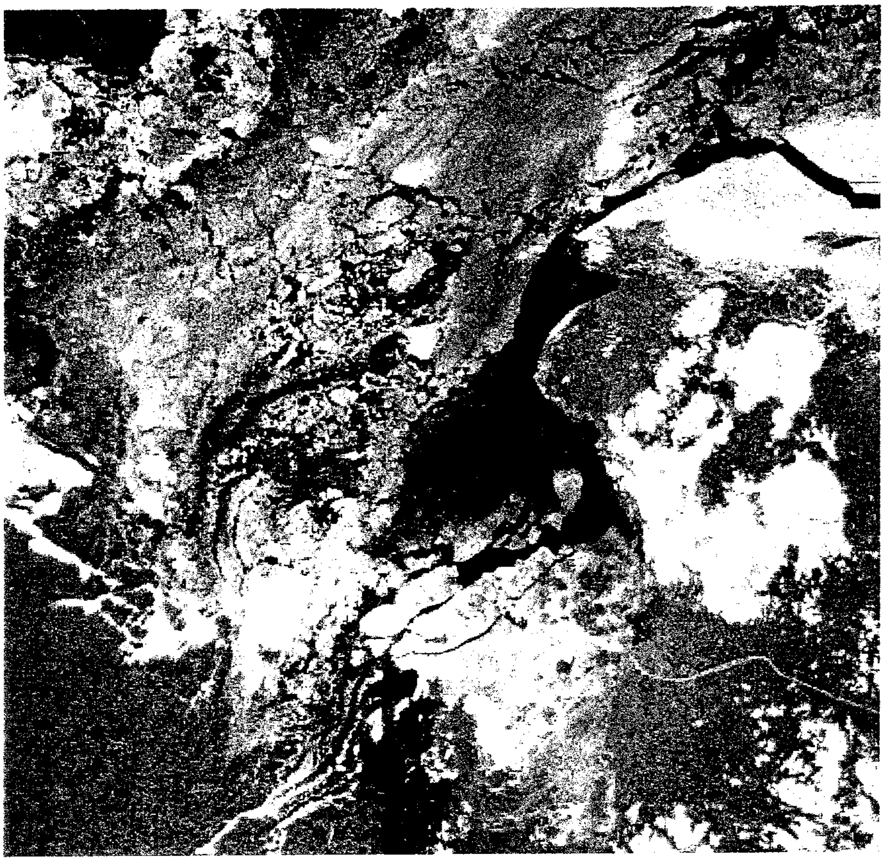

Figure 7.13. Radarsat image 25 February.

7.2.4. Surface properties for SAR-data validation

27 SAR images from the Canadian satellite Radarsat were received during 16 passages, see Table 7.3. The Radarsat SAR instrument operates with the frequency 5.3 GHz and HH polarisation. The images are of format ScanSAR Narrow with a resolution of 50 x 50 m^2. Each image covers an area of 300 x 300 km^2. The SAR scenes were received at SMHI Norrköping by FTP from Tromsö Satellite Station (TSS) during the field campaign. Full resolution images were available on CD-ROM in CEOS format in April.

Two ERS-2 SAR images of type PRI (Precision Resolution Image) were received on 1 and 4 March. Each scene covers 100 x 100 km^2. The resolution of the PRI images is 25 x 25 m^2.

Table 7.3. Obtained Radarsat images during field campaign. BB - Bay of Bothnia BS - Bothnian Sea. Ground truth measurements, see Chapter 7.2.4.

Date	*Time (UTC)*	*Size (km2)*	*Area*	*Ground truth*
980216	15:46	300*300	BB	Yes
980218	04:58	600*300	BB+BS	Yes
980219	15:59	600*300	BB+BS	Yes
980221	05:10	600*300	BB+BS	Yes
980222	16:11	300*300	BS	Yes
980223	15:42	300*300	BS	
980224	05:23	600*300	BB+BS	
980225	04:53	600*300	BB+BS	Yes
980226	15:54	300*300	BB	
980228	05:06	600*300	BB+BS	Yes
980301	16:07	600*300	BB+BS	Yes
980303	05:19	600*300	BB+BS	Yes
980304	04:49	600*300	BB+BS	Yes
980304	16:19	300*300	BB	Yes
980305	15:50	600*300	BB	Yes
980307	05:03	600*300	BB+BS	

Figures 7.12 and 7.13 show a subsection of two Radarsat images from 21 February and 25 February covering the area of Vallgrund. Vallgrund is the bright formation in the right part of the images. South of Vallgrund can the ship truck from Vaasa be seen. The resolution of the images is 50 m. The two images describe different weather situations. In the first image, on 21 February, the weather was mild and the snow cover on the ice was wet, while the air temperature was –10°C in the second image, see Figure 7.5. Due to the cold conditions, the contrast is better in the later image and different ice classes can be distinguished easier.

Ice mapping on local scale

To verify SAR images ice reconnaissance was carried out by snow mobile in the local area. The area was limited by ship tracks and the rest of the reconnaissance had to be done by helicopter. The main part of the fast ice west of the *R/V Aranda* and Korsö line, was described.

At some sites the height of deformed ice was measured every ten centimetres along a 20 metre long rope, fastened between two sticks about one metre above the ice surface. The roughness is characterised in terms of rms-height from these data series.

To estimate the roughness of relatively smooth ice, a ruler was photographed on the ice surface.

At one occasion, ice and snow lines were measured at three different sites, to characterise different surfaces.

Ground truth measurements were done at different undisturbed sites about 200 metres from *R/V Aranda*. Snow and ice conditions were measured in one or two pits in connection to the Radarsat passages during the field campaign. 12 out of 16 passages have ground truth data, see Table 7.3. The passages occurred at around 0500 UTC or 1600 UTC depending on ascending or descending orbits. The same parameters as at the snow/ice line were measured. For description of the measuring methods, see Chapter 7.2.1.

Helicopter born ice mapping

Ice reconnaissance on a larger scale was made by helicopter. Beside notes and descriptions of the ice conditions a JVC digital video camera was used. The camera time was logged to the helicopter GPS. The video tapes will be used for estimation of the ice concentration and ice surface roughness, in order to verify SAR images.

At two occasions, helicopter reconnaissance was done on a very low altitude (30-50 metres) along straight lines, to get a more detailed view of the ice surface roughness. The lines were chosen to cover various surface types. The digital video camera was used. At some points along the lines, snow and ice measurements were done at the same time as the video filming from the helicopter.

Helicopter born laser measurements were carried out by FIMR in the local area near *R/V Aranda*. Roughness estimations were done simultaneously by snow mobile in the same area.

7.3. Summary

The field campaign is considered very successful since most of the planned activities were carried out. The weather conditions offered a great variability, which led to interesting variations in the data. The mild weather that occurred in the beginning of the period exemplified melting conditions, while the following cold period gave us a unique opportunity to study the building up of the new snow layer and extension of the ice coverage.

The drifters offered an unique data set due to the severe ice drift during the field campaign, especially during the storm events.

7.4. Field personnel and acknowledgments

The following persons were involved during the field campaign:

Scientists:	Bertil Håkansson	SMHI[1]
	Maria Lundin	SMHI
	Mats Moberg	SMHI
	Mats Granskog	UH/DG[2]

[1]SMHI (Swedish Meteorological and Hydrological Institute)

[2]UH/DG (University of Helsinki / Department of Geophysics)

Technical assistance and field work:

Björn Becker	SMHI
Anna Eklund	SMHI
Henrik Lindh	SMHI

National Maritime Administration is greatly acknowledged for support of the project and for helicopter and ship assistance during deployment and recovery of instruments.

Thanks to Henrik Lindh for all technical assistance and construction of the thermistor stick and the GPS/Argos buoys.

This project is supplied by EU DG XII MAST Programme under contract PL 96-1048.

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Håkansson, B and Rahm, L. Swedish Lagrangian current experiments. In SMHI RO No. 15. Gulf of Bothnia Year 1991 Physical Transport Experiments, pp 41-55.

Sihvola, A and Tiuri, M, Snow fork for fields determination of the density and wetness profiles of a snow pack, IEEE Trans. Geosci. Remote Sensing, 24, 5, pp. 717-721, 1986.

8. Eddy flux measurements below ice and OBL studies from *R/V Aranda* by the Hokkaido University, Sea Ice Research Laboratory

Kunio Shirasawa and Kunio Kobinata,

8.1. Objectives

The aim was to measure turbulent fluxes of heat and momentum in the oceanic boundary layer under the land-fast sea ice near the ice edge region in the Gulf of Bothnia during the BASIS field experiment. The main Ice Station was established in the land-fast sea ice region (63^{o} 08.12 N, 21^{o}14.67 E) westward from Vaasa. The ice-ocean study site of the Hokkaido University was located about 100 m from the FIMR (10m high) meteorological mast and about 280 m northwestward from *R/V Aranda*. The ice was about 42 to 45 cm thick level ice at the ice-ocean study site at the beginning of the experiment on 18 February, 1998.

8.2 Measurements, methods and data sets

(a) Under-ice current measurements

Measurements by electromagnetic current meter
Two 3-D electromagnetic (EM) current meters (Model ACM32M, Alec Electronics Co. Ltd., Japan) were deployed from the sea ice on 19 February, 1998. The EM current meters were moored from the 45 cm thick ice at the depths of 0.5 m and 5 m below the ice-ocean interface. The water depth was 15.9 m. The EM current meters provide time series of fluctuations of 3-D currents (u, v, w), of temperature (T) and conductivity (C). Salinity (S) is calculated from conductivity and temperature values. By sampling a bursting of 20 min in each hour, at a sampling rate of 1 sec, the data are collected of the duration of 8 days. The turbulent oceanic heat flux <T'w'>, momentum flux <u'w'> and salt flux <S'w'> were to be calculated from the fluctuations by the eddy correlation method. The two current meters were recovered at 7:43 UTC on 27 February, 1998, for changing memory and battery packs, and redeployed at the same site and depths at 12:38 on 27 February. The ice thickness was 47.8 cm at that time. The two EM current meters were then finally recovered on 6 March, 1998.

Measurements by ultrasonic current meter
A 3-D ultrasonic current meter (Model-SD10, Union Engineering Co. Ltd., Japan) was deployed at the depth of 0.15 m below the ice-ocean interface near the EM current meters at 13:55 UTC on 20 February, 1998. A conductivity-temperature sensor (Union Engineering Co. Ltd., Japan) was also deployed in the same frame as the ultrasonic current meter. The pair of a 3-D current meter and conductivity-temperature sensor provide time series of fluctuations of 3-D currents (u, v, w), temperature (T) and conductivity (C) at a sampling rate of 0.2 sec. Salinity (S) is to be calculated from T and C. Those instantaneous values of currents, temperature and conductivity were recorded for the duration of 15 min in each every 30 min. The turbulent oceanic heat flux <T'w'>, momentum flux <u'w'> and salt flux <S'w'> are calculated by the eddy correlation method. The current meter and C-T sensor were recovered for check and maintenance, and redeployed at the depth of 0.3 m below the ice-ocean interface at 8:21 on 23 February. The

current meter and C-T sensor were recovered on 6 March, 1998. Time series of the under-ice currents, temperatures and salinities at the depths of 0.5 and 5 m are shown in Figure 8.1.

(b) Water temperature and salinity measurements

Two conductivity-temperature sensors (Union Engineering Co. Ltd., Japan) were deployed at the depths of 0.05 and 0.35 m below the ice-ocean interface near the ultrasonic current meter deployment site on 20 February. The ice thickness was 43 cm. Time series fluctuations of temperature and conductivity were recorded at a sampling rate of 0.2 sec for the duration of 15 min at every 30 min. The two C-T sensors were recovered on 6 March, 1998.

(c) Temperature profile measurements through the air-ice-ocean

A thermistor string (Grant Instruments, UK) was installed in the air and water through the ice sheet on 18 February, 1998. One thermistor sensor was installed on a stick at a height of 1.5 m above the air-water interface. Seven thermistor sensors were installed on the stick at the air-water interface (0 cm as the base of the depth meter), at the depths of 10, 20, 30 and 40 cm in the ice, and 45 and 55 cm in the water. The thermistor stick has been kept as it was at the setting up throughout the whole sampling period. A surface radiative temperature sensor (Tasco Co., Japan) was installed near the thermistor stick to measure the surface brightness temperature on 19 February, 1998. The set of thermistors and radiative temperature sensor can provide time series of temperature profiles in the air, at the air-snow/ice surface, in the ice and in the water throughout the whole sampling period. The thermistor string was recovered on 6 March, 1998.

(d) Ice thickness measurements

Two ice thickness gauges were installed at the distance of 5 m from the EM current meter site; one towards the north and another towards the south on 19 February, 1998. The ice thickness gauge is consisted of thin wire and electric cord with a stopper and a weight. The thickness of the ice can be measured manually by reading the length of the wire. The reading was made once a day throughout the whole sampling period. The thickness gauges were recovered on 6 March, 1998.

(e) Ice core sampling

Ice cores were taken from several sites in the north, south, east and west from the *R/V Aranda*. Those will be analyzed by a thin section method and also by a CT (computer-tomography) method, to understand crystallographic structure and physical properties of sea ice. The ice cores were sent to Japan for the analysis.

8.3 Field personnel

Kunio Shirasawa, scientist
Kunio Kobinata, field assistant

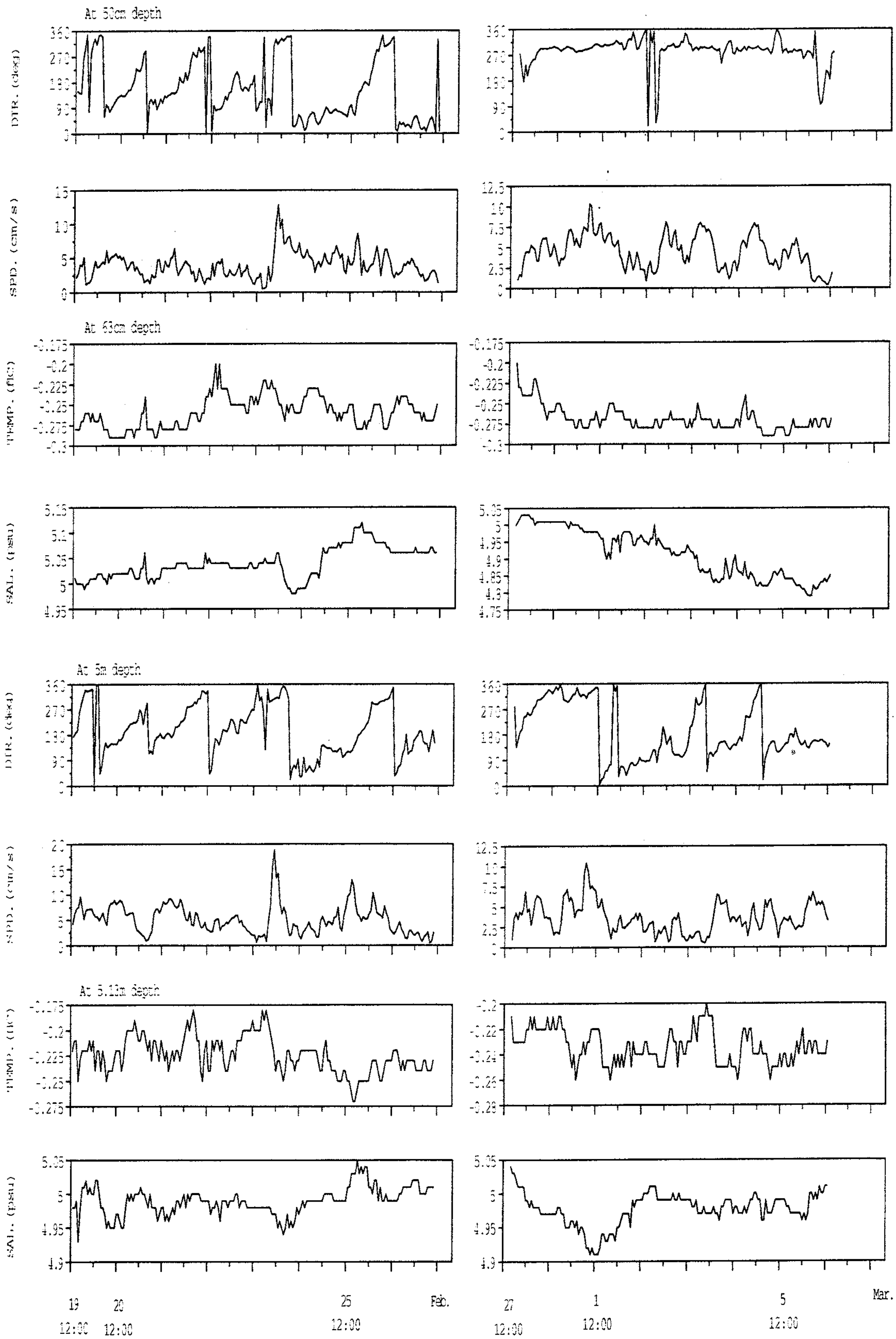

Figure 8.1. Time series of the water temperature and salinity, and current speed and direction, at the depths of 0.5 m, 0.63 m, and 5.0 m below the ice.

9. Data archive

A plan for the contents of the BASIS Data Archive is shown in Table 9.1.

Table 9.1 Contents of the BASIS Data Archive

	FIMR	**UHAM**	**UHANN**	**UUPP**	**UUPP / Östergarnsholm**	**SMHI**
1. Atmospheric data						
1.1 Surface layer						
air pressure	1 level, 10 min intervals	1 level, 10 min intervals		1 level, 10 min intervals	1 level	
air temperature	2 + 3 levels, 10 min intervals	2 levels, 1 & 10 min intervals		2 + 3 levels, 10 min intervals	5 + 1 levels	
wind speed & dir	2 + 5 levels, 10 min intervals	2 levels, 1 & 10 min intervals		1 + 1 level, 10 min intervals	5 levels	
rel. humidity	2 levels, 10 min intervals	1 level, 2 sens, 10 min intervals		-	1 level	
sensible heat flux	1 level, 10 min intervals	1 level, 10 min intervals		2 levels, 10 min intervals	3 + 1 levels	
latent heat flux	-	-		-	1 level	
momentum flux	1 level, 10 min intervals	1 level, 10 min intervals		2 levels, 10 min intervals	3 levels	
radiation	2 x Ts-rad SWR up & down 2 x net radiation 10 min intervals	Ta-rad SWR up & down LWR up & down 10 min intervals		SWR up & down LWR up & down, 10 min intervals	SWR up & down	
buoy data	3 x p, 2 x Ta, 1 x V & Vdir, 1 x RH	2 x (p, V, Vdir, Ta, RH)				

	FIMR	UHAM	UHANN	UUPP	UUPP / Östergarnsholm	SMHI
cloud data	total cover once an hour during daylight, rainfall	total & various level cover once an hour during daylight base height and thickness, 10 min		total cover during soundings	rainfall	
1.2 Radiosonde soundings	FIMR, UHAM, UHANN: 1 station; p, Ta, V, Vdir, RH profiles up to 10 km, 2 second resol.					
	R/V Aranda	Kokkola	Merikarvia	Umeå V and Vdir from pibals up to 2 km with 25 m resol.		Sundsvall & Kallax, data from standard pressure levels
1.2 Airborne data		p, Ta, V, Vdir, RH profiles, 1 s aver. (p, Ta, V, Vdir, RH, τ, H, LE, SWR↕, LWR↕) horiz. leg averages, time, position				
		Falcon	Helipod, except no radiation			

	FIMR	SMHI	UHOK
2. Ice and Surface Properties			
2.1 Ice Properties			
Ice thickness	along 50 m (L-shape), 10 points, once a day, also water level	along 100 m line, 2 m intevals, every second day	2 thickness gauges, once a day
Ice temperature and salinity	7 profiles, once	2 profiles, 5 cm resolution, every secon day, temperature only	
Ice structure			7 tomography cores
2.2 Snow Properties			
Snow Thickness	along 50 m line (L-shape), 10 points, once a day	along 100 m line, 2 m intevals, every second day	
Snow Temperature		8 profiles, 5 cm resolution, every secon day	
2.3 Thermistor Stick Air-Snow-Ice-Water	7 thermistors in ice or snow, 2 in water, 2 in air, 10 min intervals	2 m, 12 thermistors, 1 h intervals	5 thermistors in ice or snow, 2 in water, 1 in air, 10 min intervals
2.4 Buoy Data	1 x Argos position 1 x GPS position	3*ARGOS-position, 10 times a day 3*GPS-position, 10 min intervals	
2.5 Radarsat Images		Sub scenes, 50 m resolution	
2.6 Ice concentration		Radarsat data, digitized ice charts (concentration and thickness)	
2.7 Ice Roughness	laser-profilometry data, 7 h	(Radarsat data)	
2.8 Ice Drift	2 buoys; time, location, drift speed and direction	6 buoys, time, location, drift speed and dir-; Radarsat velocity fields	

	FIMR	**SMHI**	**UHOK**
3. Oceanic data **3.1 Hydrographic**			
ship CTD	pre-exp. Gulf of Bothnia 38 stations, T,S -profiles past-exp. Bothnian Sea 19 stations, T,S -profiles	pre-exp. Gulf of Bothnia, 22 stations, T,S -profiles	
ice station CTD	T,S -profiles, 12 m, 2 stations, twice a day		
thermistors	1 chain, 12 m, 1 m interval, 10 min.	1 chain: -60 - -120 m, 2 m interval, 1h 1 chain: 12 m, 1 m interval, 30 min	T & S at -0.05 and -0.35 m, 15 min
3.2 Currents			
Mechanical	speed & dir at -2 & -13 m, 10 min.		
ADCP	speed & dir at 1-m intervals, 10 min		
3.3 Turbulence			3 instruments: -0.15, -0.5, -5 m fluxes of heat, momentum, and salinity, and mean T, S and current components, 15-20 min averages

4. Supporting data		
Coastal meteorological stations:	8 FMI Stations	atmospheric pressure, air temperature, wind speed and direction
	SMHI Stations	atmospheric pressure, air temperature, wind speed and direction
Mareographs	3(-5) FIMR Stations	hourly sea level
	3(-5) SMHI Stations	hourly sea level

Appendix

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International BALTEX Secretariat Publication Series

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No. 3 : First Study Conference on BALTEX, Visby, Sweden, August 28 - September 1, 1995. Conference Proceedings. Editor: A. Omstedt, SMHI Norrköping, Sweden. August 1995, 190 pages.

No. 4 : Minutes of Second Meeting of the BALTEX Science Steering Group at Finnish Institute of Marine Research in Helsinki, Finland, January 25-27, 1995. October 1995.

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No. 11: Second Study Conference on BALTEX, Juliusruh, Island of Rügen, Germany, 25-29 May 1998. Conference Proceedings. Editors: E. Raschke and H.-J. Isemer. May 1998, 251 pages.

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No. 14: BALTEX - BASIS Data Report 1998. Editor: Jouko Launiainen. March 1999, 96 pages.

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