Ödsmål, Kville sn, Bohuslän

Hällristning
Fiskare från
bronsåldern

Rock carving
Bronze age
fishermen

MEDDELANDE från
HAVSFISKELABORATORIET LYSEKIL Nr 277

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THE BALTIC ENTRANCE PROJECT:

CURRENT MEASUREMENTS IN THE NORTHERN KATTEGAT

1974 - 1977

by

Peter Möller and Artur Svansson

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The Aanderaa measurements recorded during 1974-1977 are presented in a compressed form. In Chapter 2 the quality is described of not only the Aanderaa measurements but also of the gelatin pendulums, extensively used in the Project. Chapter 3 contains the discussion of the results, not only in relation to the Aanderaa currents but also the Aanderaa temperatures and salinities. In spite of the great time variability it is possible to confirm some of the spatial variabilities already displayed in the pendulum data.

Aa-mätningarna presenteras i comprimerad form. Kap. 2 innehåller en kvalitetsbedömning av såväl Aa-mätningarna som pendelströmmätningarna. Resultaten av Aa-ström, -temp. och -salthalt finns i kap. 3. Trots stor tidsvariabilitet, bekräftas en del av den rumsvariabilitet, som framkommit med pendelmätningarna.

19 Sammanfattningen skriven av: A. Svansson

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1. INTRODUCTION

The Baltic Entrance Project started in July 1974 and ended in December 1977. During this period a 10 stations section between Göteborg and Frederikshavn (Fig. 11) was surveyed 75 times. The daily measurements of current, temperature and salinity at the lightvessel Läsö Nord (later Läsö Trindel) were supplemented with total phosphorus determinations. A few automatically recording Aanderaa meters were used, the measurements of which will be presented in this paper. Lööf and Thorstensson (1980) described the section work methods and equipment, as well as the quality of measurements except for the pendulum current determinations which will be taken up in this paper.

The main aim of the Baltic Entrance Project was the determination of the transports of water and nutrients through the Göteborg-Frederikshavn section. By measuring simultaneously nutrients and current at the same observation point, we were able to compute the nutrient transport. The pendulum meters were well suited for this purpose, whereas the Aanderaa meters, recording every 10th minute, unfortunately were too few to suit this demand. Instead, the Aanderaa results can be used to determine the accuracy of the pendulum measurements in a similar way as the lightship data have been used (Lööf and Svansson, 1979). For the computation of tidal components and spectral characteristics the Aanderaa data are suitable in contrast to the sparsely in time sampled pendulum data.

2. THE QUALITY OF THE CURRENT MEASUREMENTS

The current measurements during this project have been carried out with two completely different methods. One method is intensive in time, the other in space. The first one consists of four selfrecording current meters deployed at two positions slightly south of the section line (Fig. 11). The other method is by means of gelatin pendulums (Haamer, 1973) which were deployed from the ship at the ten hydrographical stations of the section. The measurements were then made at standard depths (= 2.5, 5, 10, 15, 20, 30, 40,....m).

2.1. Aanderaa RCM 4.

The selfrecording instrument type is Aanderaa RCM4, an instrument equipped with a Savonius-type of rotor which integrates the current speed between the discrete samplings of the direction. The normal sampling interval is 10 minutes. In addition all instruments had temperature and depth sensors and most of the time, also a conductivity sensor was attached.

2.1.1. The anchoring system.

The rig consisted of an 8 mm steel wire with the current meters between a concrete anchor weight and a Divinyl cell subsurface buoy. The subsurface buoy (at about 10 metres depth) was connected to a small retrieval float via a thin rope. The weight was connected to another weight with a floating line and to that weight a retrieval float was connected with a synthetic rope. The whole rig was thus forming a 'U' with several possibilities for drag retrievals in case the floats were cut off. The thin wires minimized the drag forces caused by the currents.

2.1.2. The clock.

The instruments sample with an interval that is determined by a quartz clock. The manufacturer specifies the accuracy to ±2 sec/day. The in-situ measurements showed accuracies within these limits. The only problems encountered with the timing circuit, were a few cases where the instruments stalled intermittently in the middle of a measuring period. These malfunctions were probably caused by bad electric contact in the main battery circuit.

2.1.3. The pressure sensor.

The pressure sensor is a Bourdon tube driving a potentiometer. Since the pressure only was used to establish whether the instruments remained on constant depths throughout the exercise, the factory specified accuracy (in our case ±0.7 m) has not been investigated.

2.1.4. The conductivity sensor.

The conductivity which is a toroid water coupled transformer, has not been submitted to any thorough checks. The accuracy and long term stability could well be questioned, especially due to fouling. The manufacturer does not specify any accuracy.

2.1.5. The temperature sensor.

The temperature sensor was in most cases a Fenwal 2K ISO curve thermistor, with a factory specified accuracy of $\pm 0.15\ ^{o}$. When calibrated in a thermostated bath, the instruments were found to be better than the specifications ($< \pm 0.10\ ^{o}$).

2.1.6. The current direction.

The sensor is a compass needle which is clamped on to a potentiometer. The accuracy is stated to be $\pm 5^{o}$ in the speed range 5-100 cm/s and $\pm 7.5^{o}$ else. Single instruments have been individually calibrated and a maximum deviation from the straight line of 8^{o} have been encountered. This deviation is probably due to magnetization of the pressure case. This, however does not necessarily contradict the fact that within a 1-sigma distribution (>67% of the samplings) the accuracy could be the stated.

2.1.7. The current speed.

The current sensor is a modified Savonius rotor with a magnetic coupling to either a mechanical gear (in the older instruments) or an electronic rotor counter. The number of revolutions between each sampling is thus recorded and from this the speed could be calculated. The stated accuracy is ± 1 cm/s or $\pm 2\%$ of the actual speed, whichever is the greatest.

Single instruments have been individually calibrated by means of towing them in an 80-meters basin at constant speed. The Chalmers University of Technology kindly put their facilities at our disposal. The accuracy was found to be within the stated.

This type of rotor could however introduce an error in the presence of vertical movements, such as waves or unstable rigs (see eg. Karweit, 1974).

Due to the fact that speed is integrated and direction is a discrete value, another error could be introduced when the direction is fluctuating during speed integration.

Both these errors will cause a measured speed that is greater than real one. A way to partly avoid these drawbacks, is to use anchoring systems with low current drift (e.g. single ended steel wire systems) and to, anchore the meters well below the area of wave influence.

The influence of fouling to the Aanderaa rotor has been established by Jacobsen (1976). In the worst cases he found a speed reduction of 20 % compared to a new rotor. For medium velocities (10 - 70 cm/s), the linearity was however still sufficient.

2.1.8. The recording system.

The digitizing and recording system could introduce occasional errors. Errors in several channels at the same time, or in more significant bits, could be detected and corrected by the computer programs. Errors in the less significant bits could however hardly be detected, but there are no evidences of systematic errors.

The data return is about 75% counted on about half a million theoretically possible recordings. The most common reasons for no or bad data return are:

1) Time laps between instrument periods due to "ship" reasons (e.g. bad weather).

2) Instruments lost or moved due to fishing activities.

3) Instruments stalled due to battery faults.

4) Recording faults, usually due to contact problems. These contact problems were usually caused by a leaking pressure case.

The two first reasons are by far also the most common ones.

2.2. Gelatin pendulums.

In the gelatin pendulums two visual readings are made. The inclination of the compass pendulum gives the speed and the direction of the compass gives the current direction. Towing tests have shown a speed accuracy of ±1 cm/s. The accuracy of the direction measurement is not so easily determined, but a comparison with the Aanderaa meter is described in the next chapter. The swiftness with which the gelatin solidifies is, of course, dependant of the temperatures of the gelatin and the water. A too fast solidification might "freeze" the pendulum before it is stable in the water. Therefore it is best to use different concentrations of gelatin during summer and winter.

2.3. A comparison between Aanderaa RCM4 and gelatin pendulums.

In order to determine the quality differences between the two types of current meters, the R/V Thetis was anchored for two days in northern Kattegat (station GF4). A rig with five RCM4s was put out close (100-200 m) to the anchoring point. The instruments were attached at 15, 30, 50, 60 and 70 meters depth and were measuring with a 2.5 minutes interval. The depth to bottom was 79 meters. About once every hour a system of gelatin pendulums was put out from the research vessel. Each pair of measurements (same time, same depth) was plotted in figure 1. In this figure, one can see occasional large deviations from the ideal slope (=1), especially for the direction measurements. The statistics of the material could be seen in the table below.

Table 1.
Mean differences between Aanderaa (AA) and gelatin pendulums (GP).

	Speed	Direction
Mean difference (AA-GP)	0.8 cm/s	-0.2°
Standard deviation of mean	0.4 cm/s	2.5°
Number of measurements	155	200

The same computations were also applied to the material divided into three speed classes (<10 cm/s, 10-20 cm/s, >20 cm/s). the result of this could be seen in figure 2. There is a tendency for Aanderaa to measure a greater speed values than the gelantin pendulums, at least above 10 cm/s. This tendency is enlarged above 20 cm/s. When it comes to direction, the uncertainty is greatest at low speeds, where 33 % of the measurements deviates with more than 15°. The conclusion one can make out of this investigation is that a single measurement, especially of direction, is fairly uncertain, while repeated measurements converges very soon to nearly the same result (cf. figure 3). The greater mass of the Aanderaa and its combined sampling (direction) and integration (speed) could cause errors in the low speed (<10 cm/s) area. When the pendulums are lowered they might rotate and thus build up a biased torsion in the compass suspension, a torsion which might introduce an error in the direction measurements.

3. THE RESULTS OF THE AANDERAA METER MEASUREMENTS.

In December 1974 two Aanderaa meters were anchored near the Danish lightvessel Läsö Nord, at 15 m and 30 m depths (Rig no. 600). Unfortunately on 75-03-11 the lightvessel was moved to a new position, 5 nm SE of the old one. At the same time its name was changed to "Läsö Trindel". The Rig no. 600 continued, however, to be effective until the middle of April 1976 with some failure periods (Fig. 7).

During the Inout period of the International North Sea Program Jonsdap -76 (See e.g. Möller and Svansson 1978), a new Rig (no. 604), was deployed at the deepest part of the GF section, of practical reasons to the south of it, however. The Inout period lasted 40 days during March-April 1976, but Rig no. 604 continued to be effective during March-September 1976 at 8 m and 30 m depths and from December 1976 at 15 m and 30m (Fig. 8).

From May 1976 Rig no. 606 near the position of "Läsö Trindel" was deployed with instruments at 15 m and 30 m (Fig. 9).

3.1. TEN MINUTE VALUES OF CURRENT DATA.

An interval of 10 minutes was used troughout all the Aanderaa measurements. Fig. 4 shows a "stick" diagram of data obtained during one week in April 1976. The semidiurnal tide predominated during that time.

Fig. 5 shows the result of tidal analysis with the tidal program TIFA (Bieler and Svansson 1977). The figure is similar to the result presented in Bieler et al (l.c.), but there are differences which calls for a more thorough investigation.

Fig:s 6 a-g show a statistical treatment of the current meter data. They display the variability of the total mean vectors presented in Fig. 11.

3.2. MEAN VALUES OF CURRENTS.

In Bieler et al (l.c.) hourly means was used both for tidal and spectral analysis. As false frequencies may be introduced the spectral analysis was repeated with data filtered according to Pillsbury et al (1974). The differences was quite unsignificant. So far no tidal analysis was made with the filtered data. The tidal ellipses shown in Fig. 5 were derived by the hourly means.

Fig:s 7-9 show daily means of all the Aanderaa current data. In waters where tides are the dominant feature, 24 hour means may contain false frequencies as well as leftovers from the semi-diurnal and diurnal tides, particularly the solar components. In that case a filter technique is recommended. As tidal currents are not highly predominant in our material Fig:s 7-9 hopefully reflect a rather correct non-tidal state. In Möller and Svansson (1978) the daily means measured at Rig no. 604 during March-April 1976, are displayed at a more readable scale. It is there shown that most variations are caused by winds and atmospheric pressure variations. Sea level data are well correlated with the currents.
In Möller et al (l.c.) also is drawn a curve of the daily means of the "Läsö Trindel" surface current

data. Table 2 shows some comparisons of 14 day means from the rigs as well as from the lightvessel. Also the surface current statistics of the Läsö L/V data in Lööf and Svansson (1979) should be compared with our Fig. 6.

Fig. 10 shows daily mean vectors of rig no. 604 (8 m) currents presented as stick diagrams.

Table 3 shows overall means of both temperature, salinity and currents. Standard deviations are naturally high for temperature but are extremely great for currents. The mean current vectors at 15 and 30 m have also been inserted in Fig. 11. Comparison with pendulum data means (Szaron 1979) show good agreement.

The means in Table 3 (and Fig. 11) do not represent the same time period. But a study of contemporary 14 days periods in Table 2 gives us reason to believe that the means represent long term means. The currents at Rig no. 604 (and GF Station no. 4) are more or less longitudinal flowing toward the Skagerrak at 8 m depth and in the opposite direction at 15 and 30 m. But at the lightvessel positions there are no counter currents; the directions are toward NW at both depths.

3.3. TEMPERATURE AND SALINITY MEASUREMENTS.

It has already been mentioned that all the Aanderaa instruments had temperature sensors. Most of the time also a conductivity sensor was attached. Salinity was calculated with the formulae in the Aanderaa Operating Manual (1979).

3.3.1. COMPARISON WITH LÄSÖ L/V DATA.

Comparison was carried out between temperatures measured at about 8 hours in the Aanderaa instruments and at L/V Läsö. There was a correlation of 0.91 for a 45 day series of 30 m data collected in Rig. no. 600 and at "Läsö Nord". A comparison for a 43 day long series of 30 m data from Rig. no. 606 and "Läsö Trindel" gave a correlation coefficient of 0.73. The lower value may be explained by the slightly greater distance between rig and lightvessel in the latter case. (Fig. 12).

Salinity is supposed to be less accurately measured in recording instruments. Fouling, for instance, may cause a false long term trend. The same time period as that one resulting in the temperature correlation coefficient of 0.73 was used also for salinity, the coefficient now being equal to 0.52. There is reason to believe that difference in distance even if small may cause differences between L/V and rig. Fig. 13 shows temperature and salinity at about 30 m depth measured during July and August 1977. The curves follow each other (there is also a negative correlation between temperature and salinity) but there are slight phase differences; at the end of the period both temperature and salinity deviate considerably.

3.3.2. DAILY MEANS.

Fig:s 14-16 show daily means of all the temperature and salinity data. One may ask why great variations in one parameter is not always reflected in variations of the other one as the case with data presented in Fig. 13. Johansson and Svansson (1974) showed that for Bornö (in the Gullmar Fjord) data during November-March the correlation coefficient is about 0.9 and for June-August about -0.9. For remaining Spring and Autumn months the coefficient is higly variable.

4. DISCUSSION

The purpose of this paper is to present the Aanderaa measurements recorded during 1974-1977 in the Baltic Entrance Project in a brief and clear form. In Chapter 2 is described the quality of not only the Aanderaa measurements but also of the gelatin pendulums, also extensively used in the Project.

The great variability in the current data is striking. The standard deviations are usually much higher than the mean values (Table 3). Lööf and Svansson (1979) compared section data with L/V data. A similar treatment of Aanderaa data would be interesting, especially in context with the work which is going on to recompute the transport values derived by Szaron (1979). In this recomputation it will be tested if the pendulum meter data can be corrected by means of the Aanderaa measurements.

Above was suggested improved methods for tidal and spectral analysis.

5. ACKNOWLEDGEMENTS

Thanks are expressed to the crews of the R/V Thetis and the R/C Ulla Rinman for the toilsome work with the launching and recovering of the current meters, to Eva Gun Thelén and Anita Taglind who made the drawings and to Margarethe Garton who made the typewriting.

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TABLES

TABLE 2. Current comparisons

Time period	L/V Läsö N cm/s		GF600-15 cm/s		GF600-30 cm/s	
	N	E	N	E	N	E
741214-741227	+1.0	-8.1	+14.5	-3.7	+11.5	-7.3
741228-750110	+7.9	-11.5	+6.0	-4.1	+2.1	-6.4
750111-750124	+4.5	-10.1	+14.4	-8.2	+10.2	-10.2
750125-750207	+6.6	-2.2	+15.4	-13.3	+4.7	-9.2
750214-750227	+6.7	-13.5	+11.4	-20.0	+1.1	-7.6

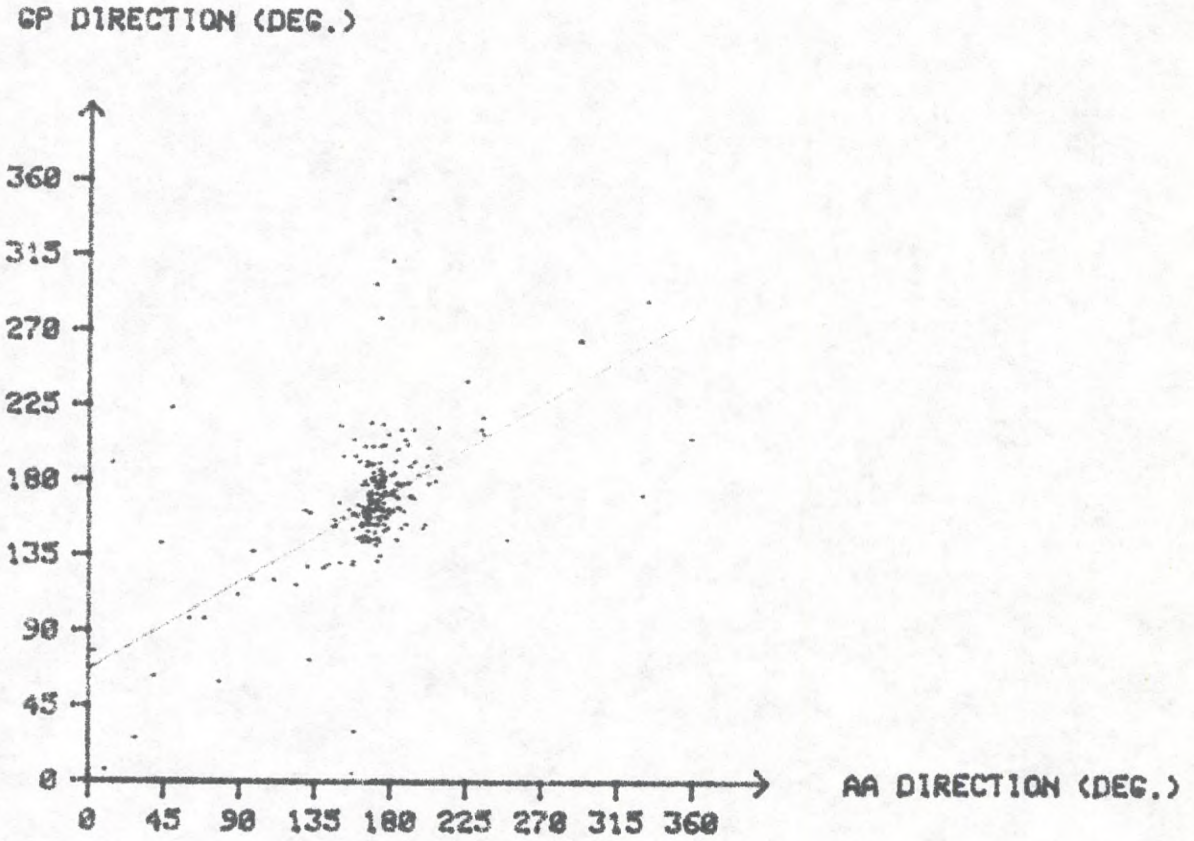
Time period	L/V Läsö T cm/s		GF606-15 cm/s	
	N	E	N	E
760427-760510	+6.6	-2.6	-1.1	+0.7
760511-760524	+9.1	-5.9	+4.9	-1.1
760525-760607	+5.7	-12.9	+3.1	-2.8
760608-760621	-9.9	-14.3	-9.4	-0.4
760624-760707	+13.8	-11.0	+4.4	-4.4

TABLE 3. Overall means(MV) and standard deviations(SD).

Meter number	Time period		t °C	S °/oo	Depth m	Current component N cm/s	Current component E cm/s	Current vector Dir. °	Current vector Vel. cm/s
600-15	19741213-19760412	MV	8.15	29.08	15.0	+5.1	-10.6	296	11.7
		SD	5.07	3.12	1.2	18.2	14.3		
600-30	19741213-19760412	MV	8.55	33.04	29.5	+1.1	-6.3	280	6.4
		SD	4.38	0.98	1.5	13.9	11.5		
604-8	19760308-19760928	MV	11.04	-	9.8	+0.7	+0.6	44	0.9
		SD	5.85	-	1.1	17.5	14.3		
604-15	19761221-19771209	MV	8.06	28.11	12.7	-3.9	+2.5	147	4.6
		SD	4.96	3.71	3.0	19.5	15.7		
604-30	19760308-19771003	MV	8.10	33.47	30.2	-7.4	+1.3	170	7.5
		SD	3.89	1.30	2.1	16.0	11.2		
606-15	19760426-19771119	MV	11.06	30.43	15.0	+4.3	-2.0	335	4.8
		SD	4.78	2.21	2.0	21.9	11.8		
606-30	19760426-19771209	MV	9.84	33.30	28.9	+3.4	-2.4	325	4.1
		SD	3.68	0.97	1.8	20.1	7.6		

A DIRECTION COMPARISON (AANDERAA/GELATIN).

FIG 1



A SPEED COMPARISON (AANDERAA/GELATIN PENDULUMS).

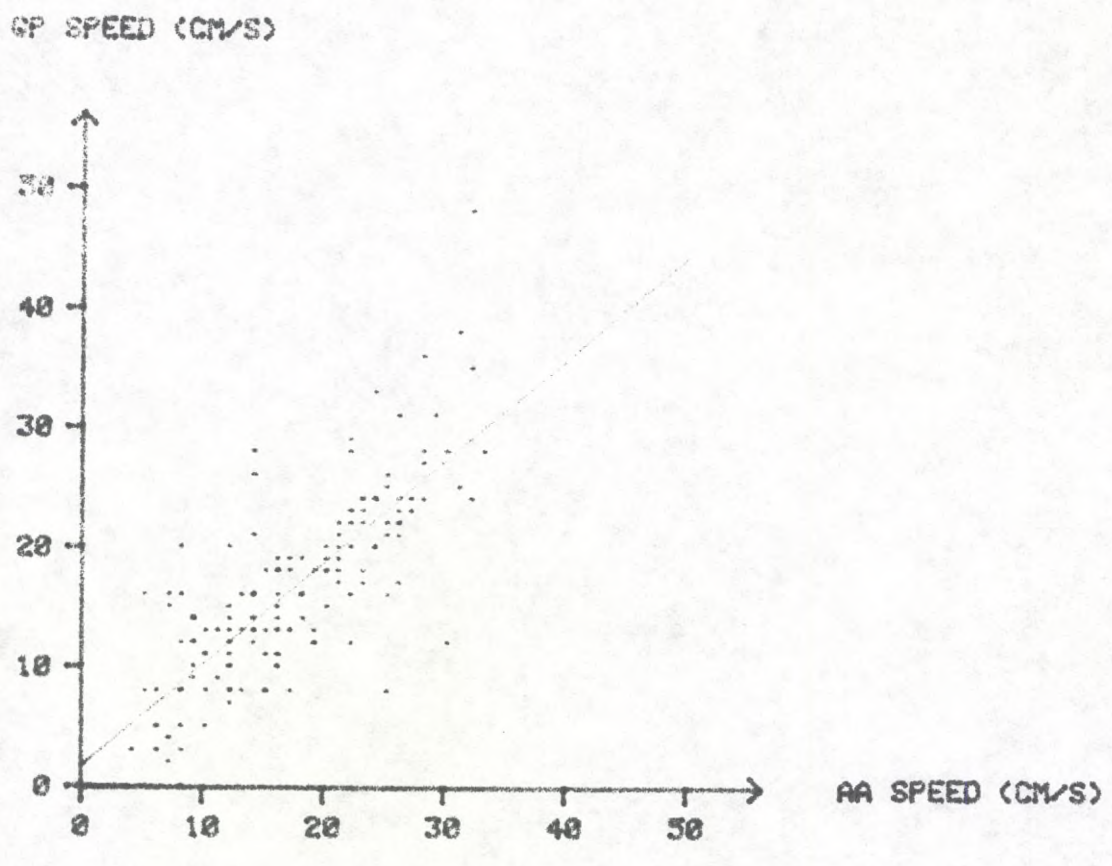
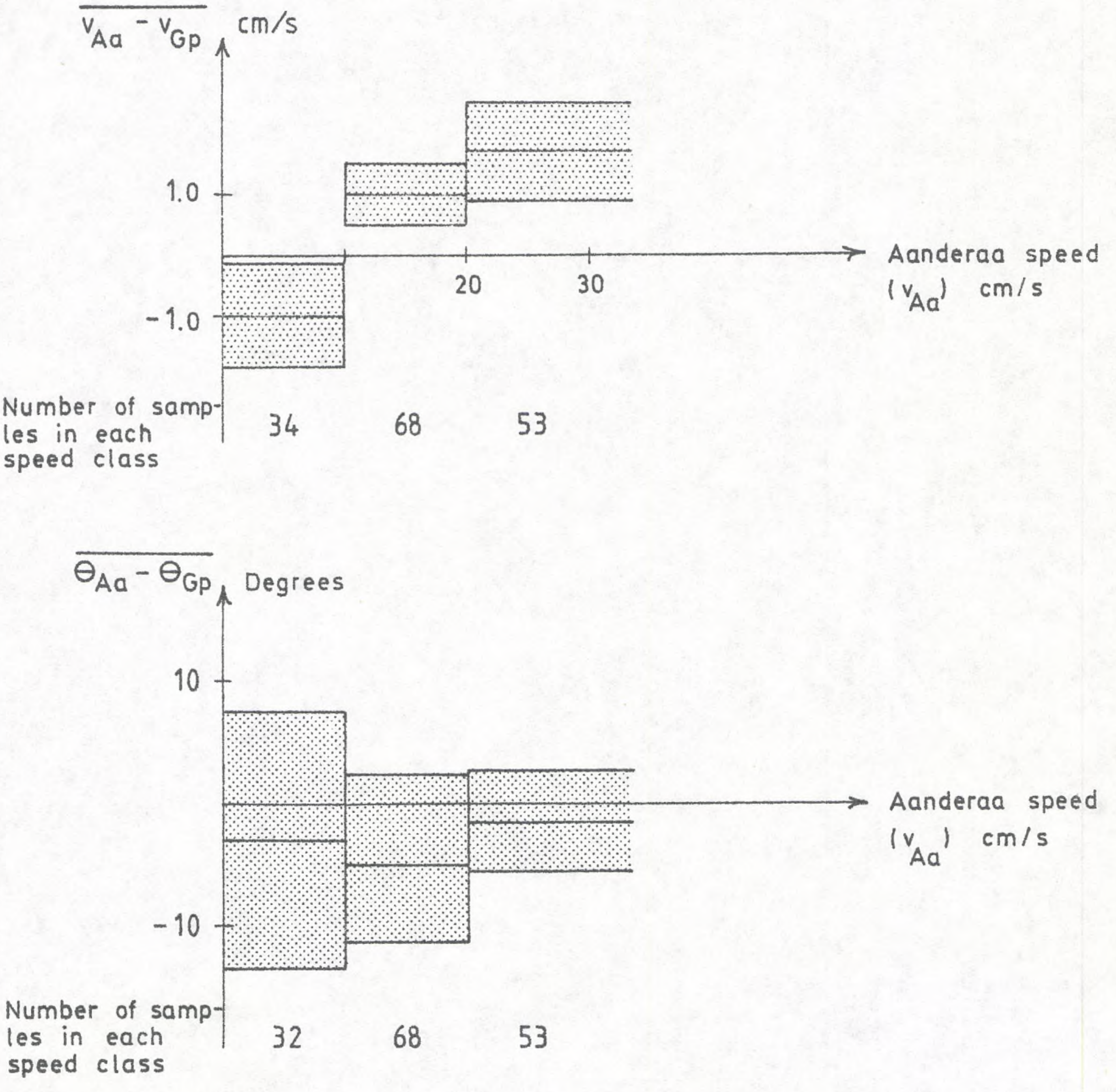


FIG 2

Mean differences between Aanderaa recording current meter (Aa) and gelatin pendulums (Gp) diveded into speed classes



A comparison between Aanderaa (——) and gelatin (- - -) current measurements

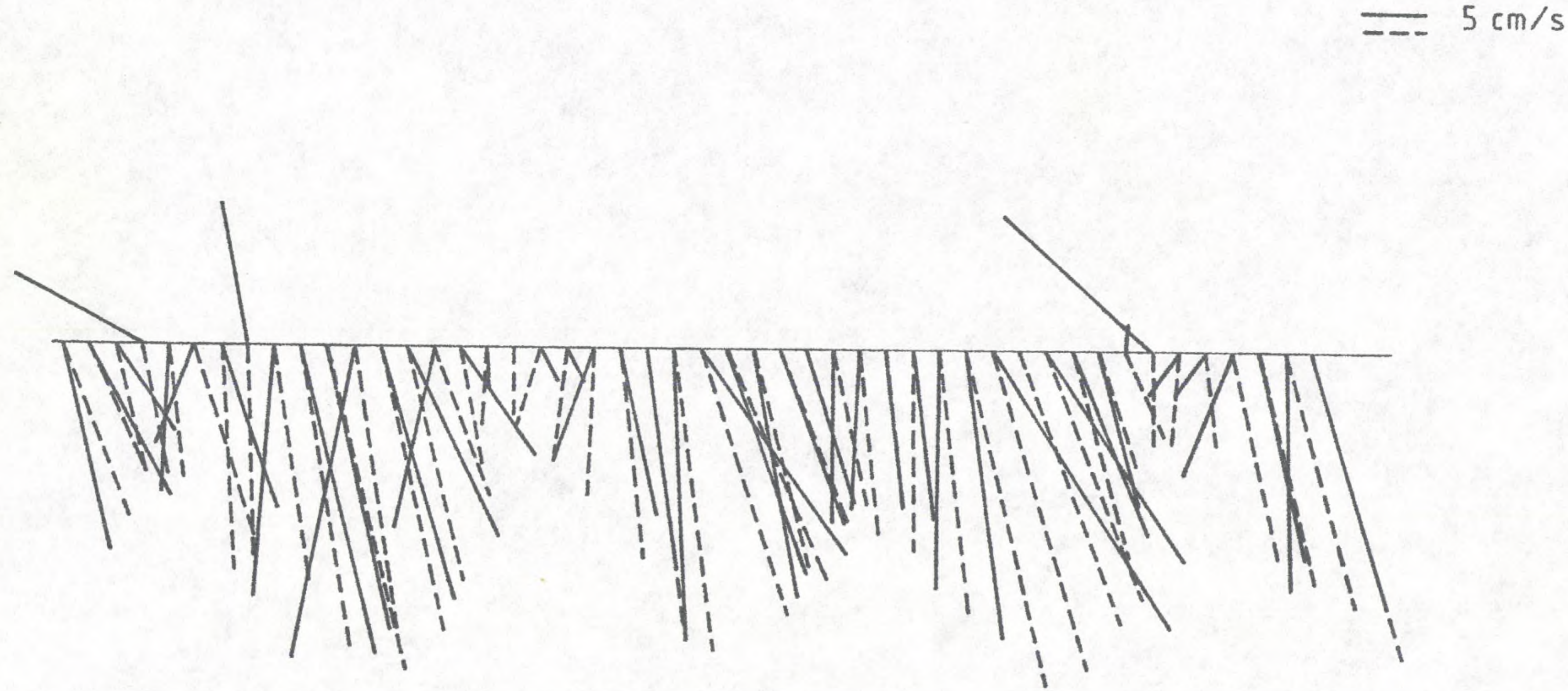


FIG 3

GF-SECTION

CURRENTS MEASURED EVERY 10TH MINUTE

STATION 604 30 METER

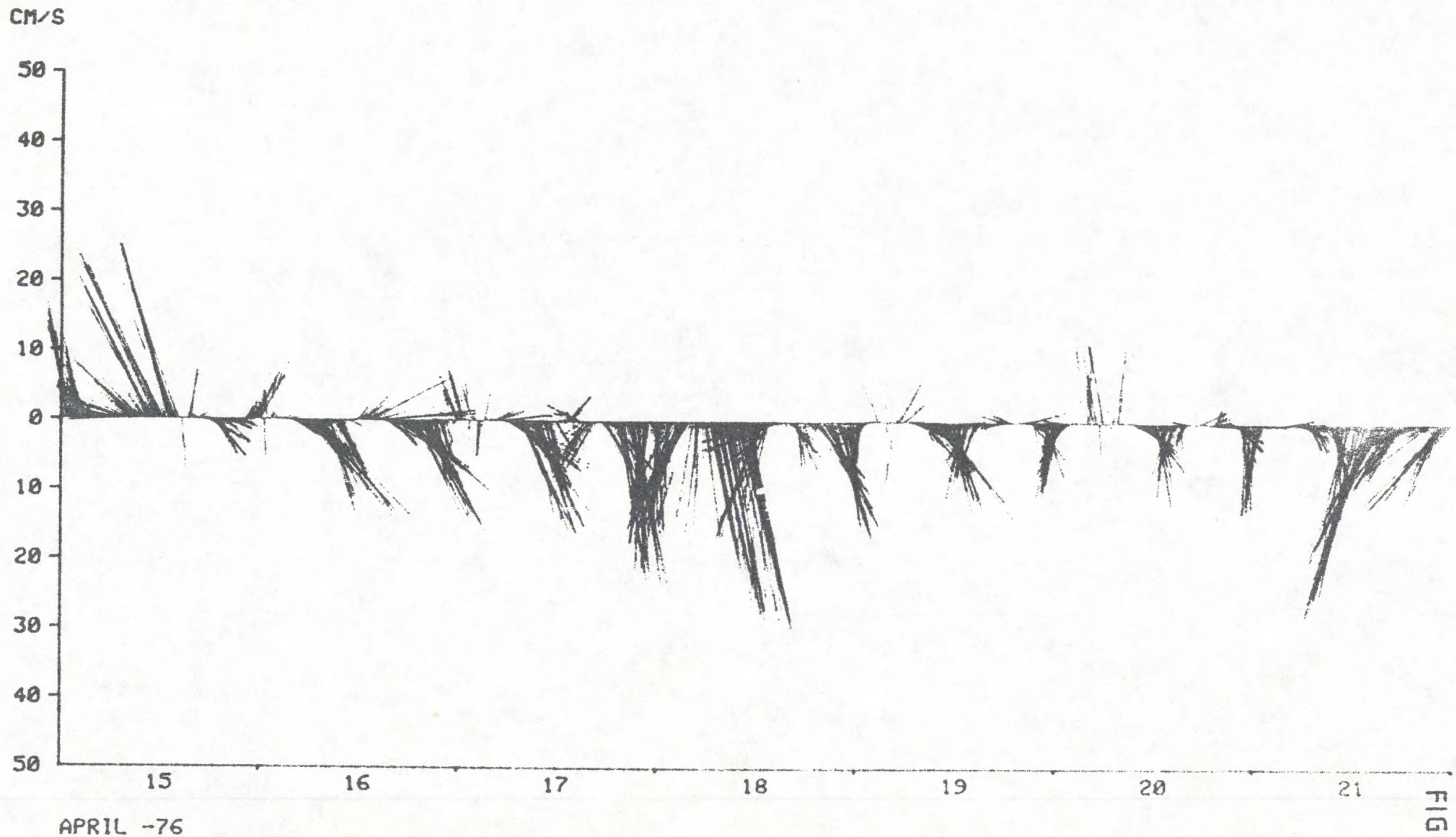
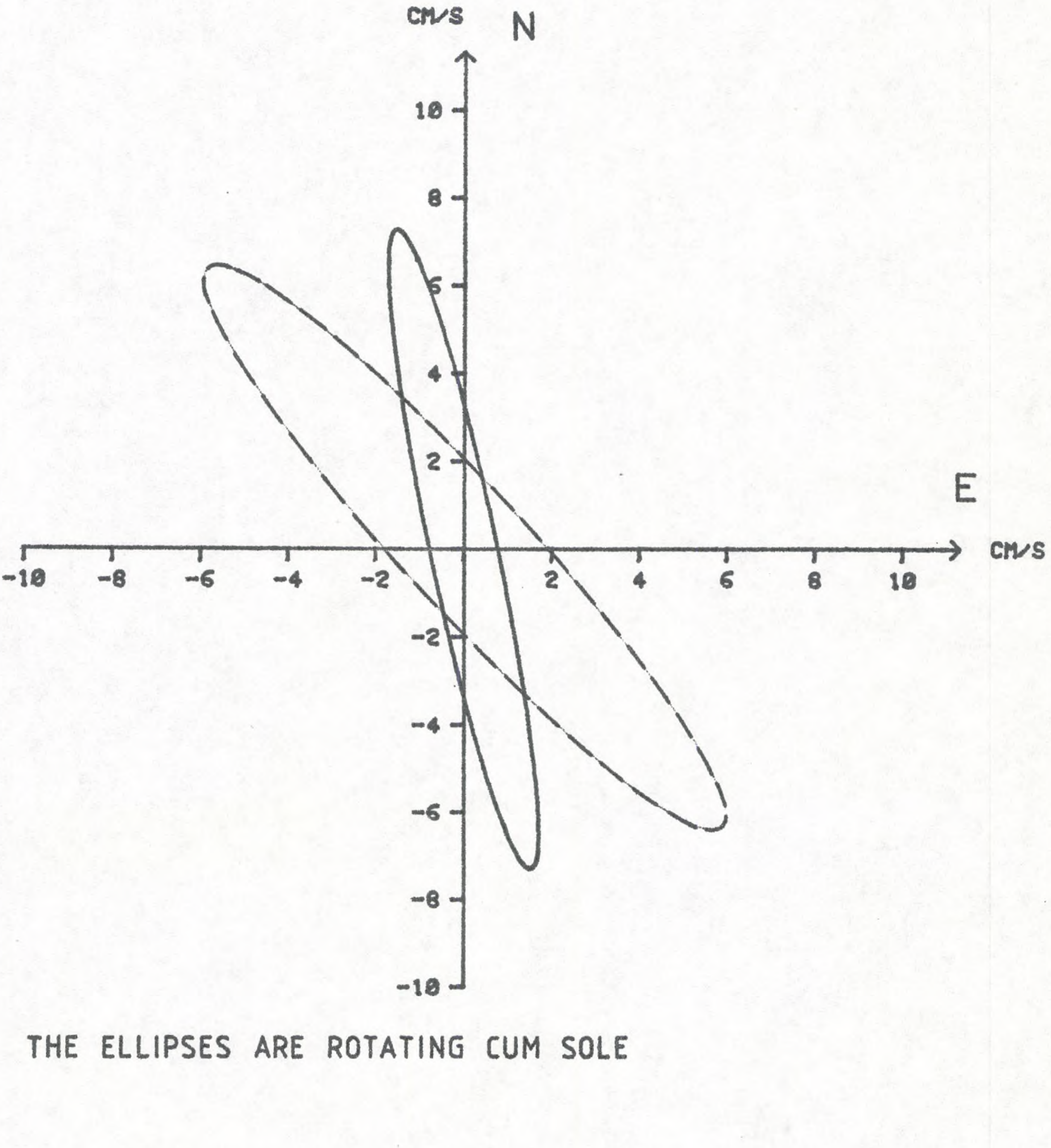


FIG 4

FIG 5

TIDAL CONSTITUENT M2 AT GF604 8 METER — — —

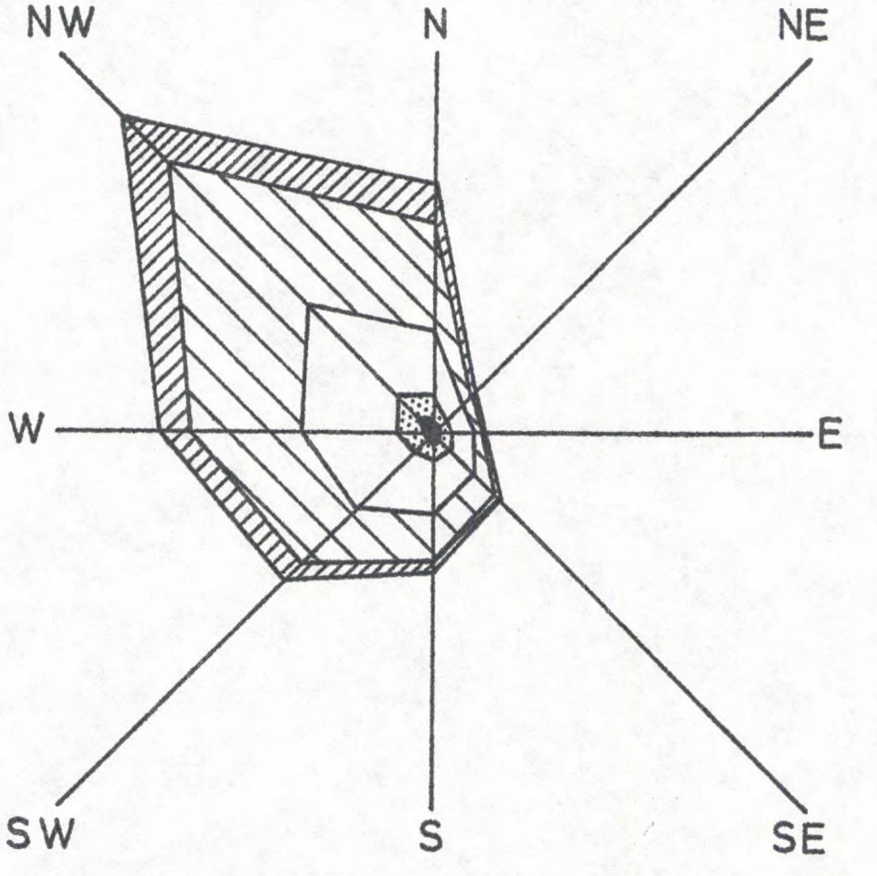
AND 30 METER (JONSDAP 76) ———



THE ELLIPSES ARE ROTATING CUM SOLE

FIG 6 a

600 - 15 m



0 - 5 cm/s
5 - 10 "
10 - 20 "
20 - 40 "
40 - "

2 mm ~ 1%

600 - 30 m

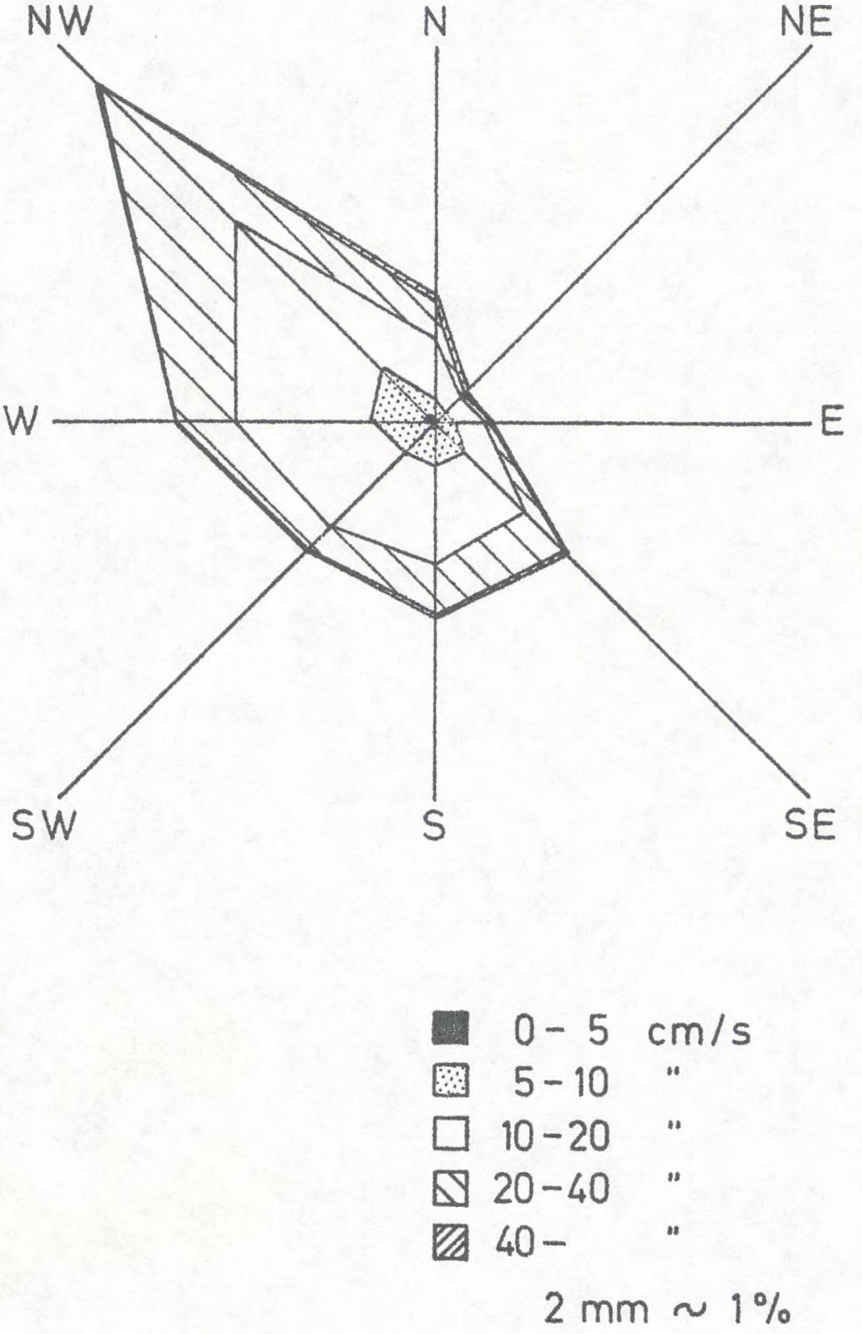


FIG 6c

604 - 8 m

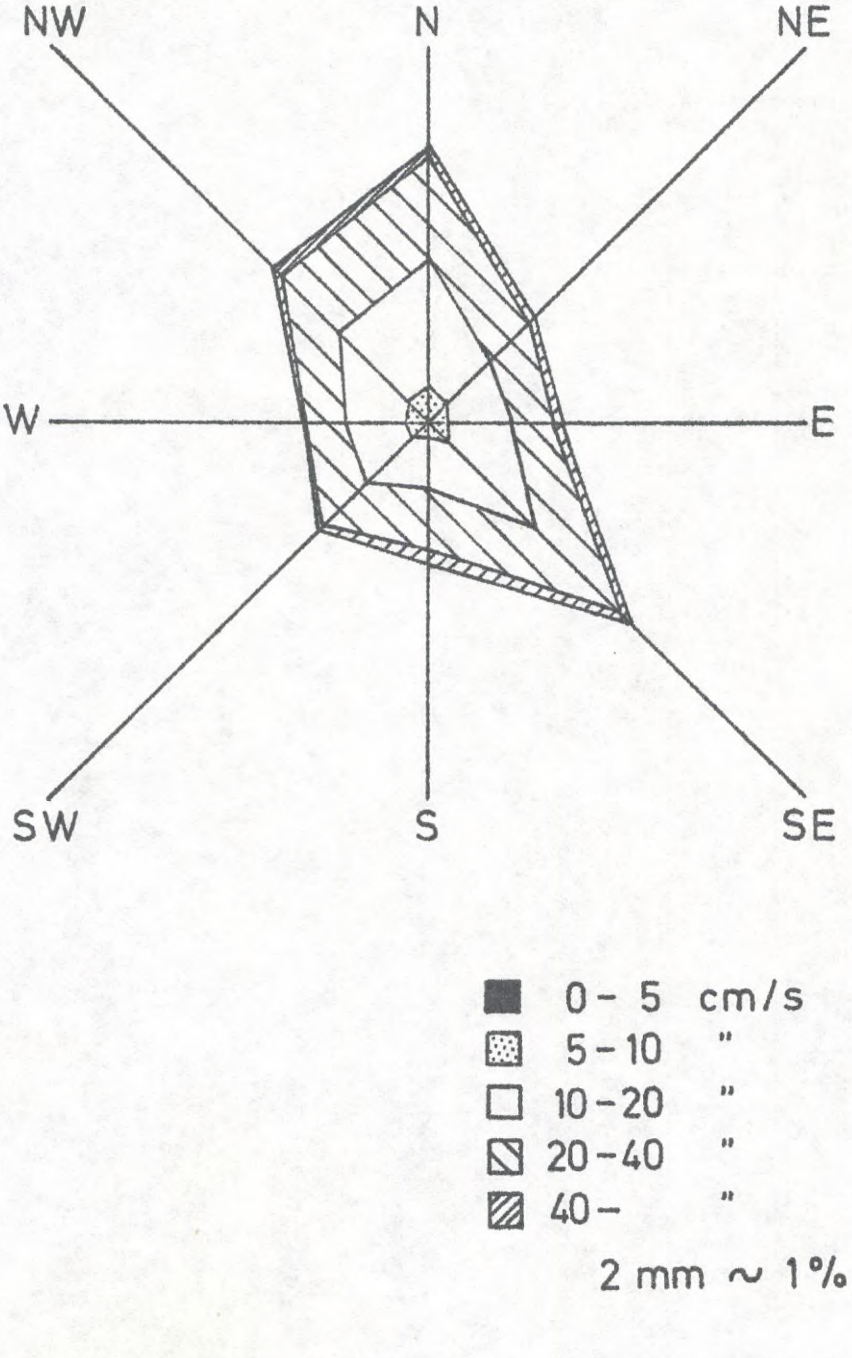


FIG 6d

604 - 15 m

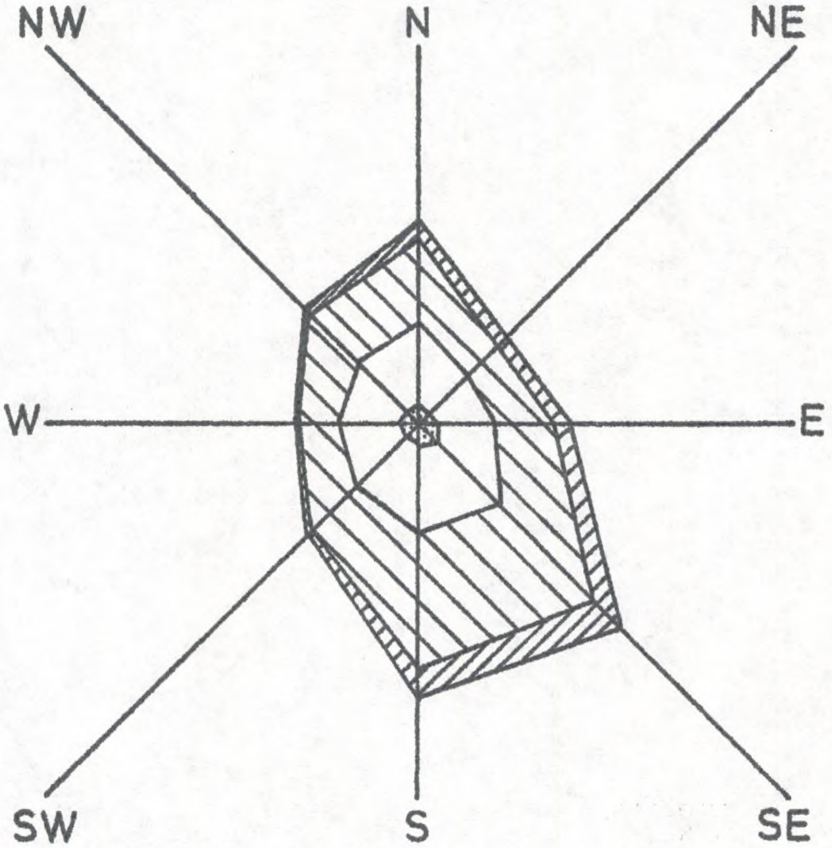
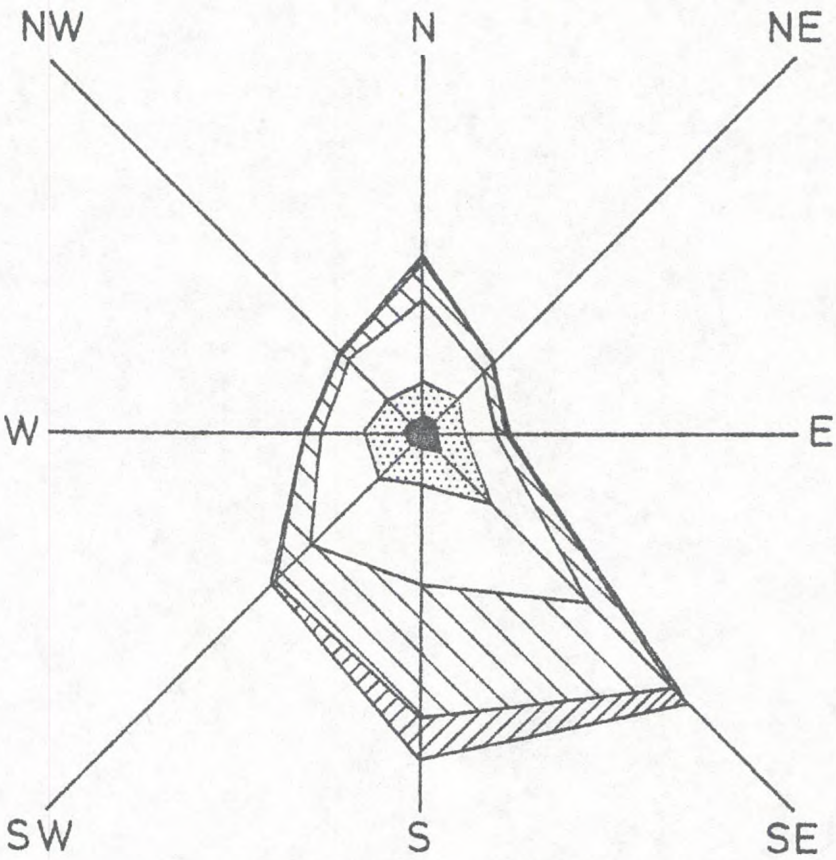


FIG 6e

604 - 30 m



0- 5 cm/s
5-10 "
10-20 "
20-40 "
40- "

2 mm ~ 1%

FIG 6 f

606 - 15 m

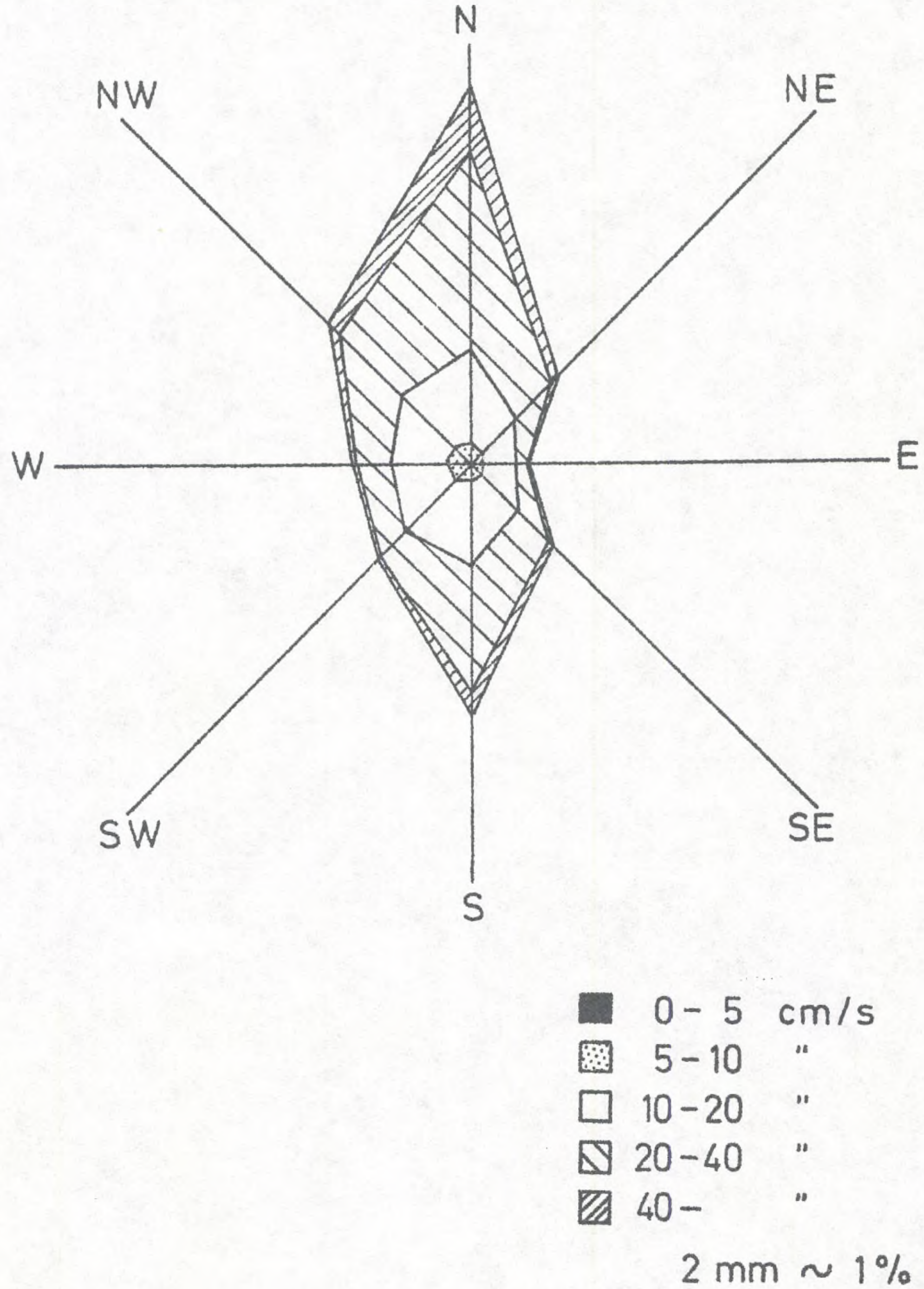
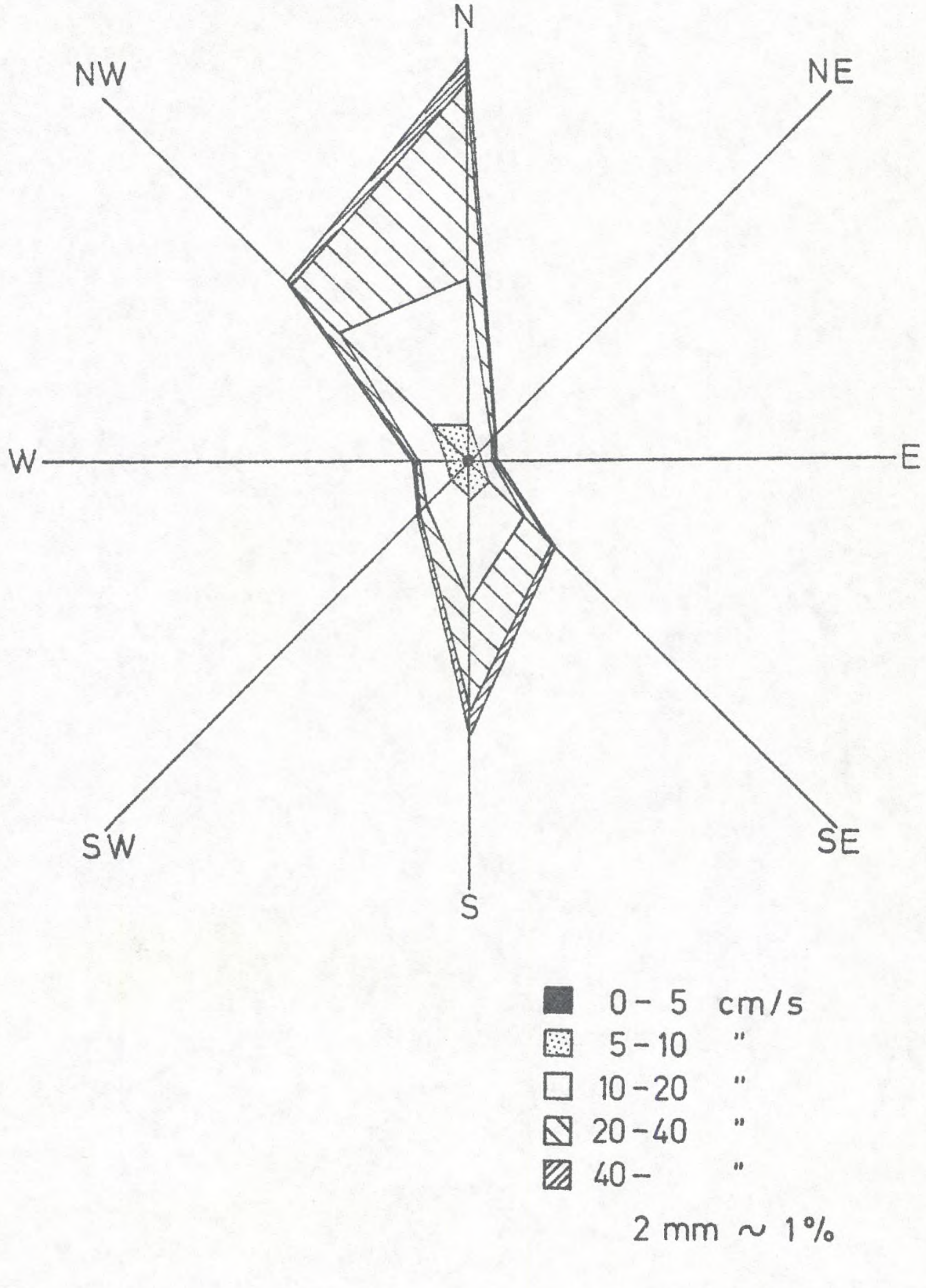


FIG 6 g

606 - 30 m



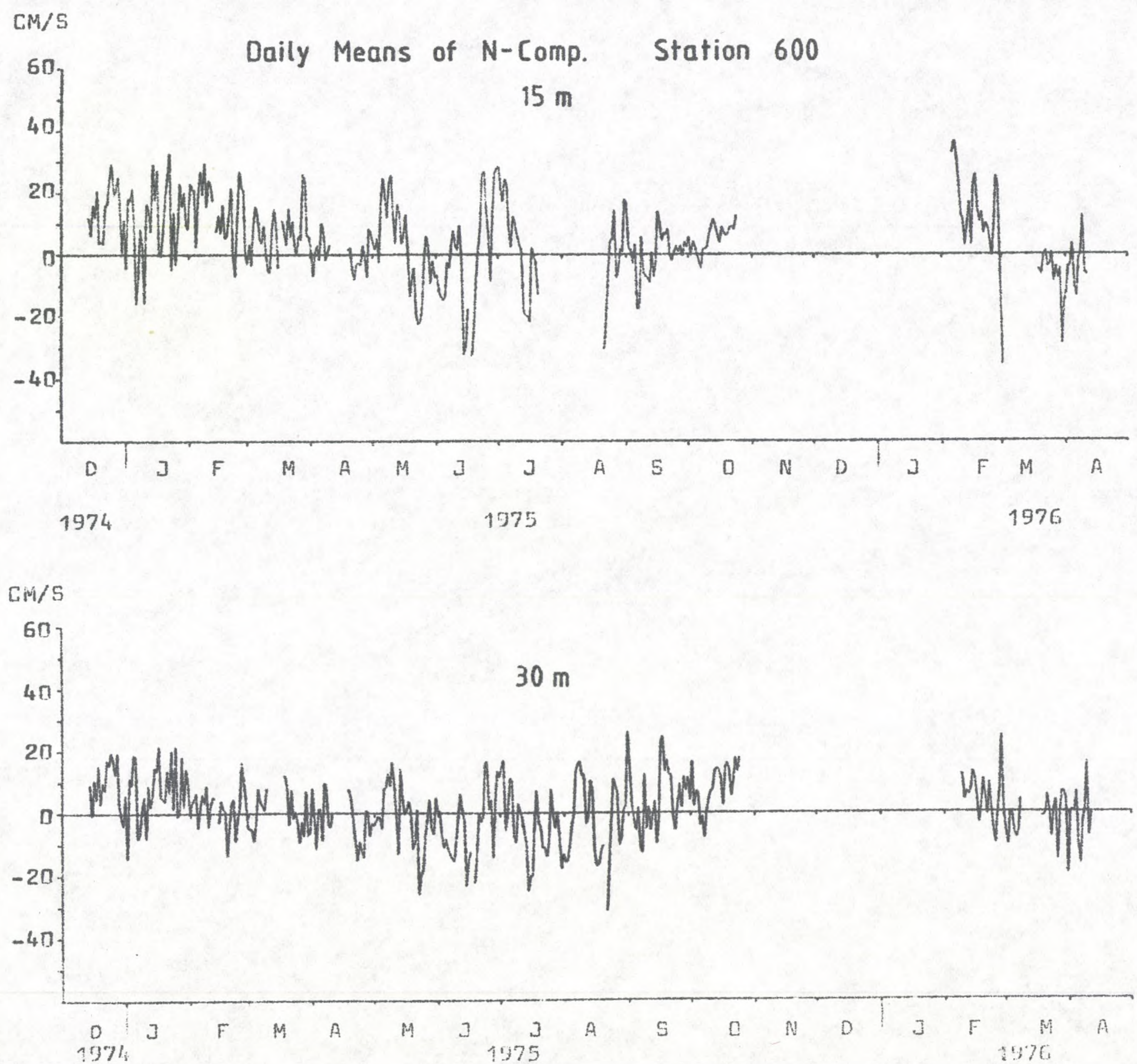

Daily Means of N-Comp. Station 600
15 m
CM/S
60
40
20
0
-20
-40
D J F M A M J J A S O N D J F M A
1974
1975
1976
30 m
CM/S
60
40
20
0
-20
-40
D J F M A M J J A S O N D J F M A
1974
1975
1976

FIG 7

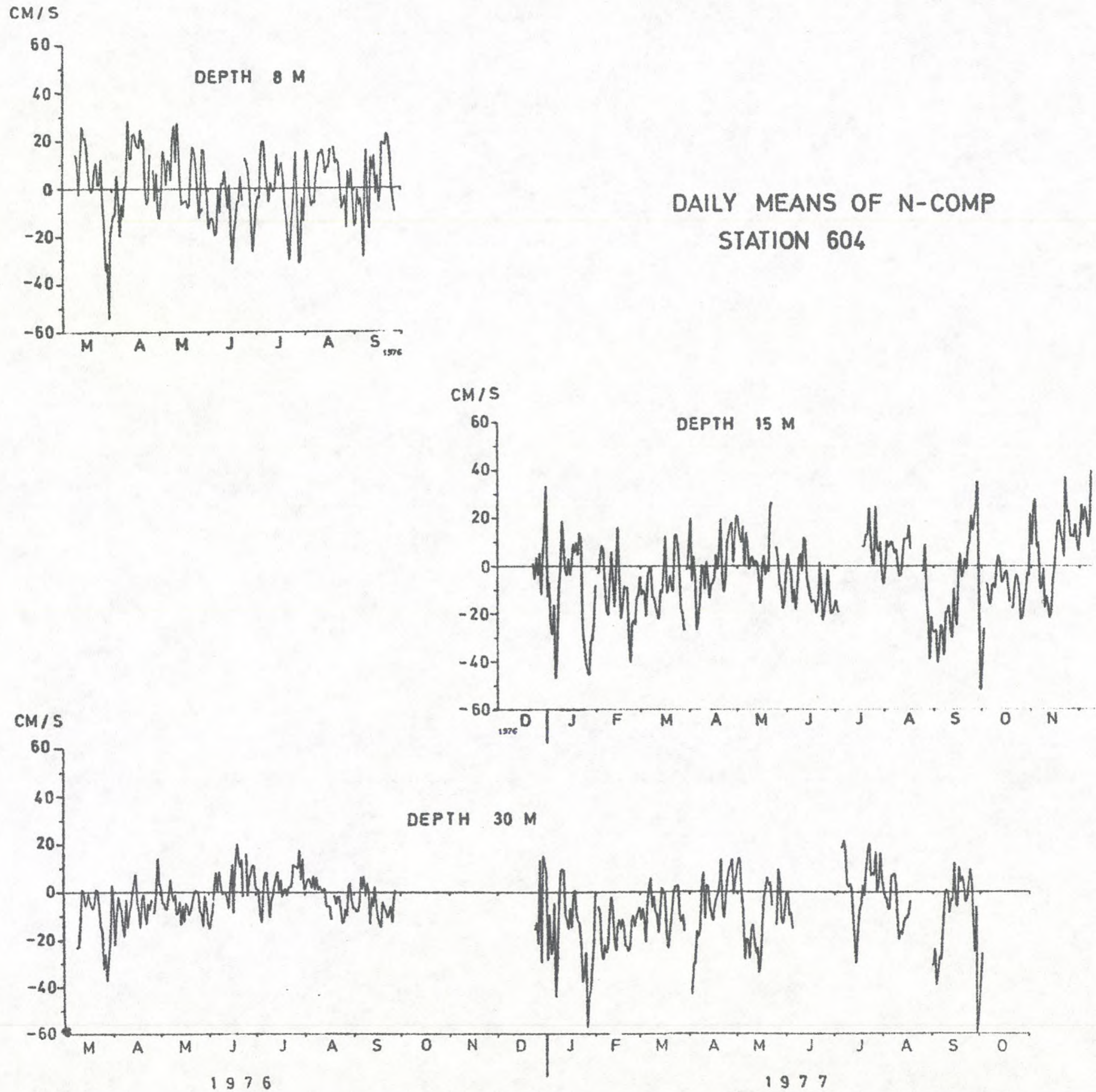
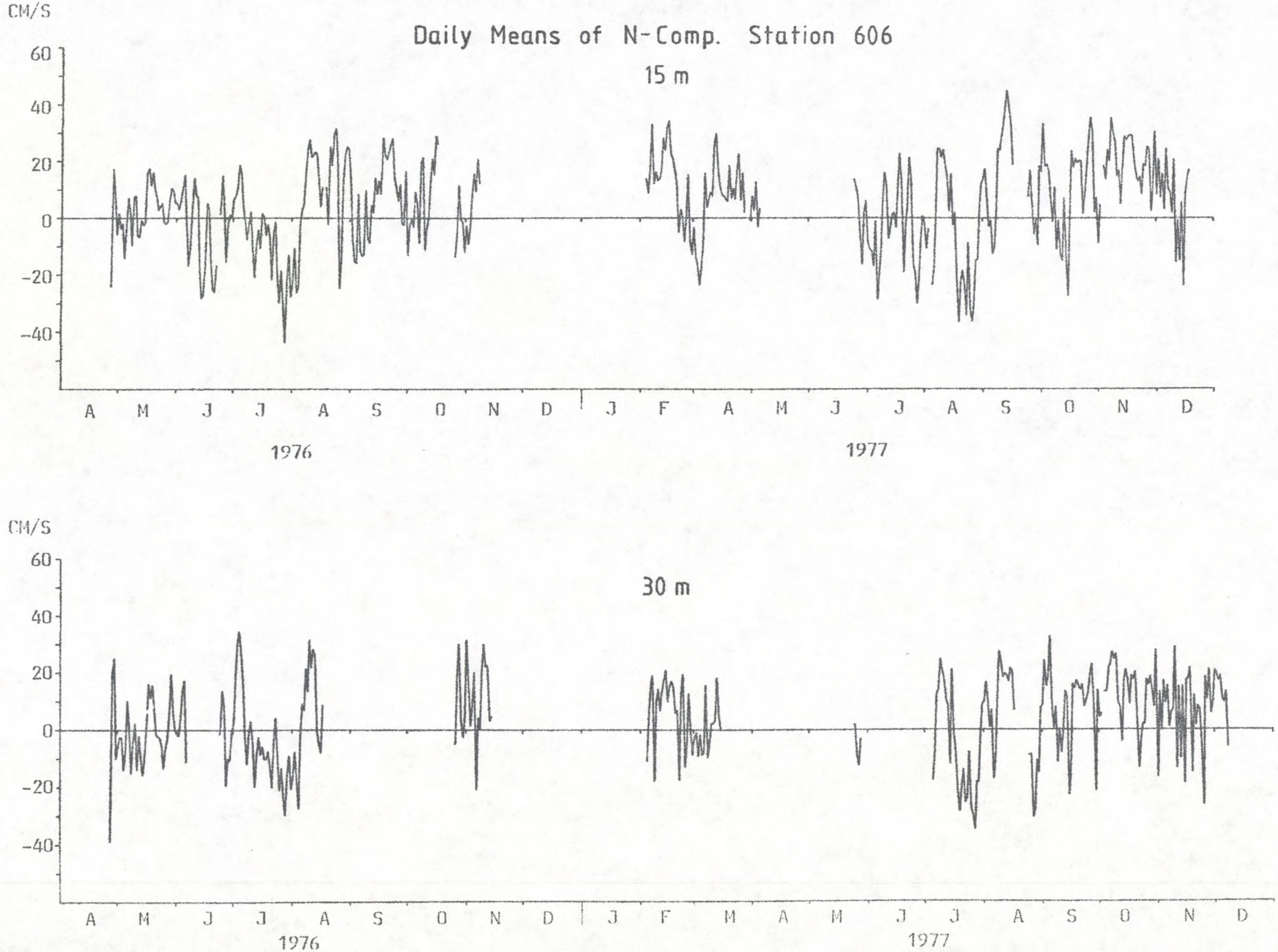

DAILY MEANS OF N-COMP
STATION 604
DEPTH 8 M
DEPTH 15 M
DEPTH 30 M
CM/S
60
40
20
0
-20
-40
-60
M A M J J A S
D J F M A M J J A S O N
M A M J J A S O N D J F M A M J J A S O
1976
1977

FIG 8



Daily Means of N-Comp. Station 606
15 m
CM/S
60
40
20
0
-20
-40
A M J J A S O N D J F A M J J A S O N D
1976
1977
30 m
CM/S
60
40
20
0
-20
-40
A M J J A S O N D J F M A M J J A S O N D
1976
1977

FIG 9

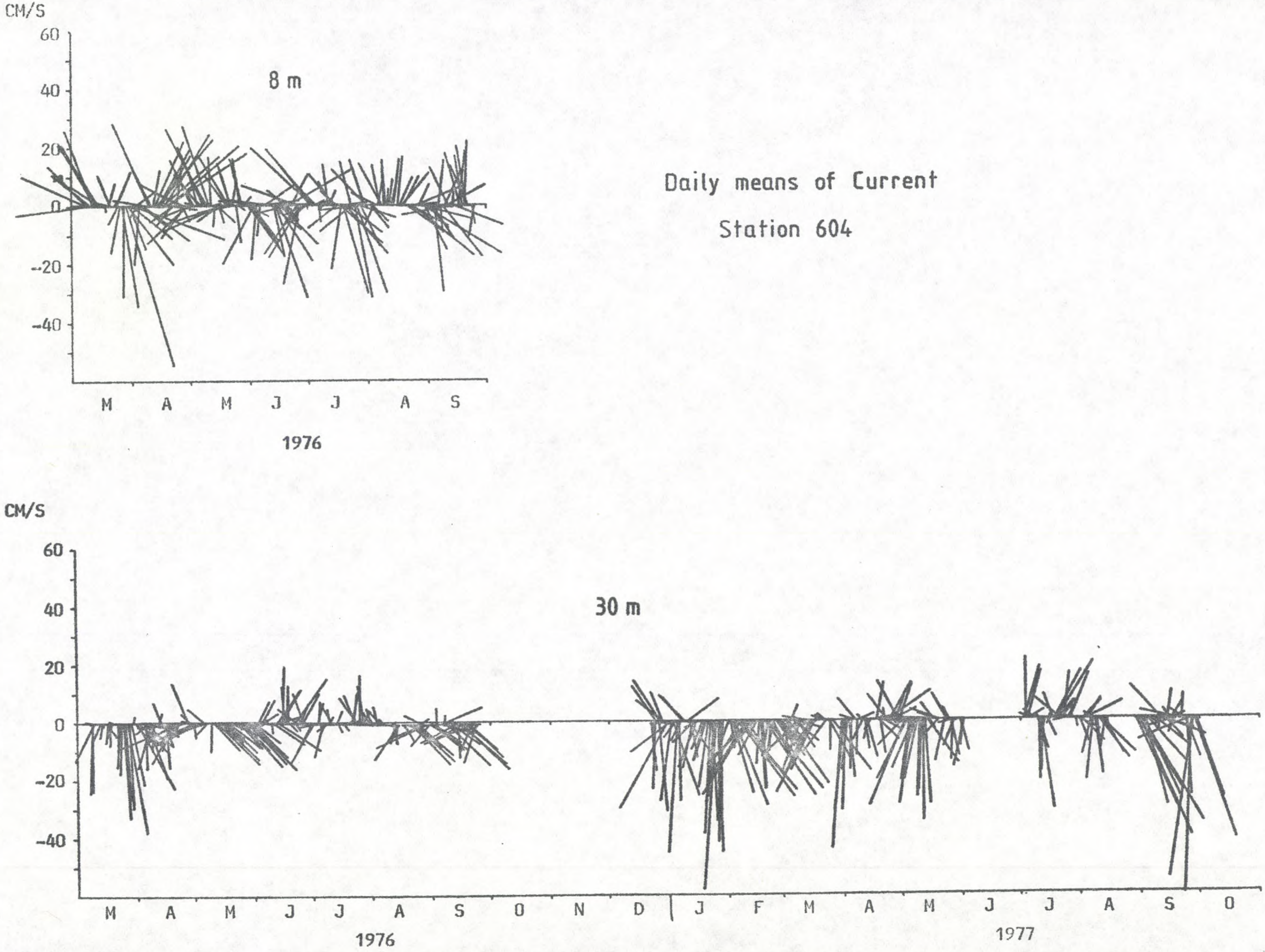
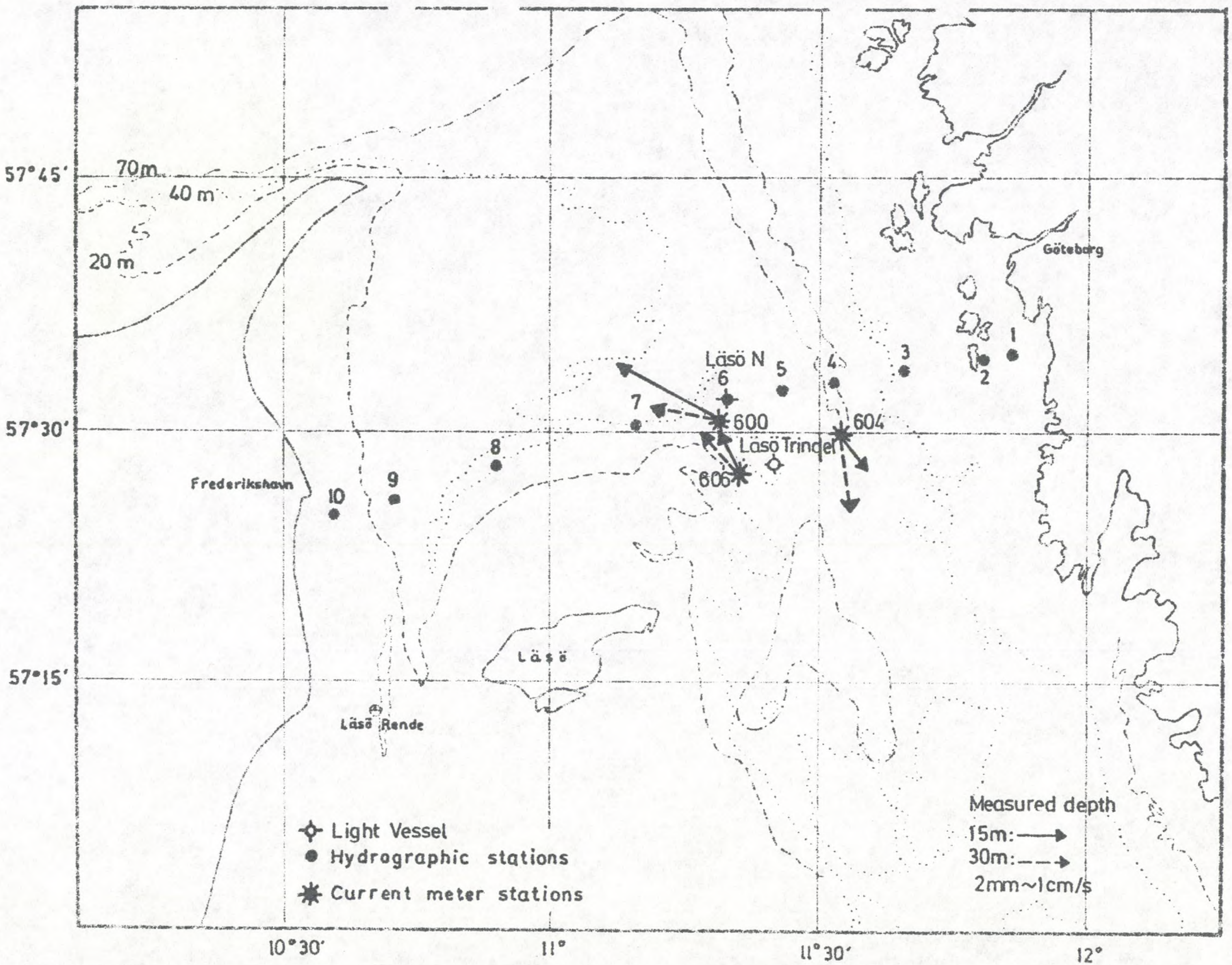

Daily means of Current
Station 604
8 m
CM/S
60
40
20
0
-20
-40
M A M J J A S
1976
30 m
CM/S
60
40
20
0
-20
-40
M A M J J A S O N D J F M A M J J A S O
1976
1977

FIG 10



57°45'
57°30'
57°15'
10°30'
11°
11°30'
12°
70m
40 m
20 m
Göteborg
Läsö N
Läsö Trindel
600
604
606
1
2
3
4
5
6
7
8
9
10
Frederikshavn
Läsö
Läsö Rende
Light Vessel
Hydrographic stations
Current meter stations
Measured depth
15m:
30m:
2mm~1cm/s

FIG 11

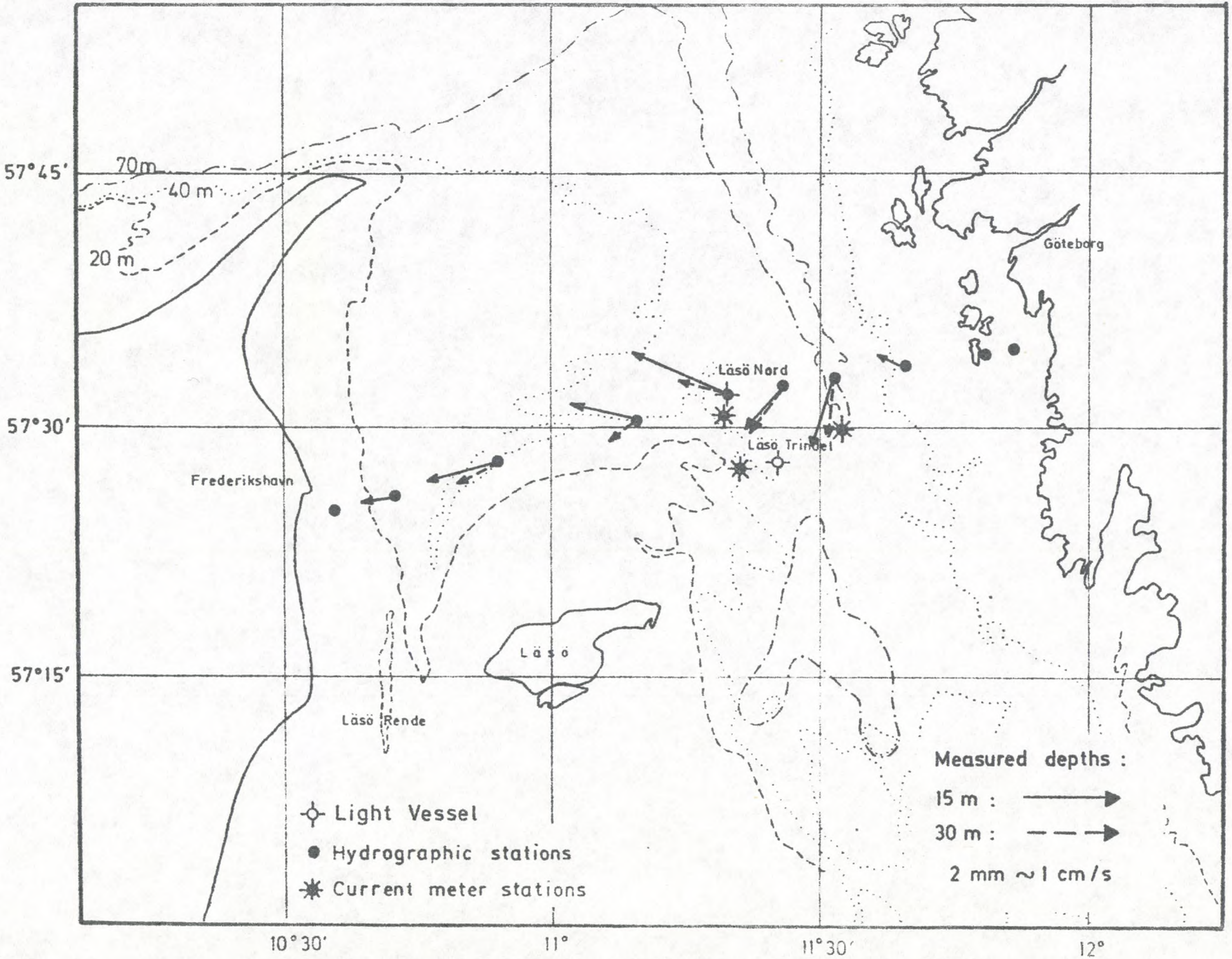
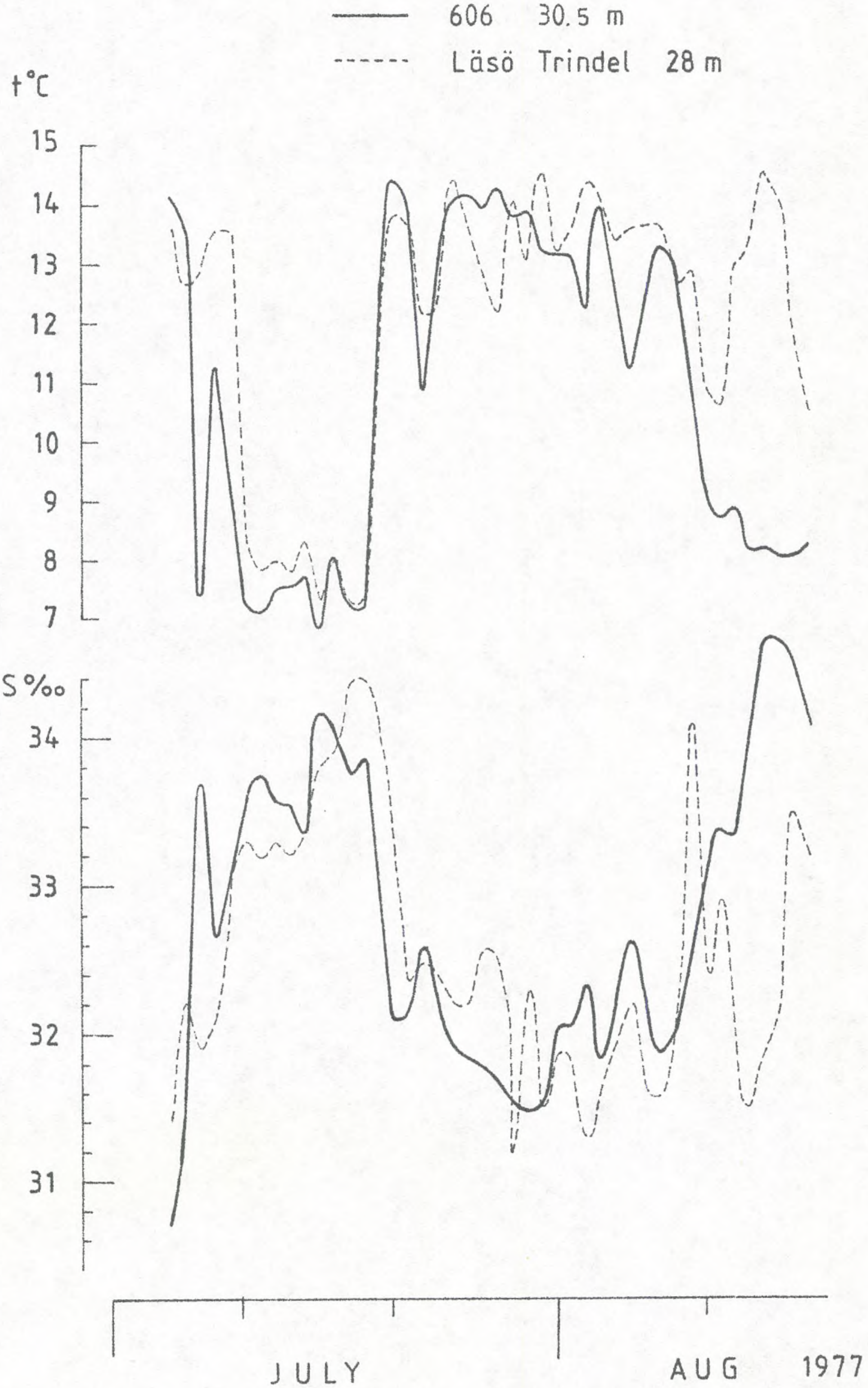

57°45'
57°30'
57°15'
10°30'
11°
11°30'
12°
70m
40 m
20 m
Frederikshavn
Göteborg
Läsö Nord
Läsö Trindel
Läsö
Läsö Rende
Light Vessel
Hydrographic stations
Current meter stations
Measured depths :
15 m :
30 m :
2 mm ~ 1 cm/s

FIG 12

FIG 13



606 30.5 m
Läsö Trindel 28 m
t°C
15
14
13
12
11
10
9
8
7
S‰
34
33
32
31
JULY
AUG 1977

Daily means of T and S Station 600

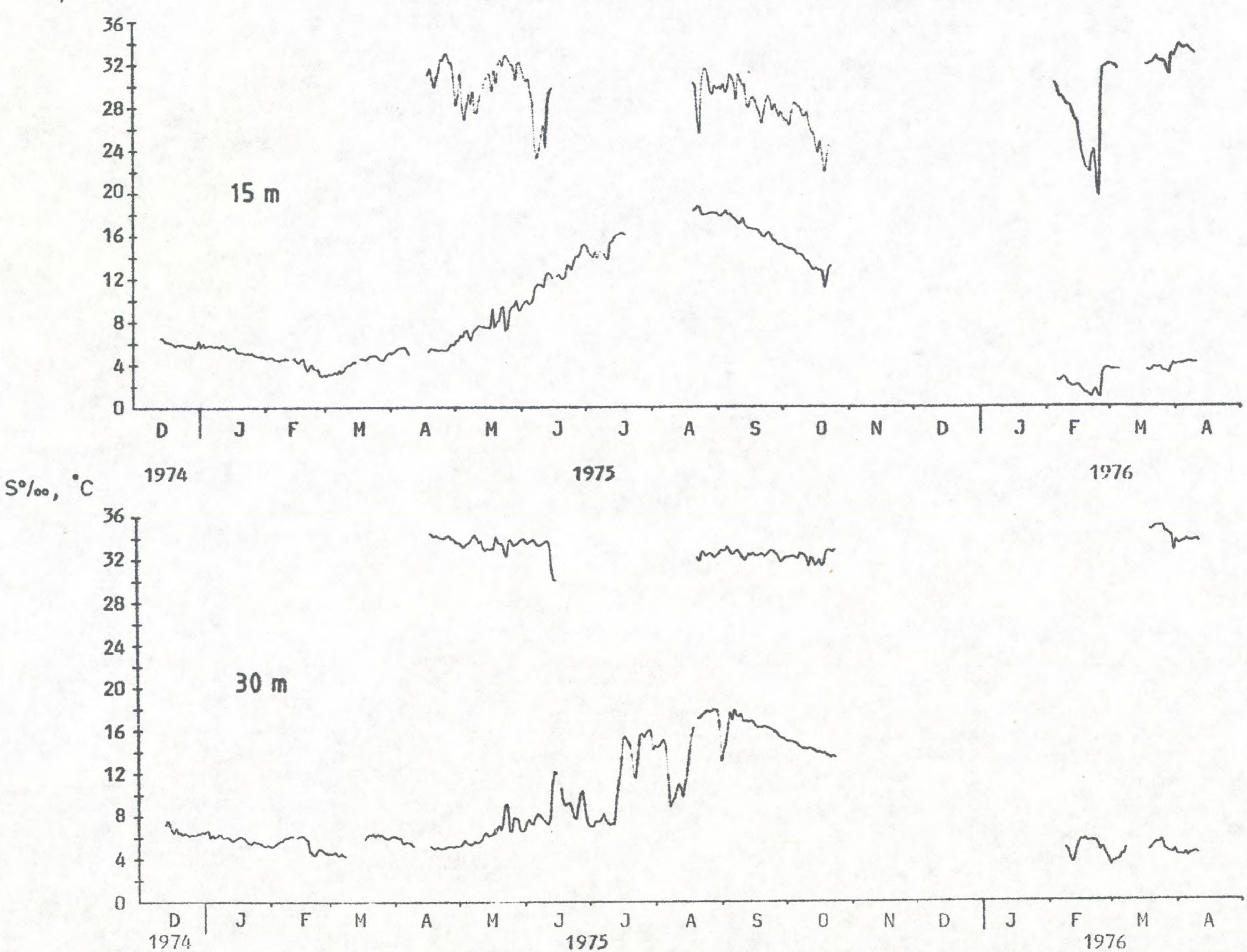


FIG 14

Daily means of T and S

Station 604

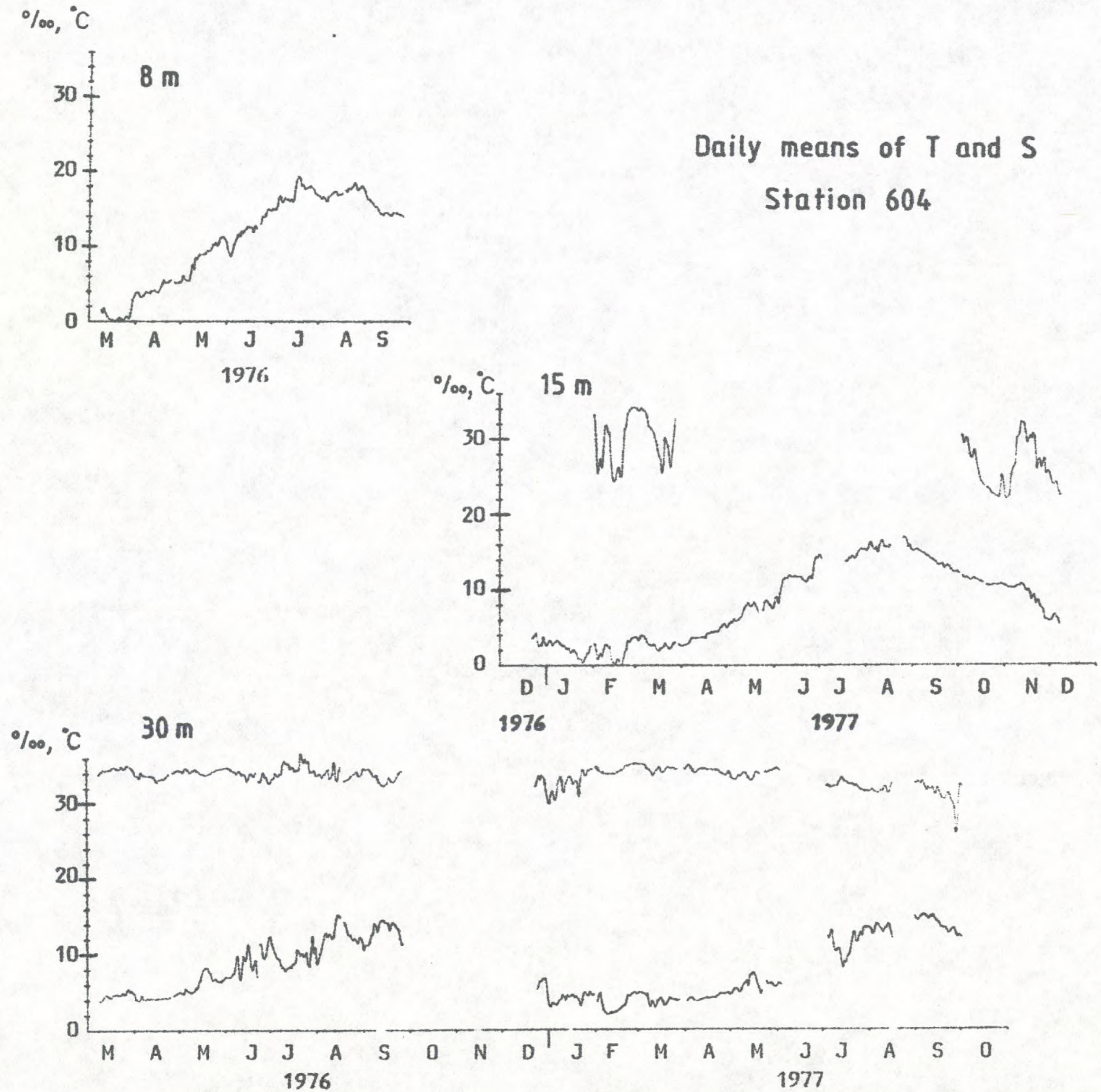


FIG 15

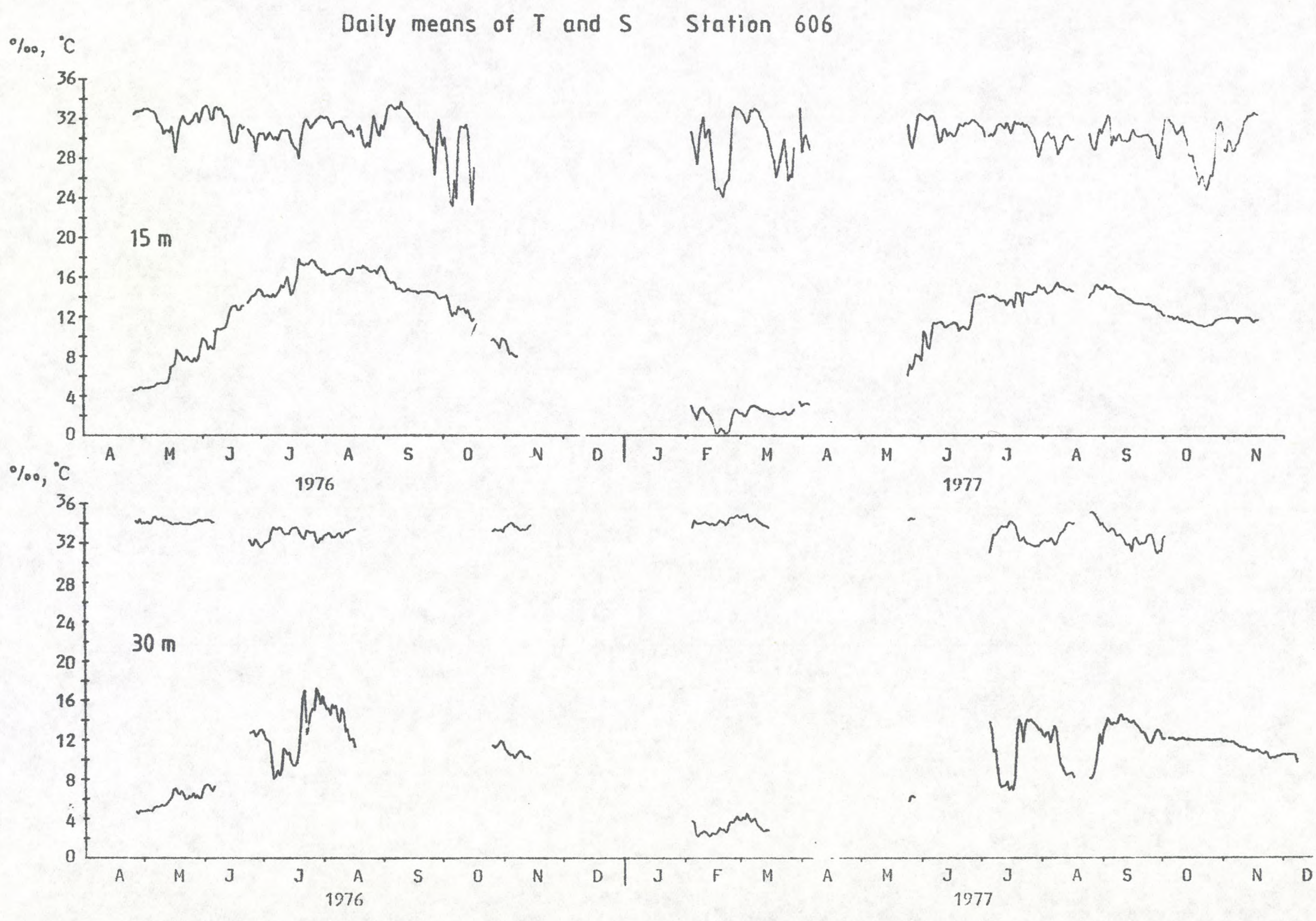

Daily means of T and S   Station 606
°/oo, °C
36
32
28
24
20
16
12
8
4
0
15 m
A M J J A S O N D J F M A M J J A S O N
1976
1977
°/oo, °C
30 m
A M J J A S O N D J F M A M J J A S O N D
1976
1977

FIG 16