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INSTITUTE OF HYDROGRAPHIC RESEARCH
GÖTEBORG SERIES No 1

THE BALTIC ENTRANCE PROJECT:
Analysis of Currents Measured at Läsö Nord/Trindel Lightvessel 1974 - 1977

by

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October 1979

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☐ PROJEKTBESKRIVNING
☐ TITELBLAD-RAPPORTER

2 REF

PR

3 Datum
1979-09-03

4 Ärendebeteckning (Diarienr)

5

6

7 MI projektnr

8 Projekt

☐ 1 Uppläggning ☐ 2 Komplettering ☐ 3 Avslutat

9 MI rapportnr

10 Intrapportör

11 Kontraktnr

12 Startår

13 Slutår

14 MI projektnr (i förek fall)
1258

15 Finansierande organ

SNV FO-nämnd, kontrakt nr 7-182/74-78

16 Projektets/Rapportens titel och undertitel

THE BALTIC ENTRANCE PROJECT:

Analysis of Currents Measured at Läsö Nord/Trindel Lightvessel 1974 - 1977

17 Projektledare/Rapportförfattare

Lööf, Staffan (författare)
Svansson, Artur (projektledare och författare)

18 Sammanfattning av projektet/rapporten (ange gärna målsättning, metod, teknik resultat m m)

The hydrographic conditions in northern Kattegat were investigated in a project "The Baltic Entrance Project: the GF Section". In this work mean values of wind and current measurements are computed and their statistical distribution is shown. Annual means of lightvessel observations during 1964 are presented. Transports of water, salt and total phosphorus are computed. Simulation of low frequency sampling are performed using high frequency data. The choice of sampling occasions and sampling frequency is important since it influences the above mentioned transports.

De hydrografiska förhållandena i norra Kattegatt har undersökts i ett projekt betitlat "The Baltic Entrance Project: the GF Section". I detta papper redovisas medelvärdeberäkningar av vind och ström. Den statistiska fördelningen presenteras också. Årsmedelvärden av strömmätningar utförda 1964 på fyrskeppen i Kattegatt och Bälthavet visas. Transporter av vatten, salt och totalfosfor beräknas. Simulering av provtagning med låg frekvens utförs m h a högfrekvensdata. Val av mättillfällen och -frekvens påverkar transportberäkningarna märkbart.

19 Sammanfattningen skriven av
S. Lööf

20 Förslag till nyckelord

Y, hydrografi, provtagningsfrekvens, transport, Kattegatt

21 Klassifikationssystem och klass

22 Indexterm

23 Bibliografiska uppgifter

Meddelande från Havsfiskelaboratoriet Lysekil nr 252
IHR Göteborg Series No 1

24 ISSN

25 ISBN

26 Hemligt

☒ Nej ☐ Ja, jämlikt ___ paragraf ___ § sekretesslagen

27 Språk
Eng

28 Antal sidor
17 s 10f

29 Pris

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by

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Abstract

At the Danish lightvessel Läsö Nord/Trindel measurements of wind and surface current were performed every three hours. Once a day samples were taken for the determination of salinity and total phosphorus. Daily, monthly and annual mean values are computed and the statistical distribution is shown. For a comparison the annual means of 1964 of lightvessel observations in the Kattegat and the Belt Sea are presented.

Transports of water, salt and total phosphorus are computed from lightvessel observations and compared with those computed from section measurements. Transports are also computed using simulated sampling occasions at a section station and lightvessel data. Finally, the wind-current-relation is investigated.

CONTENTS

1. Introduction

At a section between Göteborg and Frederikshavn (GF section, see map) 75 expeditions were carried out during August 1974 - - December 1977. Up to November 1977 samples were also taken at the Danish lightvessel (hereafter designated by L/V) positioned close to the section station designated GF-6. Unfortunately, the lightvessel was moved in March 1975 to a new position 5 nautical miles to the south-east. The name was then changed from Läsö Nord to Läsö Trindel. It was withdrawn permanently in November 1977.

The L/V wind, current, temperature and salinity data used in this study were supplied by the Danish Meteorological Institute. Samples for the determination of total phosphorus were collected once a day on board by the crew and was analysed at the National Board of Fisheries in Göteborg. Eight times a day the speed of the surface current was estimated (tenths of a knot) and occasionally checked by means of a stop watch. Eight different directions were used by the observers. (N, NE, E etc.). Temperature and salinity were measured once a day. (Methods are described in Anon. 1965.)

At the GF expeditions measurements were made of among other things current, temperature, salinity and nutrients. The current velocity and direction were determined with a gelatin pendulum device (Haamer 1973), which gives an instantaneous picture of the current.

2. Current Statistics 1975-77

Fig. 1a shows the annual means of each of the 8 directions, separated into 3 speed intervals. There are few cases of currents towards E, SE and S. These currents are moreover usually weak.

Fig:s 1b - 1d show the corresponding means for the individual years 1975,-76,-77. They display similar features as that of the total mean.

3. Monthly Means July 1974 - November 1977

Most of L/V:s in the Kattegat show a current minimum during the summer (Svansson 1975, see also Ch. 4). Table 1 displays monthly and annual long term means at Läsö Trindel for the period 1901-30. A spring maximum is followed by a minimum in July - August. However, during the GF period there are some deviating features for Läsö L/V (Fig:s 2 and 3). The spring maximum occurs one month earlier. Furthermore, after an outflow minimum in July a maximum takes place in August. The current speed of the 3 months February, July and August is approx. the same, but in July the direction is towards SE instead of predominating NW. Looking at the monthly means of each separate year (Fig:s 4a, b and c), we find a weak inflow tendency during the summer.

4. Currents Measured at Lightvessels in the Kattegat and the Belt Sea in 1964.

Dietrich (1951) published long term means 1901-30 of surface currents measured at Danish L/V:s. He discriminated between outflow and inflow, without details however. Therefore L/V measurements made in 1964 have been studied.

The annual vectorial means for 10 Danish and Swedish lightvessels are shown in Fig. 5. Except for Anholt N, they all show outflowing surface water. Monthly means of currents measured at Skagens Rev, Vinga, Läsö and Fladen are displayed in Fig:s 6a - - 6b. At L/V Skagens Rev during summer the current is mainly east-going (50 cm/s), in March however, nearly N-going (60 cm/s). At the other L/V:s in Fig. 6 there is a general tendency to a late winter outflow maximum in February followed by a minimum in April. During the summer there is no common trend. In November another minimum appears at all L/V:s.

5. Daily and Running Means of the N-component

Fig. 7 shows the daily means of the N-component together with 17 days running means during the first half of 1976. The influence of the tide is almost neutralized in a daily mean. There is great variability, however, in the daily means. Due to this fact it is rather difficult to compute accurate transports from but a few current measurements.

If the material is smoothed, e.g. by means of running means, the rugged character disappears. In Fig:s 7 and 8 17 days running means was chosen. ("1" indicates the one-day step.) A frequently used running mean period is 14 days but since this interferes with the change of crews at the lightvessel 17 days was considered a better choice. It should, however, be remembered that all changes with periods of 17 days or less disappear with a 17 days running mean.

6. Computation of Water, Salt and Total Phosphorus Transports

6.1. Annual Means Compared with GF-6 Measurements

Transports of water, salt and total phosphorus at the lightvessel and at section station GF-6 are presented in Table 2. It must be stressed that these measurements applies only to the surface layer.(At the lightvessel surface current observations solely were carried out.)

As mentioned earlier, the current measurements reveal a great variability in the northern Kattegat. Hence one would expect that there might be important discrepancies when computing transports from two different sets of data with a sampling frequency ratio of approximately 15:1. (When computing the transports the one current measurement was chosen which was nearest in time of the salinity and phosphorus sampling.)

The general trend seems to be that the GF-6 measurements give somewhat greater net transports. However, the differencies are not so great in 1976 and 1977, but in 1975 the net transports computed from section data are roughly 2 to 4 times as great as those computed from lightvessel data. Looking at the in- and outward transports of water respectively we can see that in 1976 and 1977 they are almost the same, but in 1975 the outward transport decreased and the inward one increased in comparison to 1976 and 1977 giving a considerably lower resulting outward transport. For salt, the inward transport is very much the same for all three years whereas in 1975 the outward transport is considerably lower. The transport of total phosphorus seems to follow the pattern for water.

6.2. Use of Simulated Data Series

In Lööf (1979) the effect of a varying sampling freguency is demonstrated. Salinity and total phosphorus data from the lightvessel and from GF-6 were processed. Furthermore, different sampling series were simulated using the high frequency measurements from the lightvessel. In the present work the data processing has been extended to calculations of transports of water, salt and total phosphorus. The principles and criteria for the simulation have been retained. A description is to be found in
./. Appendix A.

Table 3 gives the results of the calculations. |MAX| and |MIN| indicates the highest and the lowest value respectively of the 72 calculations.

7. Relation Wind - Current

The wind speed and direction were measured at the L/V simultaneously with the current. Fig. 9 shows the monthly means of winds during the GF period (wind in the direction of the arrows). Westerly and south - westerly winds dominate.

A frequently asked question is to what extent the surface current is influenced by the wind. Table 4 shows statistics concerning the wind-current relation (daily means of both parameters).

Note that no attention has been paid to the strength of either the wind or the current. For both parameters 8 intervals surrounding the 8 main directions of the compass were used. Adding the no wind/no current state a matrix of 9 times 9 elements were set up. Then all the daily means of wind and surface current measured at the L/V during the GF period were compared and each time the contents of the appropriate matrix element was increased by one.

As can be seen from the table wind from one direction often means current towards approximately the same direction, i.e. wind and current are opposed to each other. Northerly winds result in currents towards N - NW, easterly winds currents towards N - NE, westerly winds currents towards W - SW. However, southerly winds give a more scattered pattern. - This is in rather good agreement with the wind-surface current charts presented by Dietrich (1951).

A simple way of getting a rough estimation of the influence of the wind on the surface currents is to compute the vector difference between the mean vector of the entire period studied and the monthly mean vector (Palmén 1930). Probably there is no simple relation between wind and surface current in the Kattegat (Svansson 1975). Table 5 shows this vector difference, the corresponding mean value of the wind and the direction difference between the two. In most cases the surface current lies to the right of the wind. In July there is an outstanding maximum of vector difference, 14 cm/s. In June, however, it is only one third as great. So it is remarkable that the corresponding mean values of the wind are identical in June and July both in direction and velocity. Obviously, no quantitative relation exists between wind and surface current in this case.

Acknowledgements

Thanks are due to the crew onboard the Läsö Nord/Trindel lightvessel for their kind cooperation with collecting the samples and making the observations and to the Danish Meteorological Institute for kindly delivering lightvessel data.

This work was supported by grants from the Swedish Environment Protection Board.

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Appendix A.

Principles and criteria used for simulated data series.

The choice of sampling occasions at the GF section was governed by among other things meteorological conditions. During periods of strong winds/rough sea it was not possible to carry out hydrographic expeditions with the vessel available. Furthermore, no sampling has been performed on certain days of the week or more frequently than once a week.

It is rather difficult to answer the question wether the choice of sampling occasions have influenced the final result of the investigation of the hydrographic conditions. Rough wind conditions are usually associated to large mixing and water exchange. But due to inertia the water movements do not stop abruptly when the wind creases. So nevertheless, rough weather conditions may sometimes be represented in the section measurements.

In Lööf (1979) it was shown how the choice of sampling occasions influenced the result of a series of total phosphorus measurements. To study this problem closer some simulated cruise data were produced using the daily observations at the lightvessel. By means of certain criteria (see below) a number of section sampling occasions were simulated. Current, salinity and total phosphorus data at 0 m were sorted out from the lightvessel data bank and the transports were calculated.

Criteria for simulations.

1) Invalid days: every Friday, Saturday and Sunday, holidays and some weekdays in association with holidays.

2) Only one sampling per week.

3) Number of sampling occasions per simulation: 72. This corresponds to the number of cruises at the section up to the withdrawal of the lightvessel.

4) Highest acceptable wind velocity (daily means) at the lightvessel: 8 m/s. A sampling occasion generated with a wind velocity exceeding this value was rejected and a new one was sought.

A simulation was accomplished according to the following procedure. First a time interval was defined within which all sampling occasions would lie. The first section cruise took place on August 7, 1974. Therefore August 5, 1974 was defined as the start of the period since this day was the first valid day in the first sampling week. This date is now transferred to a relative time scale and designated day no. 0 (zero).

The lightvessel was permanently withdrawn on November 24, 1977. The last day when complete casts were made was November 21, 1977 which constitutes the end of the period. This day is designated no. 1204.

With the aid of a computor a series of random numbers in the interval 0 - 1204 was now generated. Every number, equivalent to a day in the period 740805 - 771121, was compared with a table containing invalid days according to the criteria. If found, the generated number was rejected and a new one was sought. This was repeated until 72 valid numbers were obtained. They were thereafter sorted in ascending order (the only reason for this is that this will speed up the following processing). Then the numbers, being relative points of time, were translated into an absolute scale. The data of current, salinity and total phosphorus for the corresponding days were collected from the data bank and processed.

A complete simulation has now been carried out. The results of the processed data can be compared with the real measurements at the section, i.e. the first 72 expeditions up to the withdrawal of the lightvessel.

It is of course not sufficient with only one simulation in order to draw conclusions of how the choice of sampling occasions influences the results of the investigation. One simulation gives only one combination of sampling occasions. Therefore several simulations were carried out. However, the grand mean of a number of simulations rapidly converges towards a constant value. A test with surface salinity data shows that a constant value of the grand mean (taking into account the precision of the measurements) is obtained after 25 - 30 simulations. In this work 26 consecutive runs were performed (no more computor time was available at the moment).

Table 1. Monthly and annual long year (vectorial) means of surface currents (cm/s) at lightvessel Läsö Trindel. Positive values indicate outflow, negative inflow. Outflow defined as W-N-ENE (from Dietrich 1951).

Obs. period: 1901/30

Month	Surface current cm/s
Jan	14
Feb	18
Mar	24
Apr	22
May	22
Jun	14
Jul	13
Aug	13
Sep	17
Oct	22
Nov	16
Dec	17
Annual	17

Table 2. Transports at lightvessel Läsö Nord/Trindel (daily measurements) and at section station GF-6 (∾ 20 expeditions/year). Computations from pendulum surface current measurements.

a) Water ×

	km^3/year and km^2	Läsö	GF-6
1975	IN	2520	
	OUT	3390	
	DIFF	-870	-3240
1976	IN	2220	
	OUT	4680	
	DIFF	-2460	-3150
1977	IN	2160	
	OUT	4560	
	DIFF	-2400	-2730

b) Salt

	10^6 tons/year and km^2	Läsö	GF-6
1975	IN	54 056	
	OUT	85 973	
	DIFF	-31 917	-69 774
1976	IN	56 605	
	OUT	113 481	
	DIFF	-56 876	-62 245
1977	IN	53 366	
	OUT	110 061	
	DIFF	-56 695	-53 215

c) Tot-P

	10^3 tons/year and km^2	Läsö	GF-6
1975	IN	44	
	OUT	83	
	DIFF	-39	-68
1976	IN	40	
	OUT	91	
	DIFF	-49	-64
1977	IN	41	
	OUT	89	
	DIFF	-48	-64

× Transports of water based on 8 observations/day

Table 3. Transports at lightvessel Läsö Nord/Trindel. Computations from uncorrected surface current measurements. Sampling occasions simulated according to principles discussed in Apendix A.

a) Water — km^3/year and km^2

	IN	OUT	DIFF
|MAX|	2763	5997	-4400
|MIN|	1469	3512	-1024
Grand Mean	2129	4278	-2149
Stand Dev	357	554	842
CV %	18	13	39
Use of all observations during the period	2268	4192	-1924

b) Salt — 10^6 tons/year and km^2

	IN	OUT	DIFF
|MAX|	66 700	126 700	-86 700
|MIN|	37 900	85 200	-20 900
Grand Mean	51 400	102 400	-51 000
Stand Dev	8 800	10 600	17 000
CV %	17	10	34
Use of all observations during the period	54 900	104 400	-49 500

c) Tot.P — 10^3 tons/year and km^2

	IN	OUT	DIFF
|MAX|	65	114	-85
|MIN|	27	66	-8
Grand Mean	42	89	-47
Stand Dev	12	15	26
CV %	27	17	54
Use of all observations during the period	43	89	-46

Table 4. Relation Wind - Current at Läsö lightvessel.
(Number of observations)

Current towards

Wind from	N	NE	E	SE	S	SW	W	NW	No Current
N	63	14	1	1	1	6	7	33	0
NE	54	33	4	0	1	2	7	23	0
E	42	30	7	5	2	4	2	11	0
SE	23	26	5	23	1	3	2	18	0
S	22	25	23	22	35	14	8	22	0
SW	25	8	11	14	35	64	30	19	0
W	17	4	9	6	18	61	87	30	0
NW	23	2	1	1	6	20	35	50	0
No Wind	3	1	0	0	0	0	1	1	0

Total number of observations = 1207

Period of observations : Aug. 1974 - Nov. 1977

Table 5. THE WIND INDUCED CURRENT VECTOR

Läsö Lightvessel, computed from data for the period July 1974 - November 1977.

	Induced Current Vector (towards)		Wind Towards		Diff in Dir[x]
	Dir	Vel (cm/s)	Dir	Vel (m/s)	
JAN	26	4	61	2	-35
FEB	351	7	346	1	+5
Mar	70	2		0	---
APR	81	7	97	2	-16
MAY	300	6		0	---
JUN	206	5	103	3	+103
JUL	221	14	104	3	+117
AUG	360	8	90	1	-90
SEP	154	7	52	4	+102
OCT	69	5	321	1	+108
NOV	125	8	26	3	+99
DEC	239	6	87	4	+152

x + Current to the right of the wind

- Current to the left of the wind

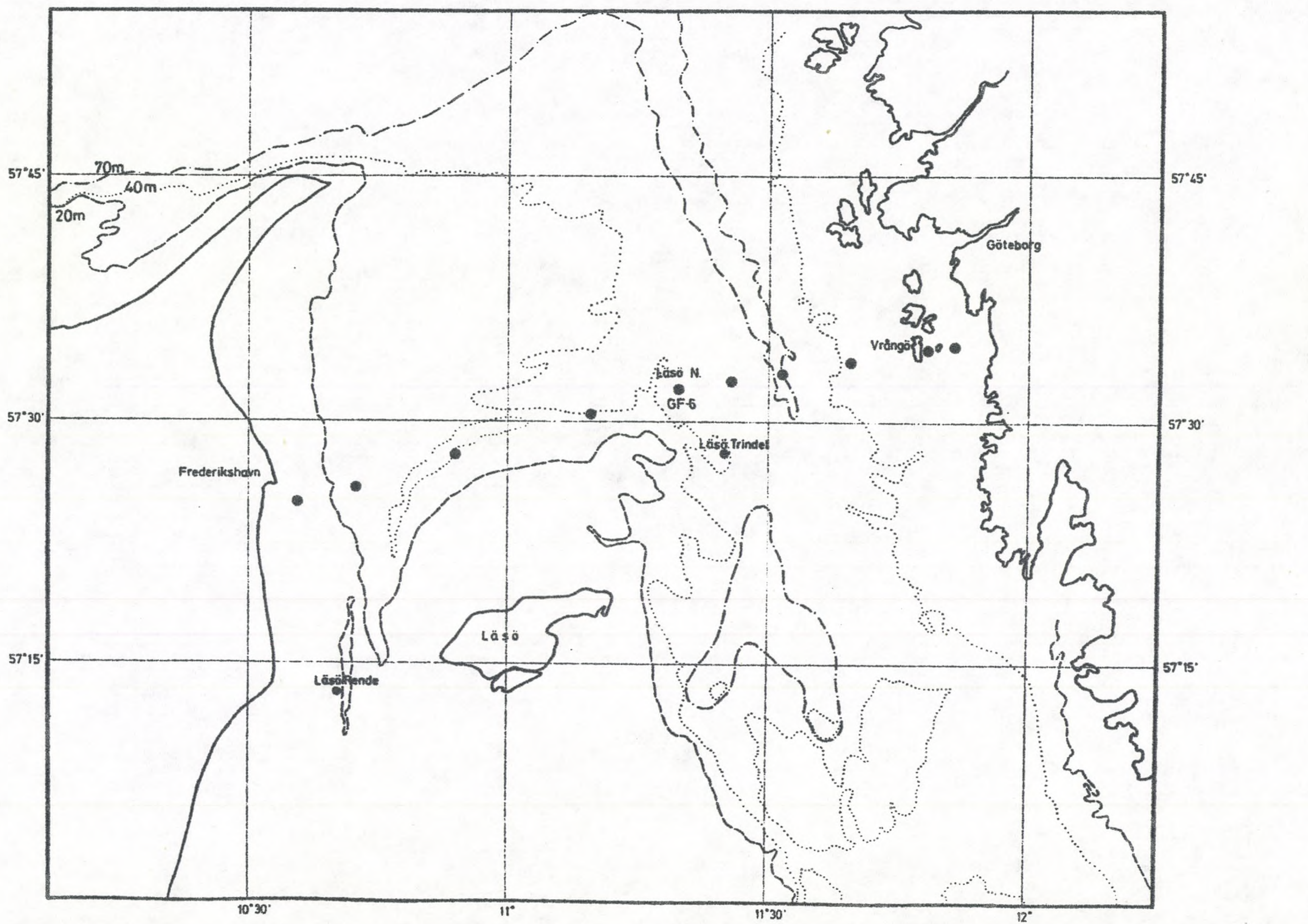

57°45'
57°30'
57°15'
10°30'
11°
11°30'
12°
70m
40m
20m
Göteborg
Vrångö
Läsö N.
GF-6
Läsö Trindel
Frederikshavn
Läsö
Läsö Rende

FIG. 1

Surface Current Statistics at Läsö Lightvessel

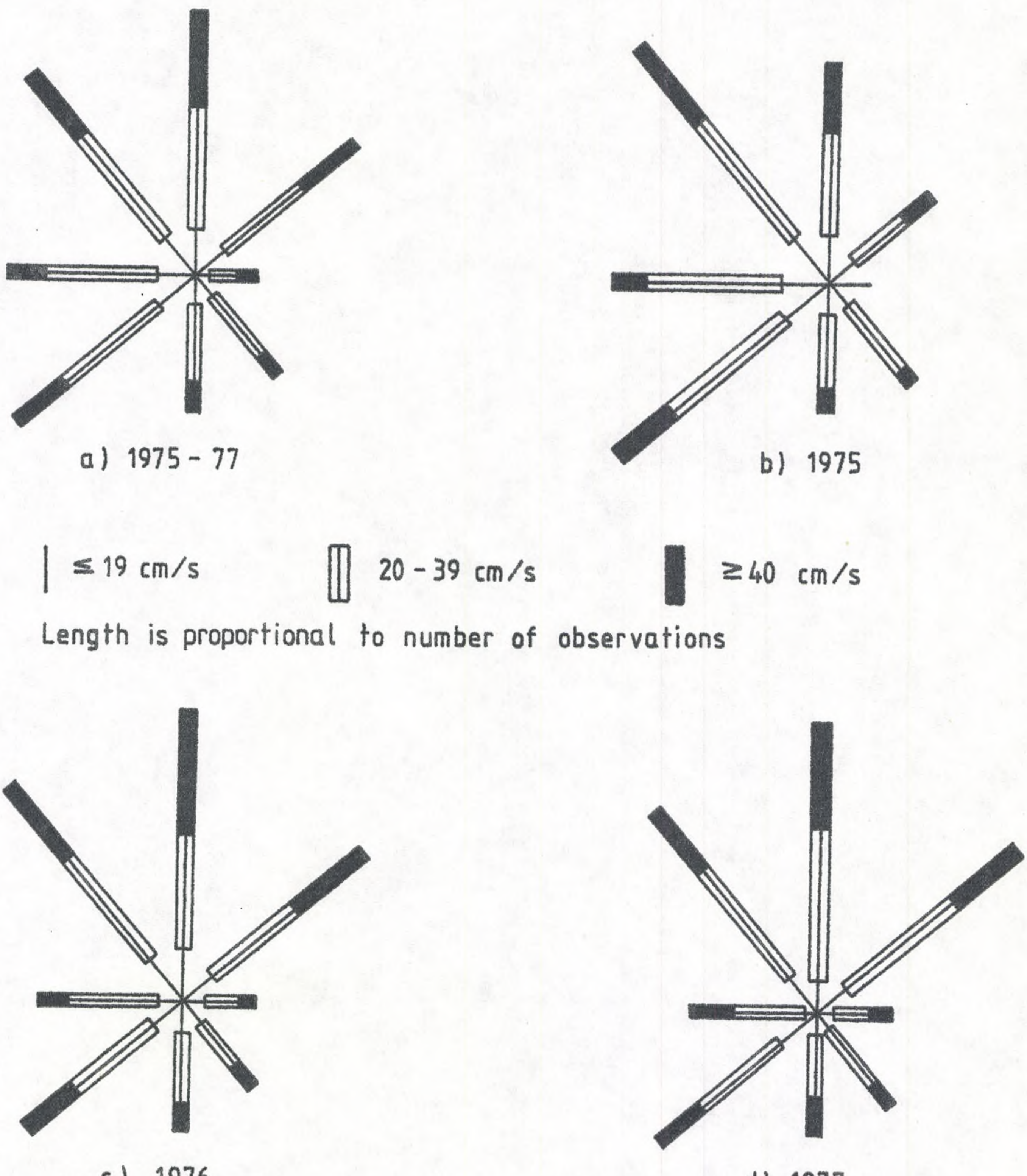


FIG. 2

Monthly Means of Surface Currents
July 1974 - November 1977 at Läsö Lightvessel

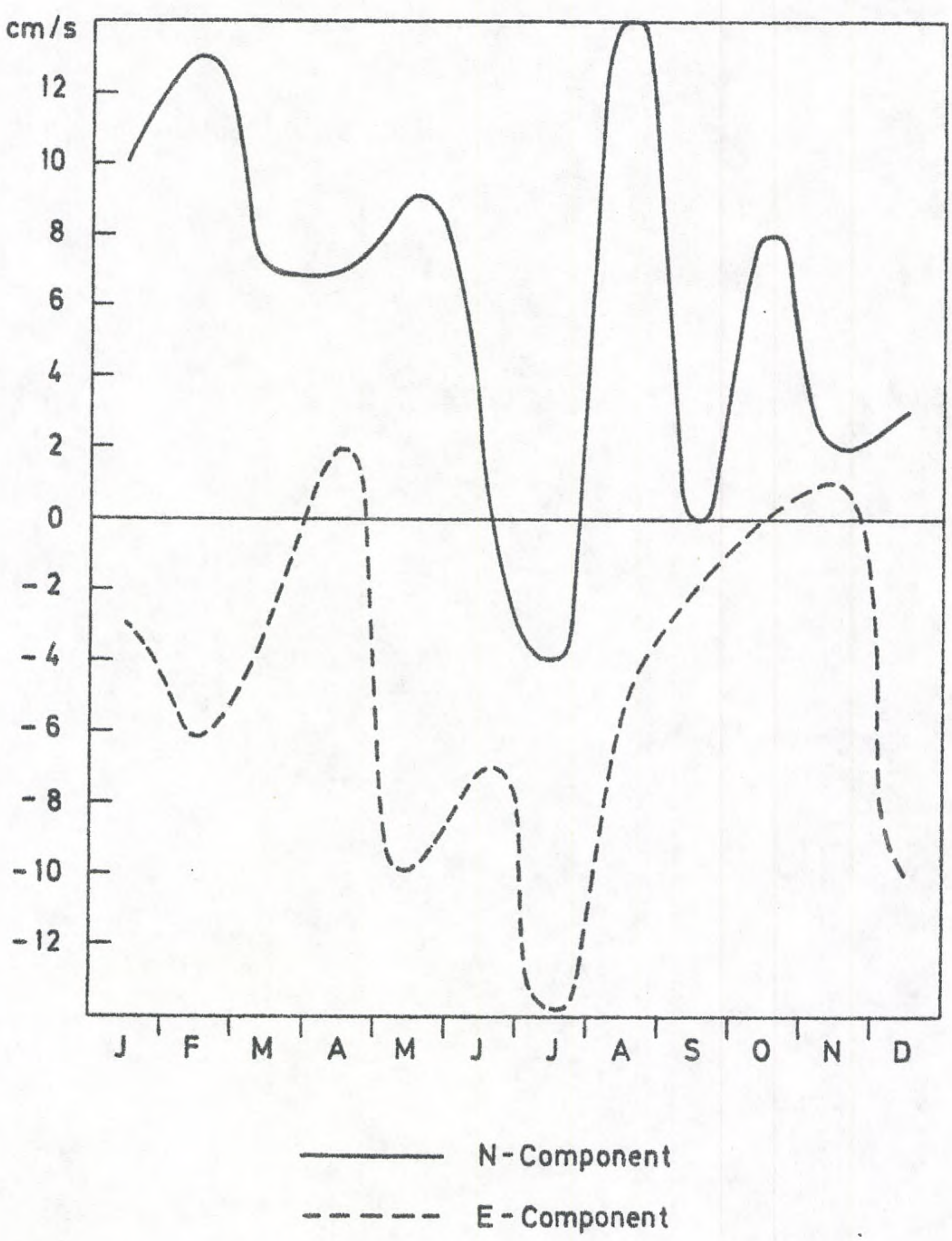
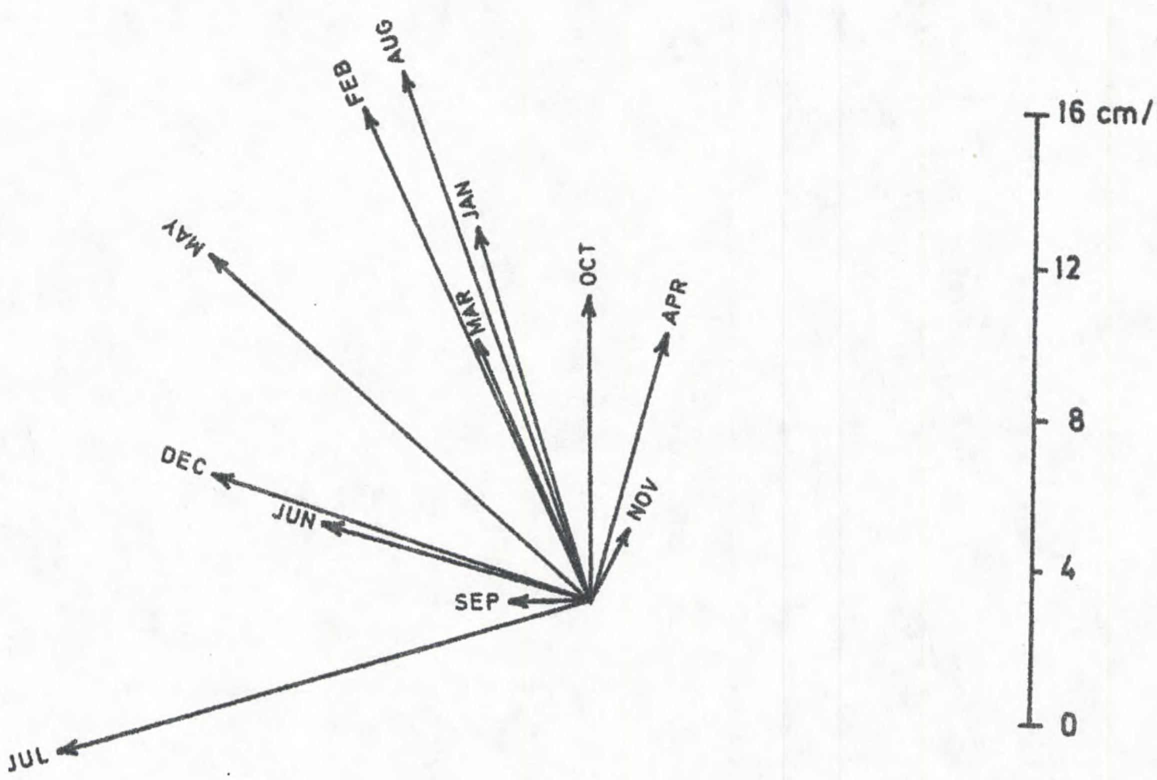


FIG. 3

Monthly Means of Surface Currents

July 1974 – November 1977 at Läsö Lightvessel



Monthly Means of Surface Currents at Läsö Lightvessel FIG. 4

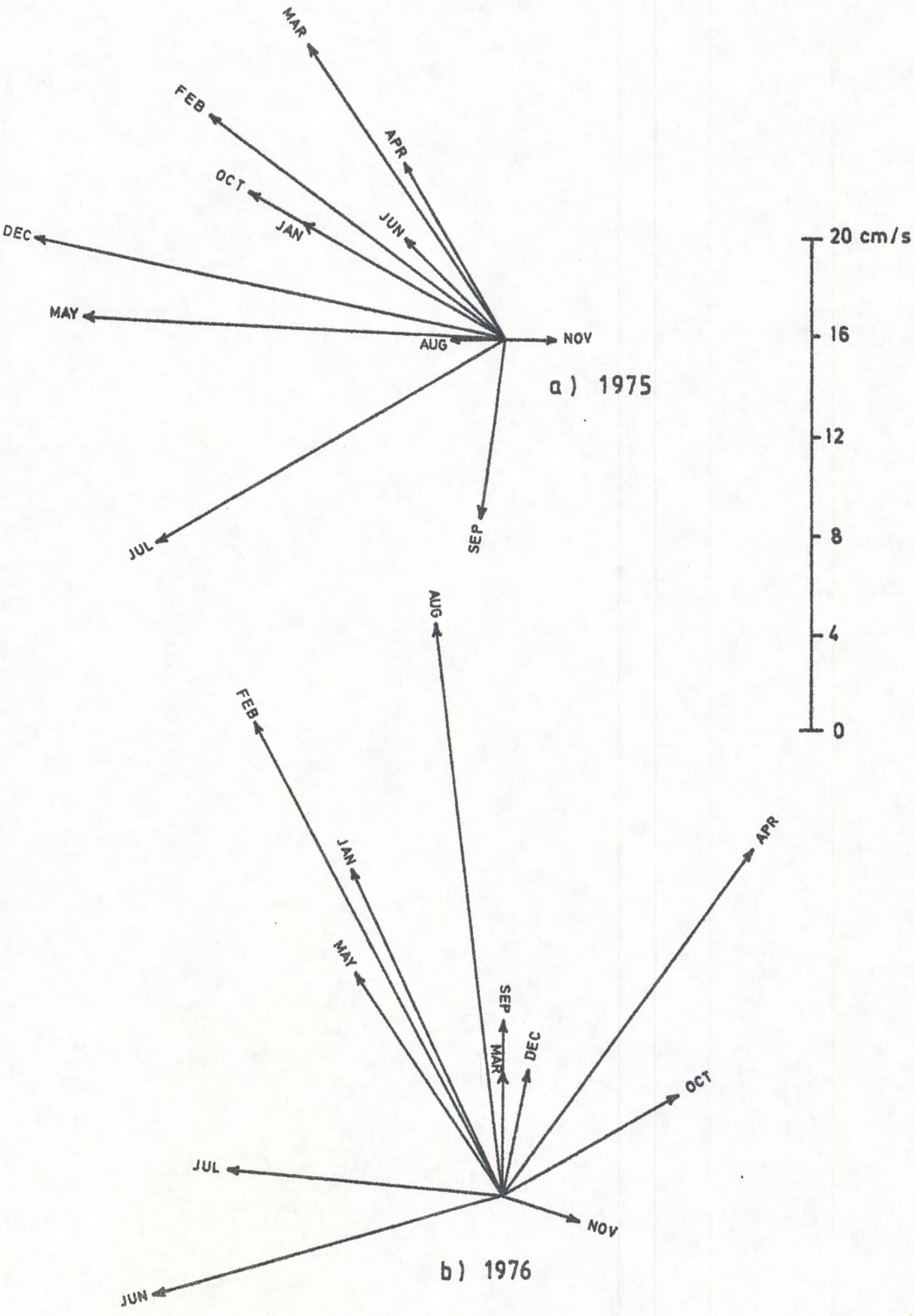
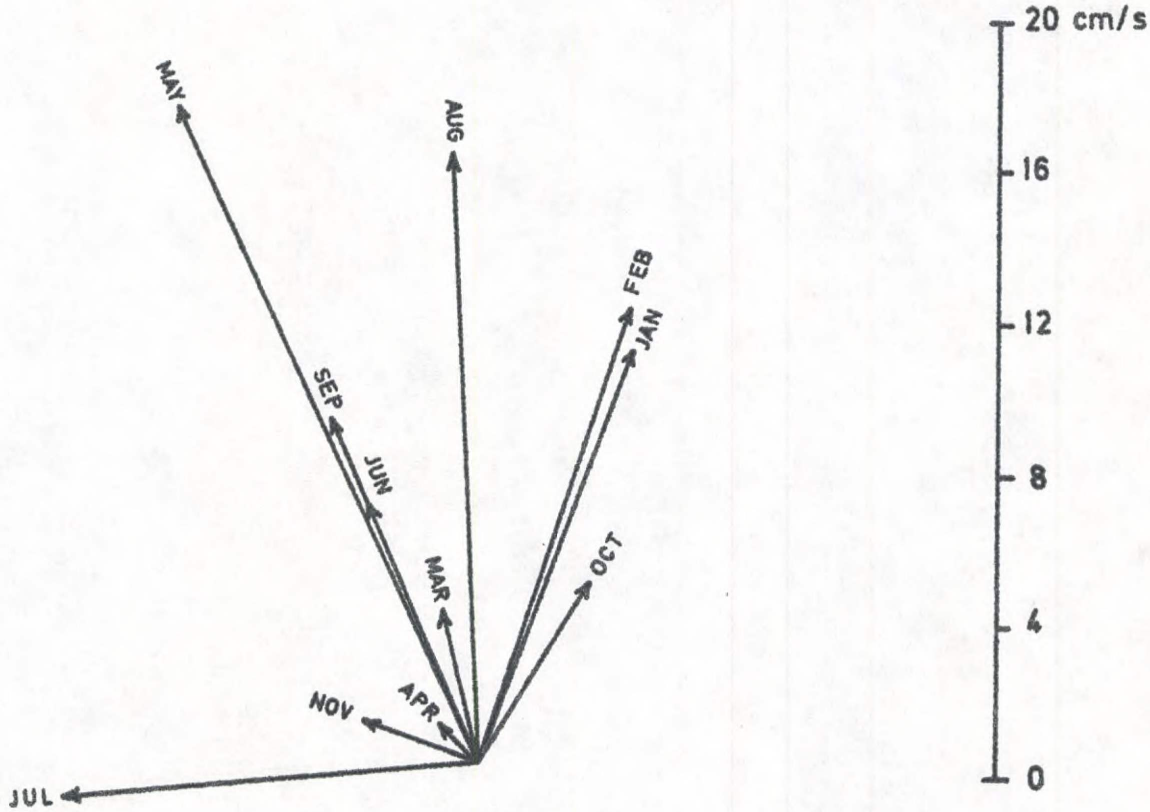


FIG. 4 c



c) 1977

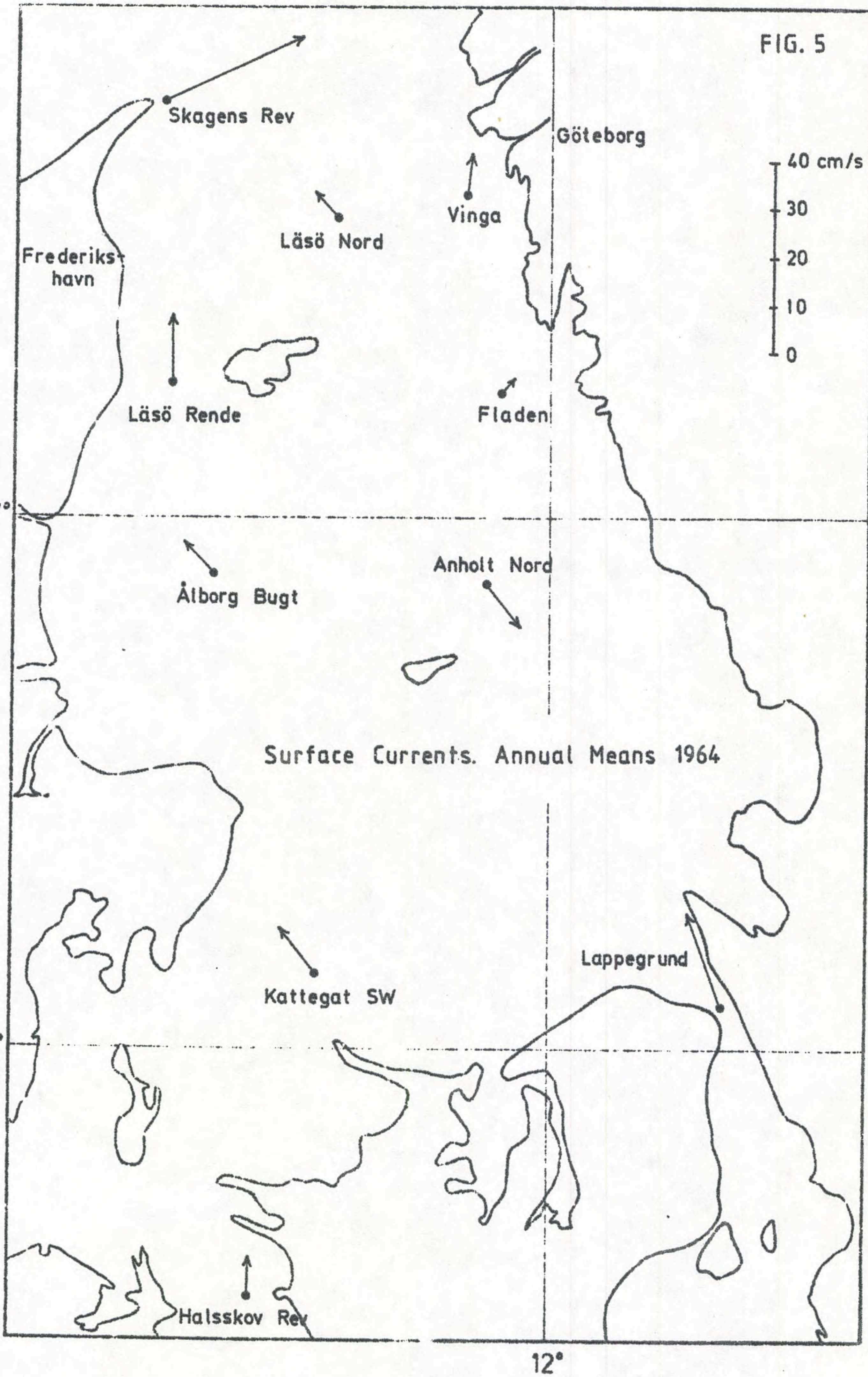
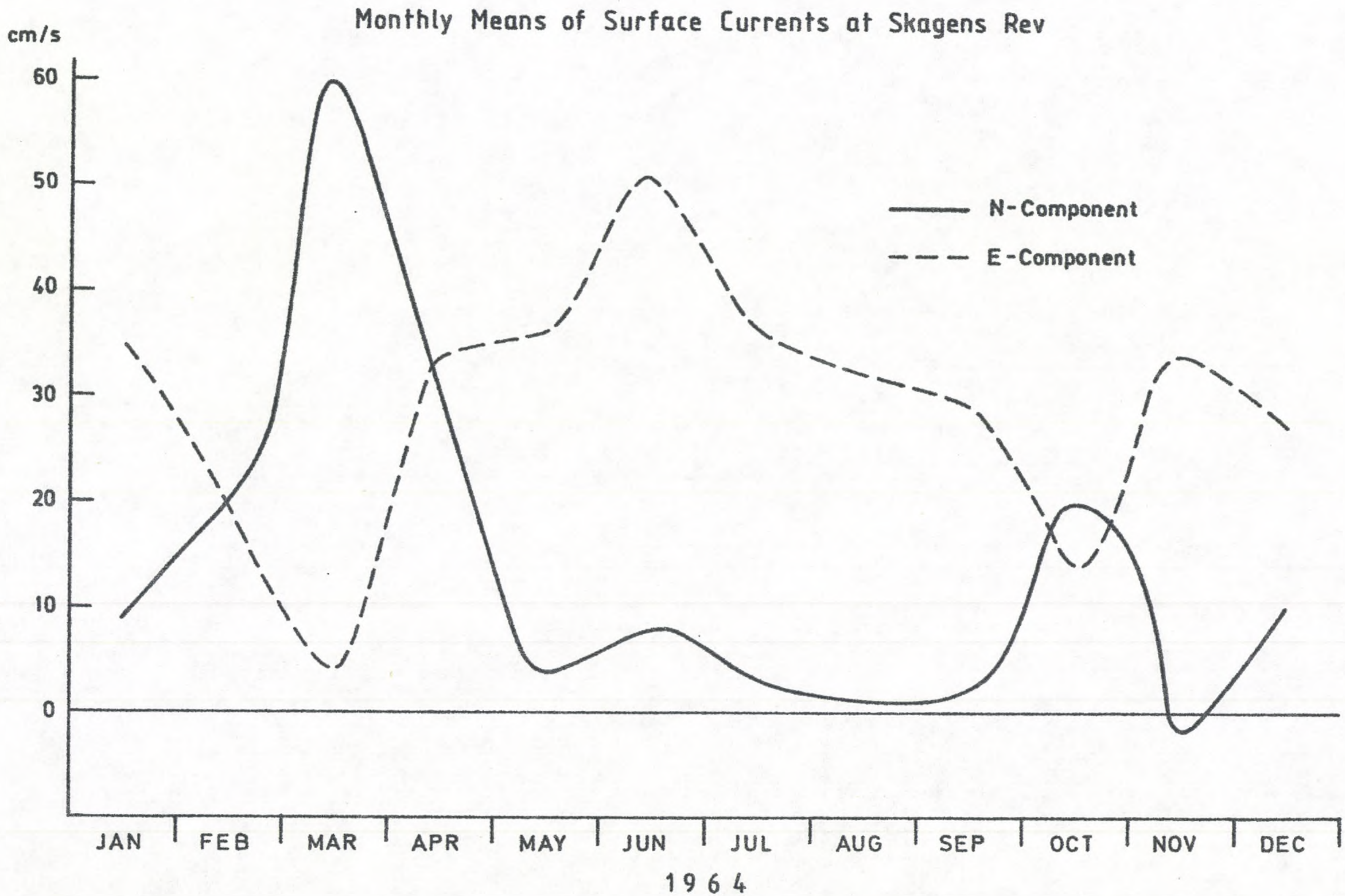


FIG. 5
Skagens Rev
Göteborg
40 cm/s
30
20
10
0
Vinga
Läsö Nord
Frederikshavn
Läsö Rende
Fladen
57°
Anholt Nord
Ålborg Bugt
Surface Currents. Annual Means 1964
Lappegrund
Kattegat SW
56°
Halsskov Rev
12°

FIG. 6a


Monthly Means of Surface Currents at Skagens Rev
cm/s
60
50
40
30
20
10
0
N-Component
E-Component
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1964

Monthly Means of Surface Currents. N-Components

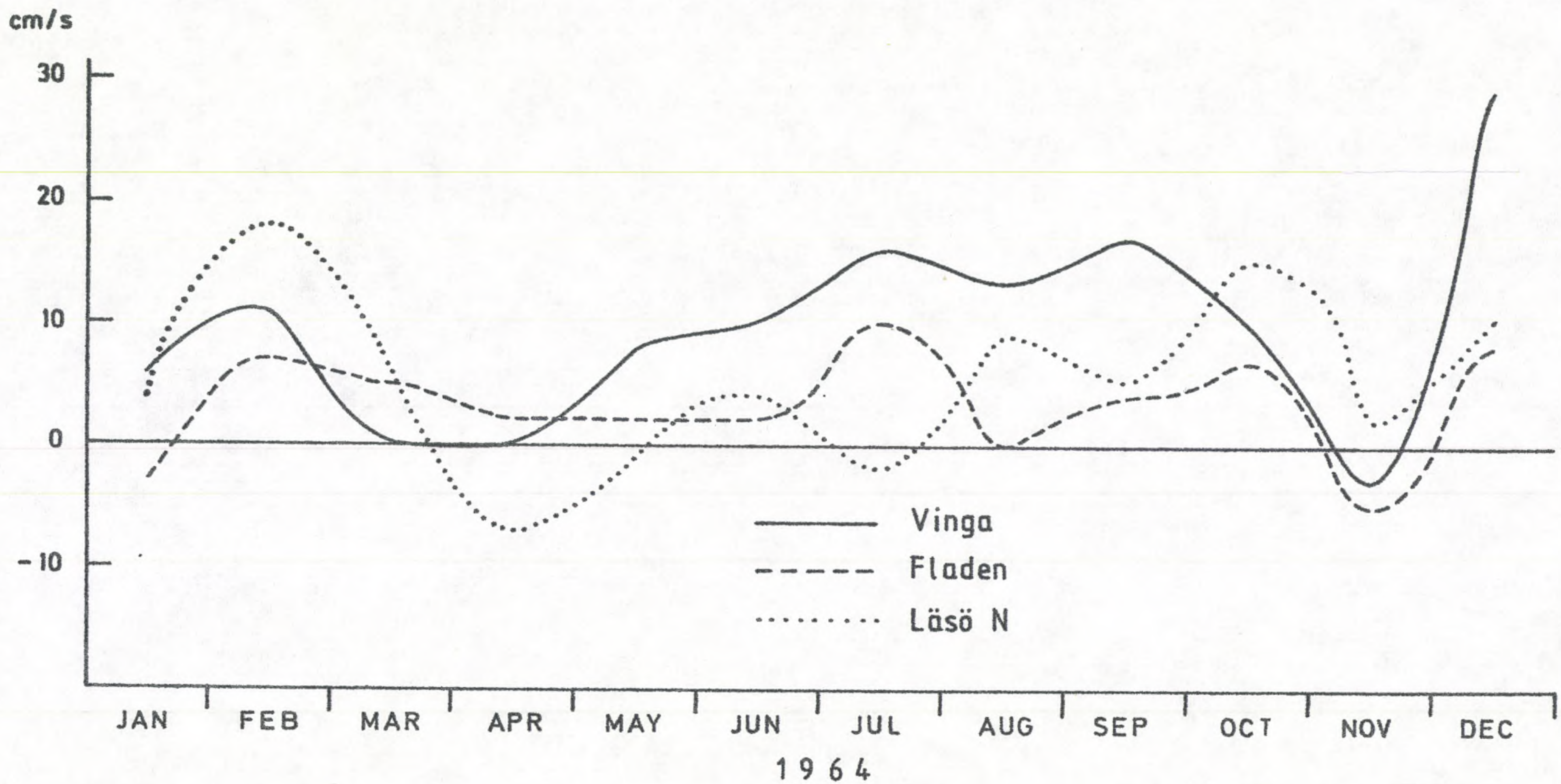
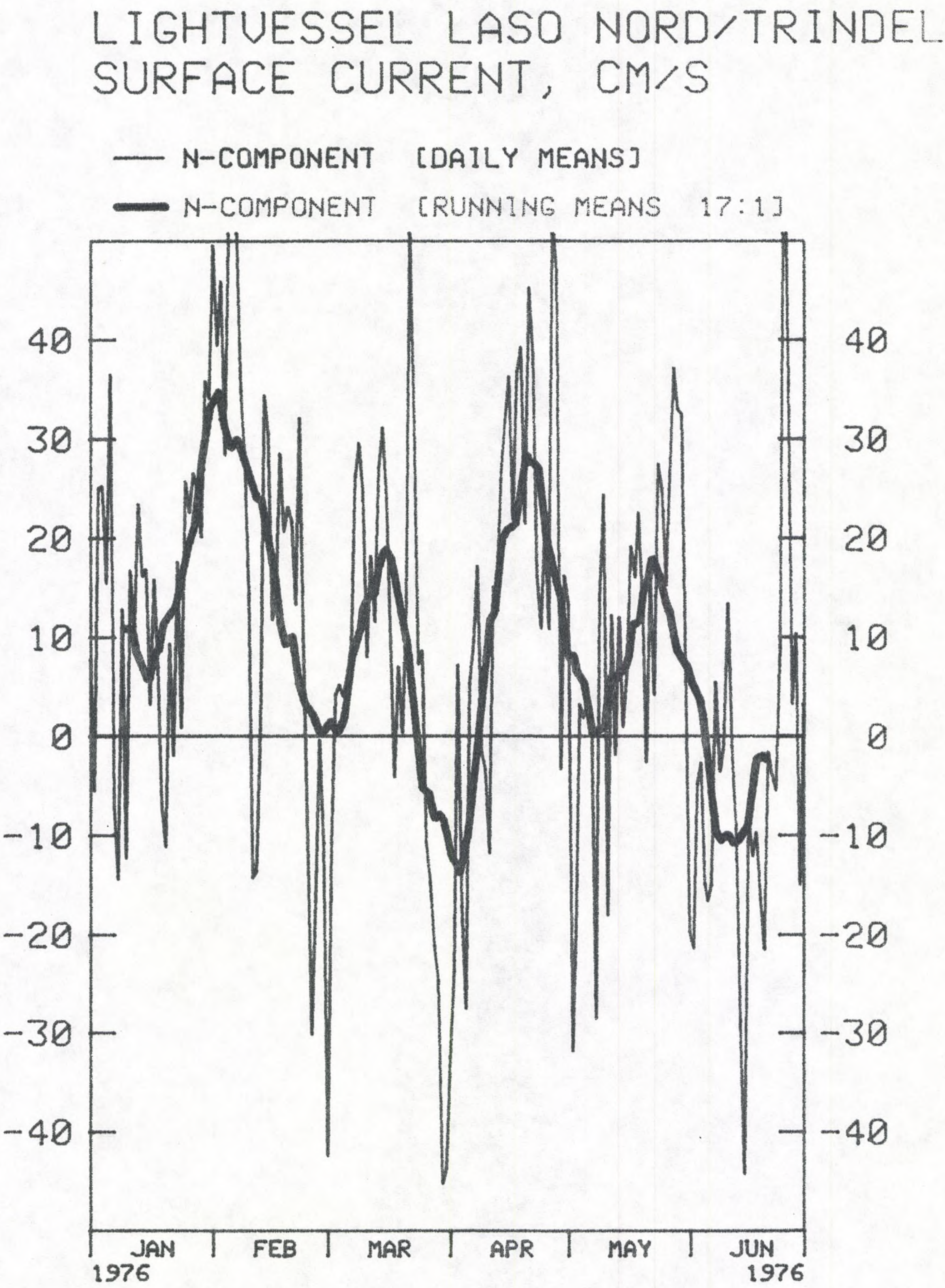


FIG. 6 b

FIG. 7


LIGHTVESSEL LASO NORD/TRINDEL
SURFACE CURRENT, CM/S
N-COMPONENT [DAILY MEANS]
N-COMPONENT [RUNNING MEANS 17:1]
40
30
20
10
0
-10
-20
-30
-40
JAN
FEB
MAR
APR
MAY
JUN
1976
1976

LIGHTVESSEL LASO NORD/TRINDEL
SURFACE CURRENT, CM/S

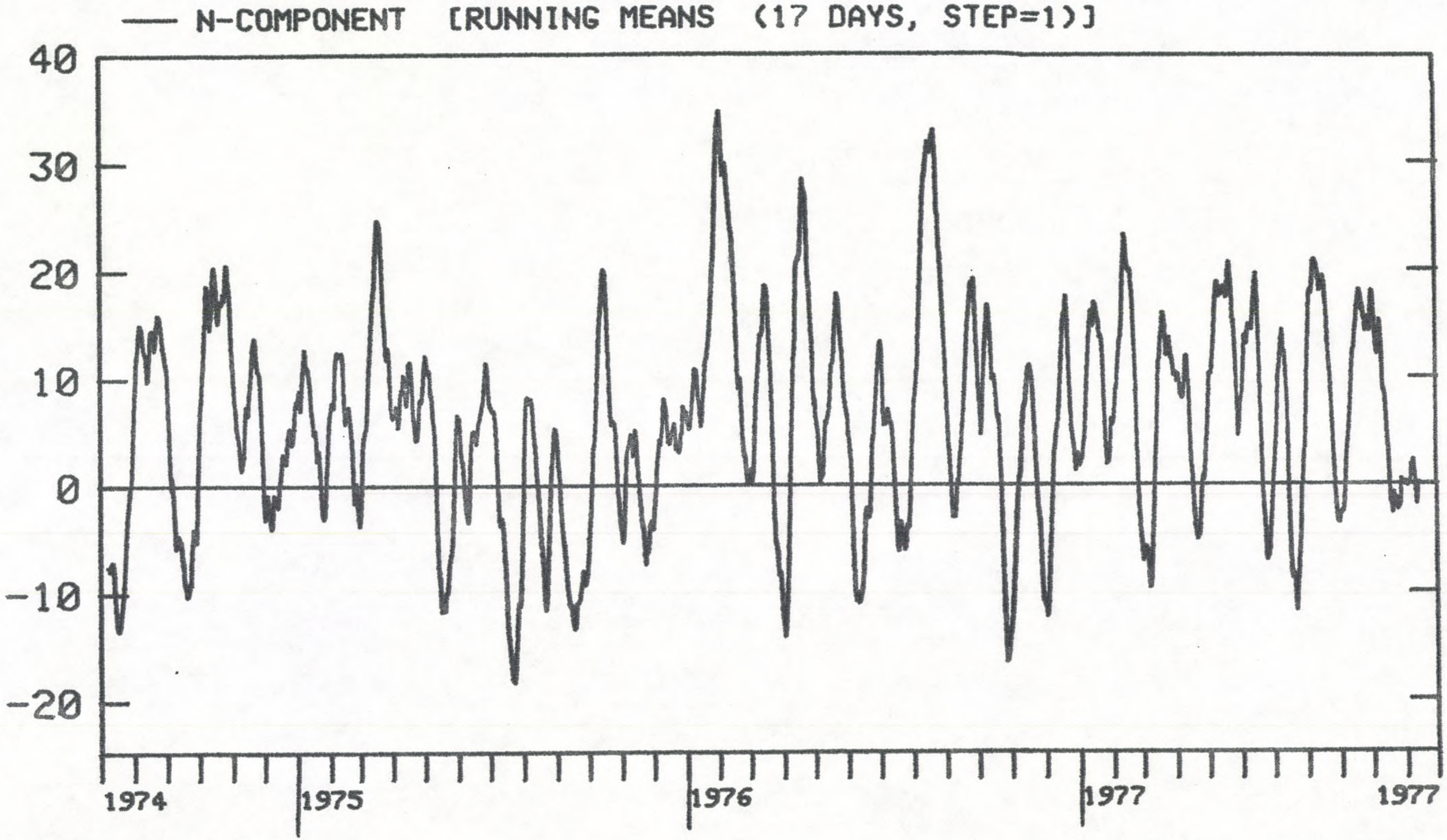
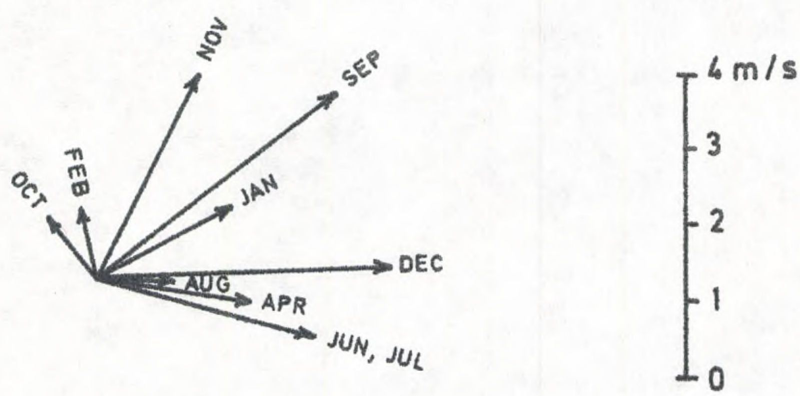


FIG. 8

Monthly Means of Winds

August 1974 – November 1977 at Läsö Lightvessel



Monthly Means = 0 for March and May