Rit Veðurstofu Íslands

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Sea Surface Energy Fluxes in the Iceland Sea in February 1997 - A Data Report

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The European Subpolar Ocean Programme - 2
(MAS2-CT95-0015)
Icelandic Meteorological Office

Contents

Abstract

The present data report is based on measurements obtained during an oceanographic cruise in the Iceland Sea and the Denmark Strait in February 1997. In addition to measurements of temperature, humidity and wind speed, calculated energy fluxes are presented. The data provide material for studies of atmosphere/sea ice/ocean interaction in the area.

Introduction

Observations and derived calculations listed in this data report present results of a co-operation between the Icelandic Meteorological Office and the Marine Research Institute, Reykjavík, in a subproject, Task 2.9, of the European project ESOP-2, The European Subpolar Ocean Programme, Phase 2. ESOP-2 is a Marine Science and Technology (MAST-III) programme of the European Commission, DG XII, Science, Research and Development (MAS2-CT95-0015).

The marine atmosphere measurements were undertaken during an oceanographic cruise on the oceanographic vessel Bjarni Sæmundsson of the Marine Research Institute. Scientific project leader of the expedition was Dr. Svend Aage Malmberg at the same institute.

The ocean area investigated is at the oceanic polar front in the northern North Atlantic, characterized by a complicated system of fluctuating currents. The relatively warm Irminger Current, which is a branch of the Gulf Stream System of the North Atlantic, approaches from the south and flows clockwise around Iceland. On the other hand, the southward flowing East Greenland Current, with its branch, the East Icelandic Current, brings cold low-salinity water masses and sea ice into the area.

The Greenland and Iceland Seas

The present report can be seen as a continuation of similar data reports, accounting for a) observations during joint Danish Icelandic cruises in the Iceland and Greenland Seas in 1987 - 1991 (Jakobsson & Björnsson 1992), b) the first half of ESOP (Einarsson & Jakobsson 1994) and c) the second half of ESOP (Wallevik & Jakobsson 1996). The cruises described in the first report were the combined Danish/Icelandic contribution to the international Greenland Sea Project. The reader is referred to the first report (Jakobsson & Björnsson 1992) for further information concerning measurements and calculations. For convenience, some parts of these earlier reports are repeated here. Appendix C by Halldór Björnsson, B.S., thus appears again as the same calculation procedure was applied in the present report.

The Iceland Sea is defined as the oceanic area between Iceland, Greenland and Jan Mayen, overlapping the southern part of the Greenland Sea which extends from Scoresby Sound to Spitsbergen. Sea ice amount in the Iceland Sea is quite variable from year to year, depending on three fluctuating parameters, i.e., 1) variable sea ice advection in the Arctic East Greenland Current, 2) variable stability conditions in the local ocean surface layer due to changing temperature and salinity and 3) the dominating pressure configuration prevailing in the atmospheric general circulation across the North Atlantic. Favourable conditions for ocean bottom production in the Iceland Sea are considered substantial, though far from comparable to conditions in the Odden sea ice area between Jan Mayen and Spitsbergen, the central research area of interest to ESOP-2.

Observations and data

In the following report an account is given on the meteorological measurements, made mainly for the purpose of estimating surface energy exchanges. The resulting surface exchange estimations based on the measurements will be presented. Besides three-hourly synoptic observations at standard hours and similar observations at stationary oceanographic stations, including sea surface temperature, additional measurements were undertaken at the oceanographic stations. The measurements constituted the parameters needed for the surface energy exchange calculations, i.e. air temperature, wet bulb temperature and wind speed.

The general observation site of the additional measurements was off the ship's port side in the stern. The anemometer, giving instantaneous readings in units of m/sec, was fixed on a bar stretched during time of observation approximately 3 meters outward from the ship's rail. (Weather Monitor II, Davis Instrument Corp.) The thermometer was placed at the ship's hull during the time spent at the oceanographic station. Height above sea level was approximately 5 meters.

As far as possible, proper exposure of instruments was sought. Care was taken to avoid radiational effects while measuring temperatures and, similarly, obstruction of the air flow caused by the ship. Due to the low temperatures frequently encountered, patience had to be shown in waiting for the wet bulb thermometer to reach the natural balance with its surroundings. Despite common difficulties of maritime measurements and use of relatively simple instrumentation and techniques, compared to arrangements needed for micro-meteorological studies, the observations in the Bjarni Sæmundsson voyages are considered reliable for bulk aerodynamic formulae applications, particularly in estimating average energy exchange for ocean areas of considerable extent.

It is hoped that this fourth and last data report in a series, describing maritime measurements and surface fluxes in the Iceland and Greenland Seas, will provide further material for the study of atmosphere/ocean interaction in the western part of the Greenland, Iceland and Norwegian Seas (The Nordic Sea). This is an important area for studying the climate of the North Atlantic Ocean and the surrounding area. Sampling of sea surface variables and air-sea fluxes are of increasing interest in the study of dynamics of climate (Weller & Taylor 1993).

Acknowledgements

Co-author of this report and a partner in the ESOP-2 project, Dr. Thor Jakobsson, would like to express his appreciation and thanks to Dr. Svend Aage Malmberg at the Marine Science Institute for enjoyable co-operation, not least during the expedition. Further, he gratefully acknowledges the co-operation of the other author, Jón Elvar Wallevik, B.S. He analyzed the data according to the calculation procedure described in Appendix C and prepared tables and graphs for publication.

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References

Jakobsson, Th. & H. Björnsson 1992. Late Summer Sea Surface Energy Fluxes in the Iceland and Greenland Seas in 1987 - 1991 (report no. 1). Icelandic Meteorological Office, Reykjavík.

Einarsson, H. & Th. Jakobsson 1994. Sea Surface Energy Fluxes in the Iceland and Greenland Seas in 1992 - 1994 (report no. 2). Icelandic Meteorological Office, Reykjavík.

Wallevik, J.E. & Th. Jakobsson 1996. Sea Surface Energy Fluxes in the Iceland and Greenland Seas in 1994 - 1995 (report no. 3). *Rit Veðurstofu Íslands,* VÍ-R96002-ÚR01, Icelandic Meteorological Office, Reykjavík.

Weller, R.A. & P.K. Taylor 1993. Surface Conditions and Air-Sea Fluxes. CCCO-JSC Ocean Observing System Development Panel, Texas A&M University, College Station, TX 77843-3146, 131 pp.

Appendix A
Original data

Cruise on research vessel “Bjarni Sæmundsson”

February 1997

Date	Station	Time	Latitude	Longitude	Wind (m/s)	Max (m/s)	Wind knot(*)	Temp dry	Temp dry (*)	Temp wet	SST	SST (*)	Pressure (mb)	Remarks
13.02	45	05:30	65°30'	24°34'	2,7	3,6	9	0,6	0,6	-2,0	0,2	0,3	990,0	
13.02	46	06:45	65°35'	24°55'	6,7	8,0	18	1,8	1,8	-0,8	2,8	2,4	990,4	
13.02	47	08:15	65°40'	25°15'	12,1	13,4	30	1,4	1,3	0,6	4,0	4,0	990,4	
13.02	48	09:50	65°45'	25°38'	12,1	13,4	30	1,2	1,2	0,8	4,0	4,0	991,0	
13.02	49	11:25	65°50'	26°00'	11,6	13,4	30	1,0	0,9	0,8	4,1	4,2	991,0	
13.02	50	13:00	65°56'	26°29'	11,1	13,0	24	2,4	2,0	2,2	5,0	5,1	991,0	
13.02	51	14:15	66°21'	26°47'	8,5	11,2	30	1,6	3,1	1,4	5,6	5,5	991,0	
13.02	52	15:30	66°05'	27°03'	12,1	13,4	28	3,0	3,1	2,7	4,2	4,5	992,0	
13.02	53	18:00	66°13'	27°28'	8,9	11,2	18	3,3	3,3	3,1	4,4	4,4	991,0	
13.02	54	20:40	66°09'	27°16'	5,4	6,7	9	2,8	2,4	2,6	4,9	4,4	992,5	
13.02	55	22:10	66°05'	27°04'	8,0	9,4	16	3,8	4,2	3,8	5,9	5,8	992,0	
14.02	56	14:50	66°30'	23°00'	9,4	11,6	24	1,2	1,0	0,8	0,7	0,8	997,0	
14.02	57	16:10	66°41'	23°08'	9,4	11,6	24	1,0	1,3	0,8	1,4	1,5	997,0	
14.02	58	17:30	66°53'	23°18'	12,1	13,4	30	-0,2	0,5	-0,2	1,4	1,3	997,0	
14.02	59	19:30	67°05'	23°27'	12,1	13,4	24	-0,4	0,0	-0,4	0,6	0,8	998,5	
15.02	60	05:15	67°00'	20°47'	9,4	10,3	24	1,4	1,5	1,2	1,5	1,5	998,0	
15.02	61	07:10	66°45'	20°47'	7,6	8,9	18	1,6	2,2	1,2	1,8	2,0	998,3	
15.02	62	09:00	66°30'	20°47'	4,9	5,4	9	0,0	1,0	0,0	1,8	1,9	999,5	(a)
15.02	63	16:45	66°38'	20°42'	3,1	4,0	10	0,8	1,2	0,6	1,4	1,4	1000,6	(b)
15.02	64	22:10	66°16'	18°50'	5,4	6,7	13	0,0	0,1	0,0	1,9	1,9	1001,5	
15.02	65	23:15	66°24'	18°50'	5,4	6,3	13	0,2	0,2	0,0	1,7	1,6	1001,5	
16.02	66	00:30	66°32'	18°50'	4,5	5,9	13	0,3	0,2	0,3	1,6	1,5	1001,5	
16.02	67	02:10	66°44'	18°51'	6,7	8,0	13	0,7	0,6	0,6	1,5	1,5	1001,0	
16.02	68	04:20	67°00'	18°50'	7,2	7,6	18	0,9	0,9	0,8	1,5	1,6	997,0	

Remarks:

(a) → Snow showers.

(b) → Cambridge station.

Cruise on research vessel "Bjarni Sæmundsson"

February 1997

Date	Station	Time	Latitude	Longitude	Wind (m/s)	Max (m/s)	Wind knot(*)	Temp dry	Temp dry (*)	Temp wet	SST	SST (*)	Pressure (mb)	Remarks
16.02	69	06:45	67°20'	18°50'	4,5	5,4	13	1,2	1,3	1,0	1,5	1,6	995,0	
16.02	70	09:15	67°40'	18°50'	7,6	8,9	18	-0,1	0,2	-0,2	0,9	1,0	993,5	
16.02	71	11:25	68°00'	18°50'	7,2	8,0	-	-1,1	-0,4	-1,1	-1,4	-1,2	992,2	(c)
17.02	72	00:30	67°30'	16°16'	9,4	11,6	24	2,6	2,7	2,6	1,0	1,1	973,4	
17.02	73	03:50	67°10'	16°16'	11,6	12,1	30	3,1	3,1	3,0	2,0	2,0	971,0	
17.02	74	07:00	66°50'	16°15'	12,1	13,4	30	2,8	2,5	2,7	1,7	2,0	966,0	
17.02	75	19:20	68°00'	12°40'	10,3	13,4	24	0,8	0,9	0,6	-0,9	-0,8	963,3	
18.02	76	03:20	67°45'	12°58'	11,2	13,0	30	0,1	0,1	0,1	-0,9	-0,8	949,5	(c)
18.02	77	07:05	67°30'	13°16'	5,4	6,7	9	0,4	0,5	0,3	-0,8	-0,6	941,0	(d)
18.02	78	12:20	67°15'	13°34'	7,6	8,9	18	2,0	2,0	1,5	0,8	0,9	949,4	
18.02	79	17:20	67°00'	13°50'	8,9	10,7	18	2,8	3,1	2,1	1,2	1,4	949,0	
18.02	80	21:25	66°37'	14°16'	9,4	11,6	24	1,3	1,4	0,3	1,7	1,9	968,0	
18.02	81	23:25	66°22'	14°24'	6,3	7,2	18	1,2	1,3	0,7	1,7	1,7	972,0	
19.02	83	01:10	66°22'	13°35'	6,7	8,9	13	1,5	1,4	0,8	1,6	1,6	974,0	
19.02	84	03:55	66°22'	13°00'	6,7	8,0	13	1,2	1,5	0,9	1,5	1,7	976,0	
19.02	85	07:05	66°22'	12°06'	8,9	10,7	24	1,2	1,2	0,8	1,7	1,7	977,0	
19.02	86	11:00	66°22'	11°01'	8,9	10,3	24	1,4	1,1	1,2	1,6	1,6	980,0	(e)
19.02	87	14:15	66°22'	10°00'	4,5	5,4	9	1,2	0,7	1,0	0,4	0,6	980,0	
21.02	88	21:25	65°00'	13°30'	2,2	2,7	9	3,0	2,0	2,0	1,4	1,5	972,0	(f)
21.02	89	23:20	65°00'	12°49'	4,0	6,7	9	2,3	2,1	2,2	1,9	2,0	972,0	
22.02	90	02:35	65°00'	11°40'	4,5	6,3	13	2,2	2,1	2,1	1,9	2,0	971,0	
22.02	91	04:00	65°00'	11°17'	5,8	8,0	9	2,1	2,1	2,0	2,0	2,2	971,0	
22.02	92	08:00	65°00'	10°07'	8,9	11,2	18	2,3	2,3	2,1	3,1	3,6	971,3	
22.02	93	10:05	65°00'	9°00'	11,2	12,6	24	1,9	1,9	1,7	0,7	0,9	974,0	

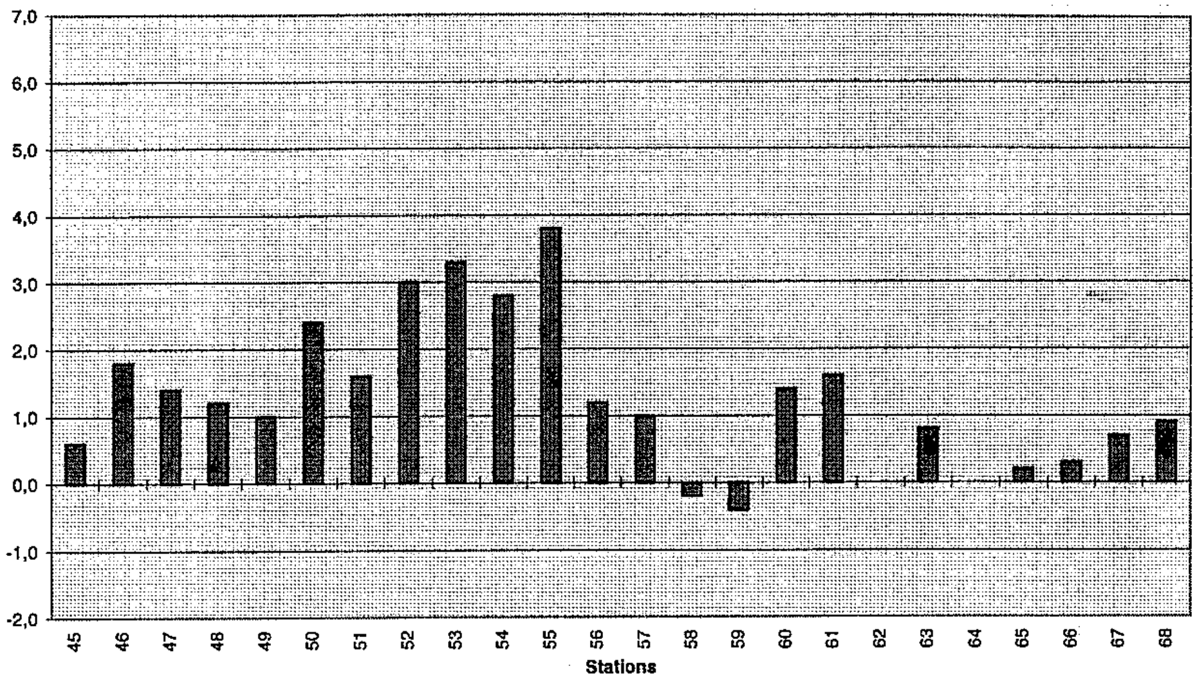
Remarks:

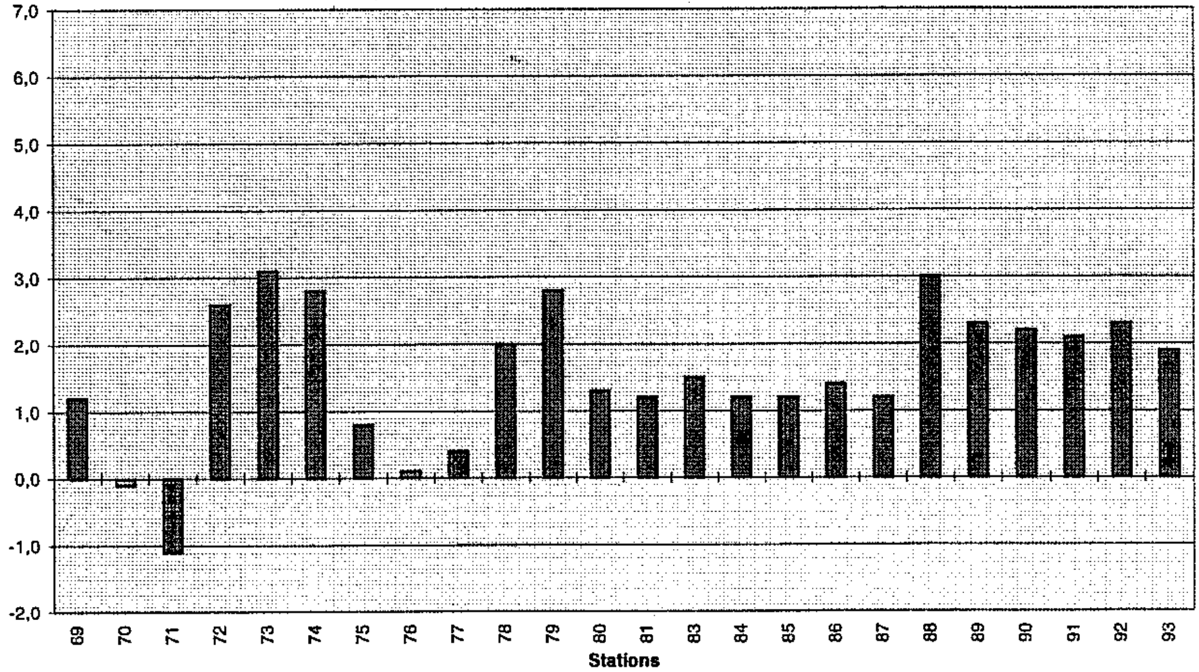
(c) → Drizzle.
(d) → Two lows nearby.
(e) → Possibly too short a time used for wet thermometer to adjust.
(f) → Dry heat possibly to high.

Cruise on research vessel "Bjarni Sæmundsson"

February 1997

Dry air temperature in C°





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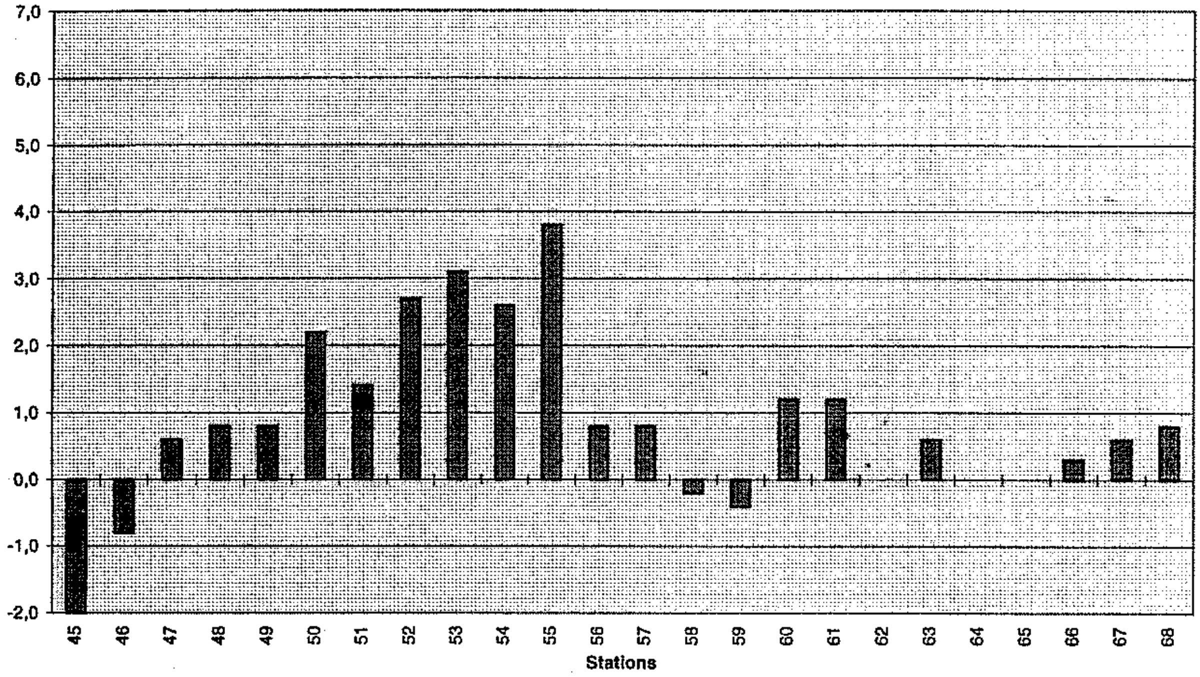
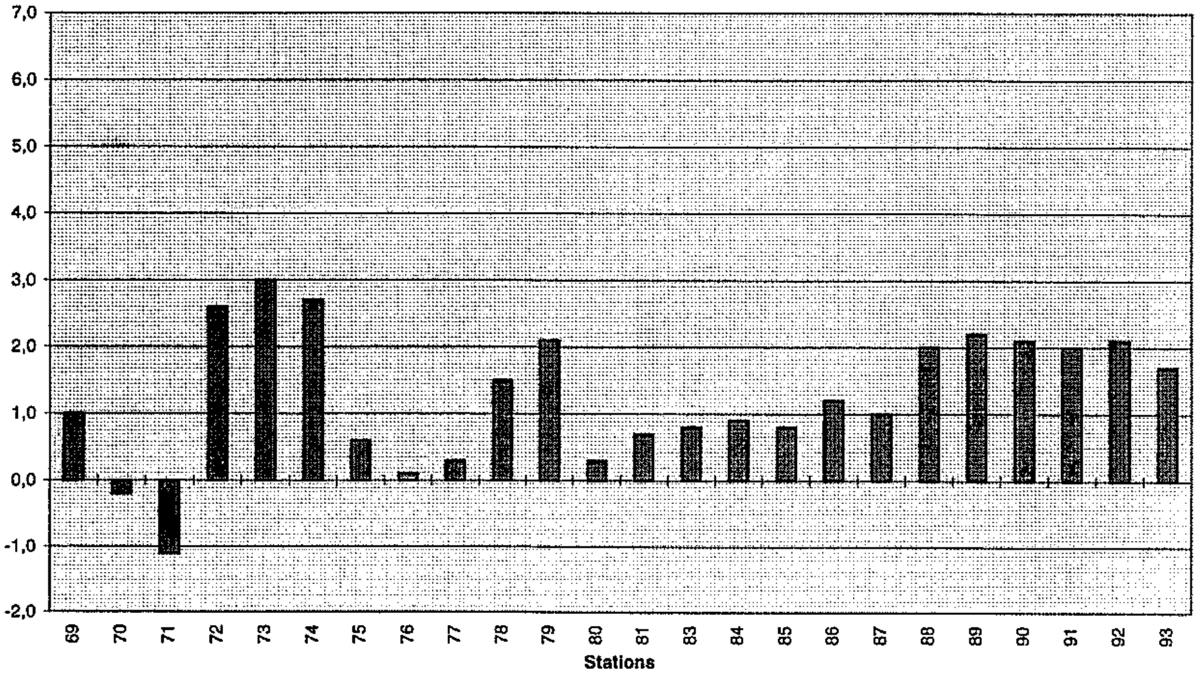
Wet bulb temperature in C°





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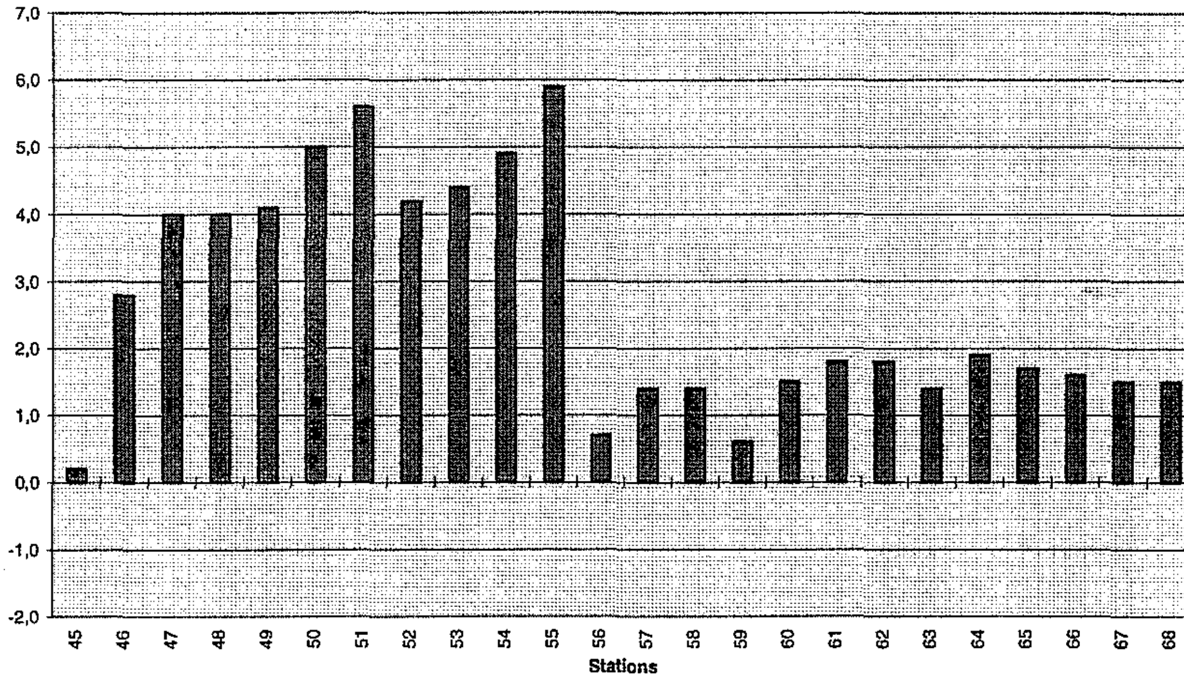
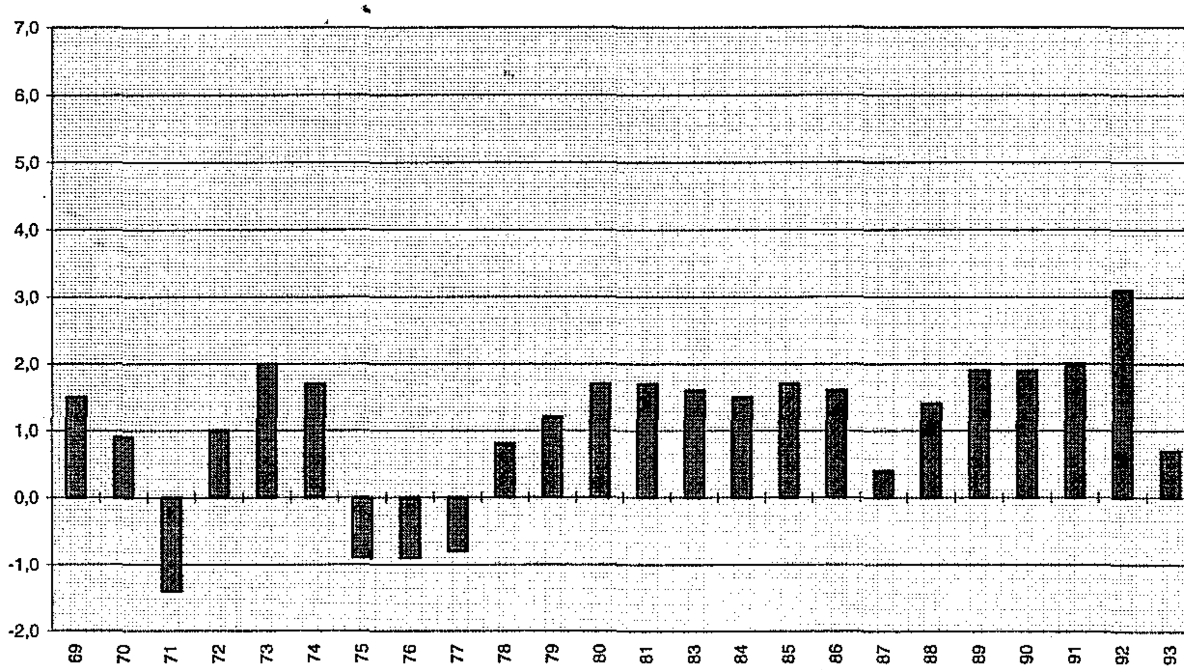
Sea surface temperature C°





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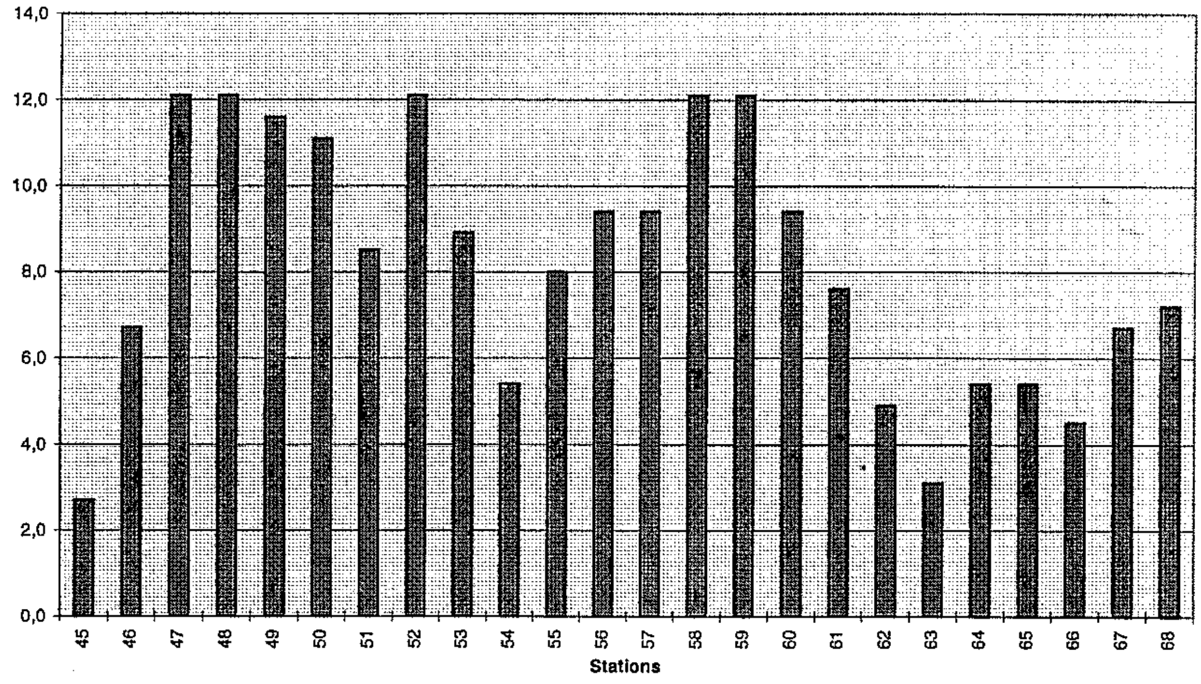
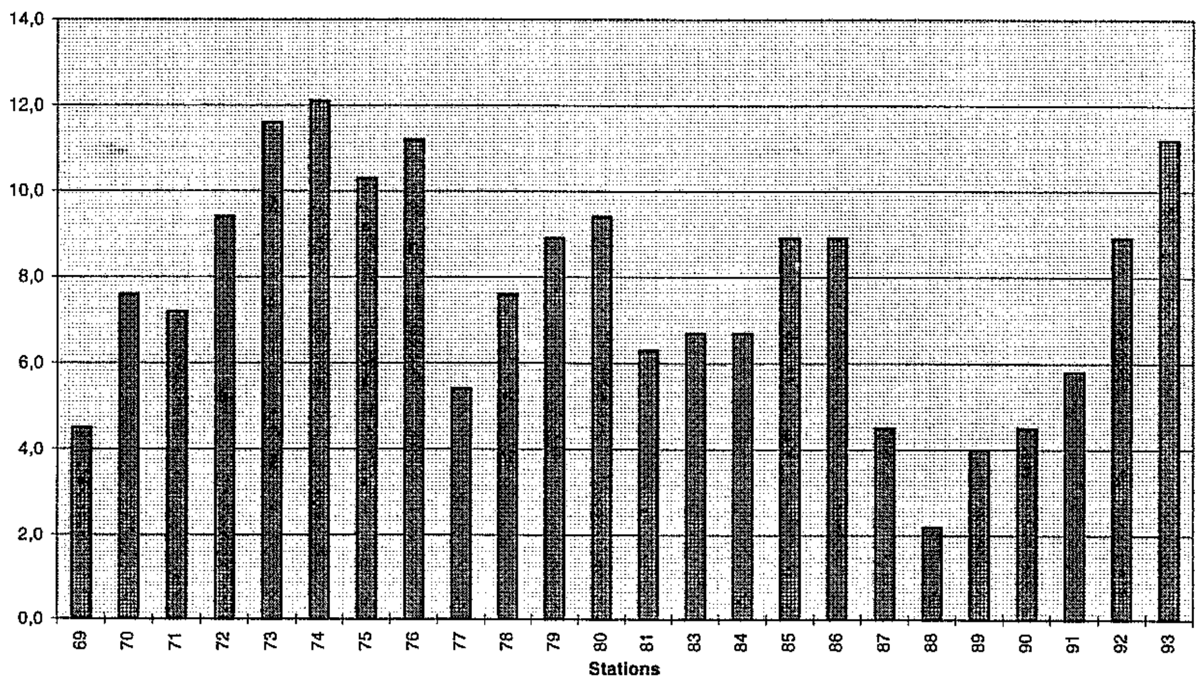
February 1997

Mean wind speed in m s^{-1}





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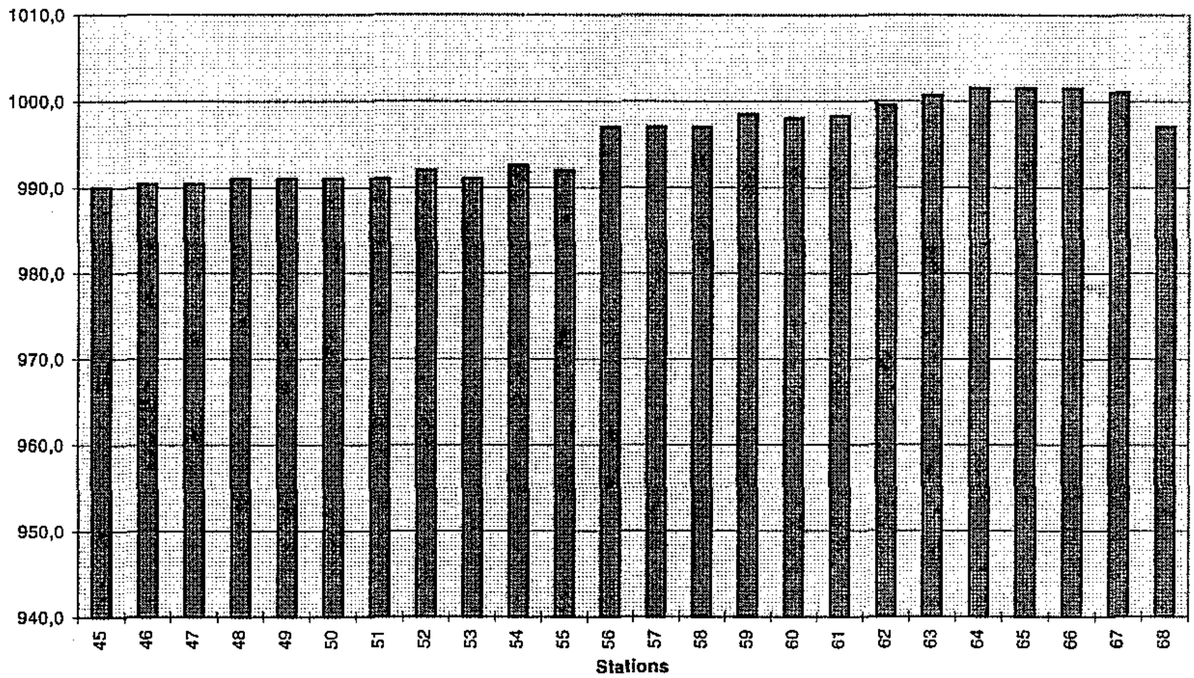
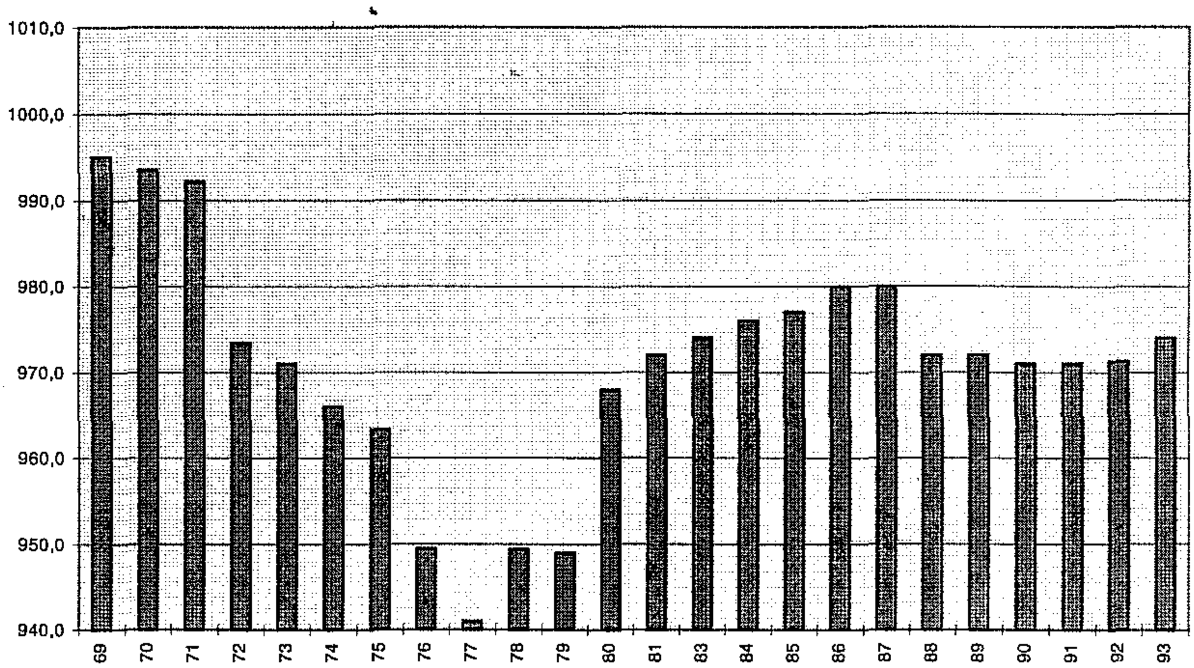
Air pressure in mb





Appendix B
Results for all stations

Cruise on research vessel "Bjarni Sæmundsson"

February 1997

Flux of sensible and latent heat in W m^{-2}

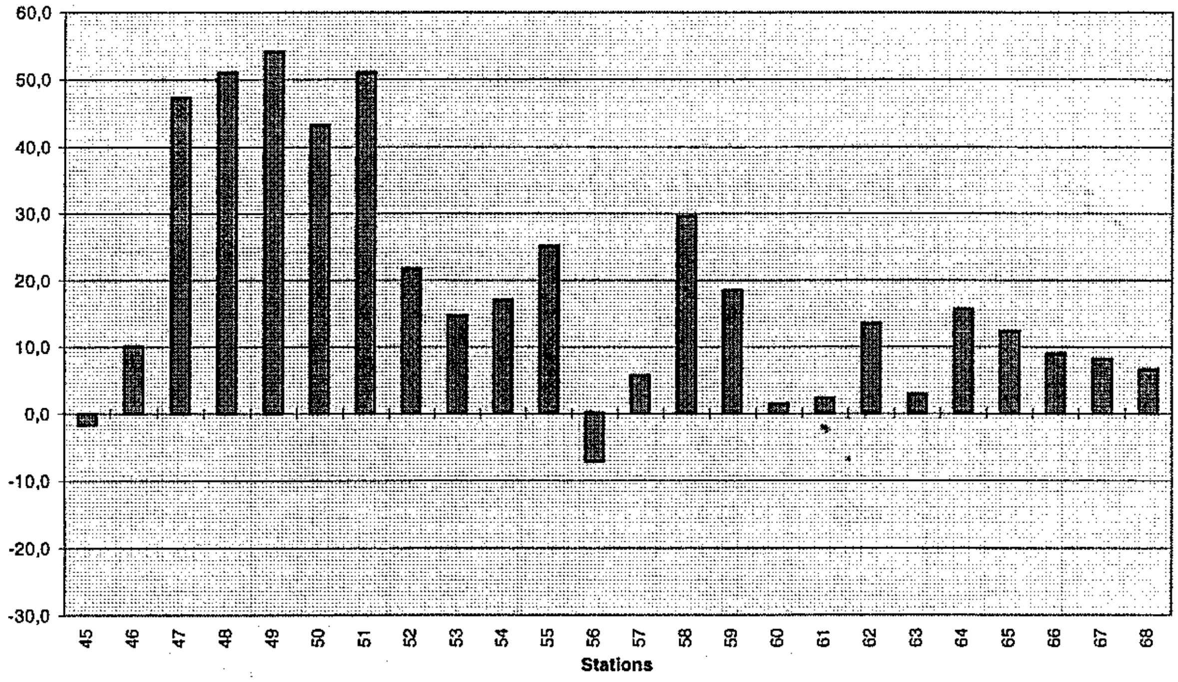
Station	QH (sensible)	QL (latent)
45	-1,6	15,2
46	10,1	49,4
47	47,3	59,1
48	51,0	49,6
49	54,2	45,8
50	43,3	39,4
51	51,0	45,4
52	21,8	24,0
53	14,7	14,3
54	17,0	15,8
55	25,1	20,2
56	-7,2	1,5
57	5,7	6,1
58	29,6	17,4
59	18,5	9,2
60	1,4	2,9
61	2,3	7,1
62	13,5	8,2
63	2,8	2,7
64	15,7	9,7
65	12,4	10,0
66	9,0	5,1
67	8,2	5,6
68	6,6	4,4

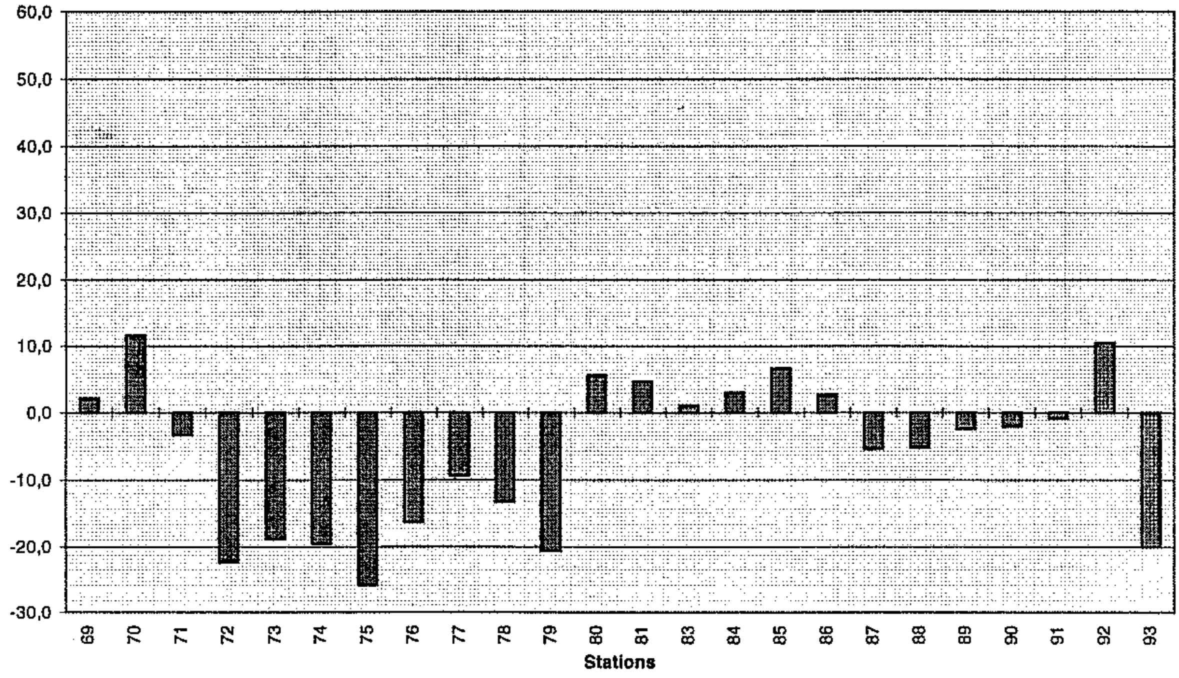
Station	QH (sensible)	QL (latent)
69	2,1	2,4
70	11,6	7,8
71	-3,3	-4,0
72	-22,3	-20,6
73	-18,8	-16,5
74	-19,6	-16,9
75	-25,9	-16,1
76	-16,3	-14,6
77	-9,4	-6,9
78	-13,2	-3,2
79	-20,6	-3,6
80	5,6	24,8
81	4,7	9,5
83	1,0	10,5
84	3,0	5,2
85	6,6	11,2
86	2,7	3,7
87	-5,4	-3,1
88	-5,2	0,8
89	-2,4	-2,2
90	-2,0	-1,9
91	-0,9	-1,1
92	10,5	10,3
93	-20,0	-13,0

Cruise on research vessel "Bjarni Sæmundsson"

<u>February 1997</u>

Flux of sensible heat in W m^{-2}

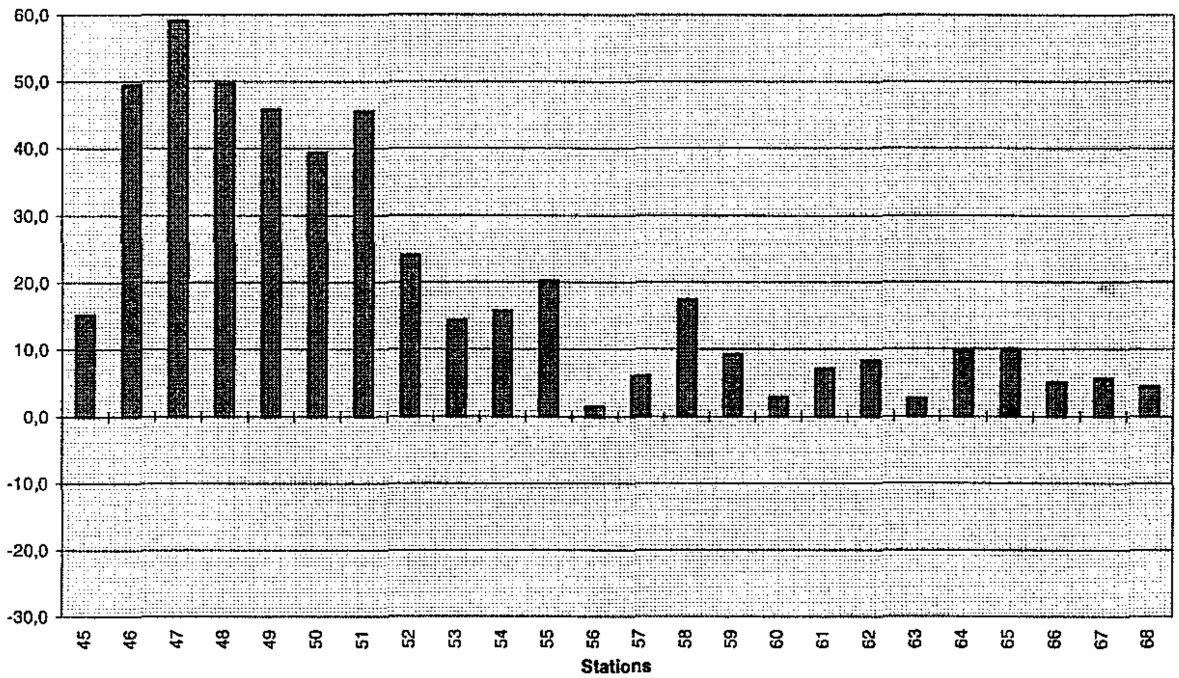


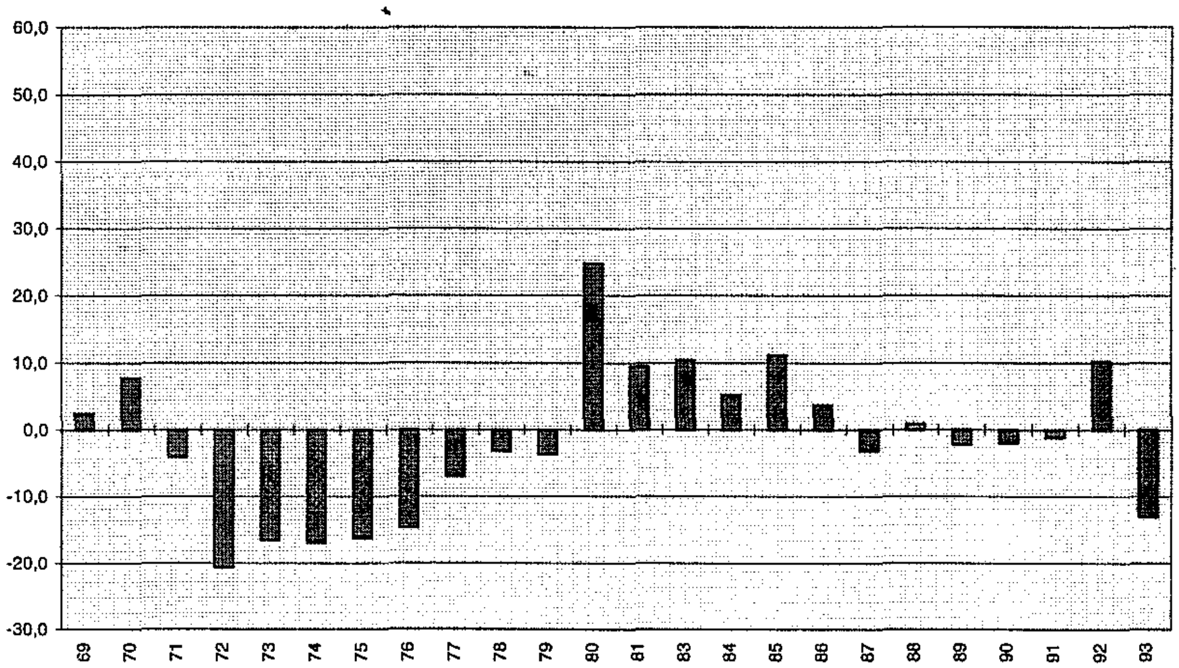


Cruise on research vessel "Bjarni Sæmundsson"

February 1997

Flux of latent heat in W m^{-2}





Appendix C
The method used to calculate fluxes

C A brief outline of the method used to calculate the fluxes

Abstract

The methods used in calculating the fluxes of latent and sensible heat over the sea surface are explained. First there is a brief overview on simple thermodynamics of moist air. The relevant thermodynamical variables are derived, and their connection with the energy fluxes. The method used in the data analysis is then explained.

C.1 On the thermodynamics of moist air

C.1.1 The equation of state for moist air

The simplest equation of state for a gas is the ideal gas relation:

$$PV = n\mathcal{R}T. \tag{2}$$

Where P is pressure, V Volume, n is the number of moles, T is the temperature in Kelvin degrees and $\mathcal{R}$ er universal gas constant. Here we shall use a slightly different notation. The vapour pressure will be denoted e and instead of n we shall use the mass of the water vapour M_v, and then the gas constant for water vapour R_v instead of the universal one $\mathcal{R}$. Equation (2) becomes $eV = M_vR_vT$. The specific weight for water vapour is $\rho_v = \frac{M_v}{V}$ so the equation of state becomes:

$$e = \rho_vR_vT. \tag{3}$$

The value of the gas constant is $R_v = 0.11calK^{-1}g^{-1}$ (or $0.461JK^{-1}g^{-1}$)

C.1.2 Moist air: water vapour content

Moist air is a combination of dry air and water vapour. If the pressure is p,vapour pressure is e, the partial pressure of the dry air is $p - e$.

The ratio of the masses of the vapour and the dry air is a common measure of water vapour content. This ratio is called the *mixing ratio.*

Let us denote it m and write $m = \frac{M_v}{M_d} = \frac{\rho_v}{\rho_d}$. Here M_d is the mass of the dry air and ρ_d its specific weight.

According to (3) $\rho_v = \frac{e}{R_vT}$ and similarily for the dry air $\rho_d = \frac{p-e}{R_dT}$.

The mixing ratio becomes:

$$m = \frac{\frac{e}{R_vT}}{\frac{p-e}{R_dT}} = \frac{e}{p-e}\frac{R_d}{R_v} \tag{4}$$

The gas constant for dry air is $R_d = 0.069calK^{-1}g^{-1}$ (or $0.287JK^{-1}g^{-1}$).
Using the numerical values for the constants (4) simplifies to:

$$m = \frac{0.622e}{p-e} \tag{5}$$

We often have $p \gg e$ and then (5) becomes $m = \frac{0.622e}{p}$

Another way to assess the amount of water vapour in air is to use the *specific humidity* q which is the ratio of the vapour mass and unit air mass.

If the density of the air is $\rho = \rho_v + \rho_d$, then $q = \frac{\rho_v}{\rho_v + \rho_d}$. As above this can be rewritten:

$$q = \frac{\epsilon R_d}{pR_v + e(R_d - R_v)} = \frac{e\frac{R_d}{R_v}}{p + e\frac{R_d - R_v}{R_v}} \tag{6}$$

Using numerical values for the constants this becomes:

$$q = \frac{0.622e}{p - 0.378e} \tag{7}$$

C.1.3 Moist air: the gas constant of moist air

The mass of moist air M is the sum of the masses of water vapour and of dry air: $M = M_v + M_d$.

The gas constant for moist air is therefore $R_m = \frac{M_v}{M}R_v + \frac{M_d}{M}R_d$.

Since $m = \frac{M_v}{M_d}$, this can be written:

$$R_m = \frac{mR_v + R_d}{1 + m} = \frac{R_d(m\frac{R_v}{R_d} + 1)}{1 + m}. \tag{8}$$

Since the ratio $\frac{R_v}{R_d}$ is 1.61, the gas constant for the moist air becomes:

$$R_m = \frac{R_d(1.61m + 1)}{1 + m} \tag{9}$$

C.1.4 Moist air: vapour pressure in air

The first law of thermodynamics can be written:

$$du = \delta q + \delta w. \tag{10}$$

Where du is the change in internal energy per mass unit, δq is the change in heat per mass unit and δw is the work per mass unit. If we put $du = c_v dT$ and $\delta w = -pdw$ into (10) we get:

$$\delta q = c_v dT + pdv. \tag{11}$$

Where c_v is the *specific heat capacity at constant volume* and dv is the differential change of the *specific volume*. Differentiation af the ideal gas relation gives $RdT = pdv + vdp$. Combining this with (11) and connecting the *specific heat capacities* at *constant volume* and *constant pressure* by using $c_p = c_v + R$ yields:

$$\delta q = c_p dT + vdp. \tag{12}$$

For isobaric processes $dp = 0$. The last term in (12) disappears, and we get $\delta q = c_p dT$.

Air can be isobarically cooled if a liquid evaporates into it. The evaporation of the liquid needs heat, which it gets from the air, thereby lowering the temperature of the air.

Consider a mass of air that is cooled in this manner, ever getting moister until it becomes saturated. Let the initial temperature of the air be T and the final temperature, the *wet bulb temperature* be T_w. Likewise call the initial mixing ratio m and the mixing ratio at saturation m_w.

The amount of heat taken from the air is $\Delta Q = L\Delta M_v$ where ΔM_v is the mass increase of the water, and L is the coefficient of latent heat.

The inital mass is $M^i = M_d + M_v^i = M_d(1+m)$

The final mass is $M^f = M_d + M_v^f = M_d(1+m_w)$

So the mass increase is $\Delta M_v = (M^f - M^i) = M_d(m_w - m)$ and the amount of heat taken up during the evaporation is $\Delta Q = LM_d(m_w - m)$.

This amount must by supplied by the cooling air:

$\Delta Q = -\int_T^{T_w} Mc_p dT = \int_{T_w}^{T}(c_{pd}M_d + c_{pv}M_v)dT$,

where c_{pd} and c_{pv} are the *specific heat capacities at constant pressure* of *dry air* and *vapour*, respectively.

This simplifies to:

$M_d \int_{T_w}^{T}(c_{pd} + c_{pv}m')dT$,

where m' is the changing mixing ratio. By assuming that the change in the mixing ratio is linearly related to temperature we substitute it with $\bar{m}$, a constant mean mixing ratio for the process.

We therefore get:

$\Delta Q = M_d(c_{pd} + c_{pv}\bar{m}) \int_{T_w}^{T} dT = M_d(c_{pd} + c_{pv}\bar{m})(T - T_w)$

The above leads to:

$$L(m_w - m) = (c_{pd} + c_{pv}\bar{m})(T - T_w). \tag{13}$$

By using $c_{pd} + \bar{m}c_{pv} \simeq c_{pd}$, (5) and $p \gg e$ we get

$$\frac{T - T_w}{e_w - e} = \frac{0.622L}{c_{pd}p}. \tag{14}$$

C.1.5 Estimation of the latent heat of evaporation

By putting $\delta w = pdv$ the first law of thermodynamics (10) can be written

$$\delta q = du + pdv \tag{15}$$

If water vapour is condensed at saturation pressure p_{sat} the amount of heat released per unit mass (which equals the coefficient of latent heat) is:

$L = u_{vapour} - u_{water} + p_{sat}(v_{vapour} - v_{water}) \simeq u_{vapour} - u_{water} + p_{sat}v_{vapour}$ because $v_{vapour} \gg v_{water}$.

Let us use (2) to get $p_{sat}v_{vapour} = R_{vapour}T$

$(R_{vapour} = 0.10974cal^\circ C^{-1}g^{-1})$.

Differentiaton gives $\frac{\partial L}{\partial T} = \frac{\partial u_{vapour}}{\partial T} - \frac{\partial u_{water}}{\partial T} + R_{vapour} = c_{vapour} - c_{water} + R_{vapour}$

By inserting the numerical values $c_v = 0.331cal^\circ C^{-1}g^{-1}$

and $c_{water} = 1.007cal^\circ C^{-1}g^{-1}$ we get

$\frac{\partial L}{\partial T} = -0.566cal^\circ C^{-1}g^{-1}$.

At $0°C$ L is: $L(0) = 597.3calg^{-1}$

A linear approximation of L(T) close to zero gives:

$$L(T) = L(0) + \frac{\partial L}{\partial T} T = 597.3 - 0.566T. \tag{16}$$

C.2 Transfer equations

The flux of sensible and latent heat can be estimated by the following equations:
Sensible heat flux:

$$Q_H = - C_z U \rho c_{pd}(T_{air} - T_{seasurface}). \tag{17}$$

Latent heat flux:

$$Q_L = - C_z U \rho L(q_{air} - q_{seasurface}). \tag{18}$$

Here C_z is a constant, *the drag coefficient* , U is the wind speed and ρ is the density of the air. For a derivation of these equations refer to [4]. The drag coefficient adopted in the present study is 1.2×10^{-3} according to [6]

C.3 Analyses of the data

Mesurements from the research wessel Bjarni Saemundsson included wind speed, air pressure, airtemperature, wet bulb temperature and sea surface temperature. From these the heat fluxes were calculated in the following manner:

- The saturation pressure at sea surface and in the air is found by using the temperature values. This can be done by looking it up in the appropriate tables. The air at the sea surface is assumed to have the same temperature as the sea. Correction is made for the effects of salinity which causes a 2 % decline in the saturation pressure at the surface.
- The latent heat coefficient L is calculated from (16)
- The partial pressure of water vapour in air is found by using (14). It is assumed that the air at the sea surface is fully saturated, so the partial pressure of water vapour at the surface is set equal to the saturation pressure at the surface.
- The specific humidity is calculated from (7)
- The density of the air is estimated by:
  1. Calculating the mixing ratio (5)
  2. Finding the gas constant by using (9)
  3. Calculating the density from the state equation (3), using the previously calculated gas constant.

  The density is thus calculated both for the air at and above the sea surface and the mean of the two is then used.
- The fluxes of sensible and latent heat is calculated according to (18 and 17)

References

[1] Howell, J.R., and R.O. Buckius, *Fundamentals of Engineering Thermodynamics*, McGraw-Hill 1987.

[2] Haltiner, G.J., and F.L. Martin, *Dynamical and Physical Meteorology*, McGraw-Hill 1957.

[3] Hess, S.L., *Introd. to Theoretical Meteorology*, Henry Holt and Co. N.Y. 1959.

[4] Roll, H.U., *Physics of the Marine Atmosphere*, Academic Press N.Y. 1965.

[5] Isemer, H.J, and L. Hasse, *The Bunker Climate Atlas of the North Atlantic Ocean, Vol. I -II*, Springer Verlag 1985, 1987.

[6] Robinson, G.D., *Another look at some problems of the air-sea interface*, Quart. J. Roy. Meteorol. Soc., 92. (451-465), 1966.

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