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CURRENT METER OBSERVATIONS IN THE NORTH CHANNEL AND THEIR RELATIONSHIP TO LOCAL WIND

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ABSTRACT

A series of current meter observations taken in spring 1985 was used, with a simplified cross-section, to estimate the transport through the North Channel of the Irish Sea. Wind data from two local stations were available over the same period, allowing a study of the relationship between wind and transport to be made. Similar relationships between wind and individual current meter records were also examined. Estimates were made of the direction of the wind component which gave the best visual correlation with transport and flow. The time lag between wind and wind induced effects was also considered.

RÉSUMÉ

L'on s'est servi d'une section simplifiée des mesures relevées au courantomètre au printemps de l'année 1985 pour estimer le transport par le canal septentrional de la mer d'Irlande. L'on disposait en outre des relevés du vent à deux stations de la région sur la même période, ce qui a permis d'étudier la relation entre le vent et le transport. Des relations analogues entre les relevés du vent et les relevés à chacun des courantomètres ont aussi été examinées. L'on a estimé la direction de la composante éolienne qui donnait la meilleure corrélation visuelle avec le transport et le débit. Le décalage temporel entre le vent et les effets du vent a par ailleurs, été considéré.

INTRODUCTION

Previous studies of the dynamics of the Irish Sea and adjoining waters have used a variety of methods to estimate the transport and currents through the North Channel.

Continuity methods using tracers such as salt and caesium 137 produced results which have been summarised by McKay and Baxter (1985). Transport estimates vary from $4.7 \times 10^4 m^3 s^{-1}$ to $5.8 \times 10^4 m^3 s^{-1}$, although earlier work by Bowden (1950) using continuity of salt and taking account of longitudinal mixing gives an estimate of $2.6 \times 10^4 m^3 s^{-1}$, and a model of caesium 137 mixing by Prandle (1984) estimated a transport of $6.0 \times 10^4 m^3 s^{-1}$.

Early use of Lagrangian current measuring methods, using surface drifters, indicated a southward flow along the Irish Coast but did not allow any transport calculations to be made.

Eulerian current measurements in the area have been restricted by the hostility of the environment and there have been no previous current measurements from the deep part of the channel where depths in excess of 200 m and strong tides make the successful mooring of current meters exceptionally difficult.

Howarth (1982) deployed a series of moorings in the Malin Shelf Sea and North Channel. However, only three of these lay in the channel.

At the same time Howarth recorded the potential of the Port Patrick to Donaghadee telegraph cable. Using Faraday's law these measurements provide another method of estimating through channel flow. The method had been used previously by Bowden and Hughes (1961), Prandle and Harrison (1975) and by Prandle (1976) and (1979). All these authors considered the possibility of a relationship between the cable potential and local wind. Howarth extended study of such a relationship to his current meter data. He observed continuous southward flow along the Irish Coast and near the Mull of Galloway but flow of variable direction at his central mooring, the direction of the flow depending on the direction of the mean wind stress. As long as the winds were not weak, his correlation between longitudinal wind stress and cable voltage was good with values of up to 0.85.

In the present study currents have been measured directly using a series of moorings across the channel (Figure 1). These have been used to estimate the overall transport. Local wind data has been used to study the wind/transport or wind/current relationship.

CURRENT METER DATA

In 1985 the MAFF, Fisheries Laboratory, Lowestoft, deployed a series of current meter moorings in the North Channel at the positions shown in Figure 1. The deployment, from 21 March to 12 June was divided into two distinct parts by the mooring servicing around 25 April. Initially, seven moorings were deployed comprising fifteen current meters. Of these, only one (AB) failed to return any data, whilst two others (FB and GM) returned curtailed records. After servicing only five moorings were redeployed and of the eleven meters, two returned no data and a third returned only seventeen days data, compared with thirty-two days and forty-five days from other meters. Coverage, especially on the eastern side, was, therefore much better for the first half of the deployment and only figures from this data set were used to estimate transport.

Current meter data was available in component form at ten-minute intervals but, initially only filtered daily means were used to calculate the transport. Data was presented in components in 330° and 60° directions (that is parallel with and perpendicular to the axis of the channel).

CALCULATION OF TRANSPORT

Transport was calculated across a section running 60° to 240°, using the 330° current component. A cross section of the channel was obtained from an echo sounder transect by the MAFF Research Vessel CLIONE. Although this may not have been very accurate, any inaccuracies apart from those at the extreme edges were considered to be insignificant compared with the uncertainties introduced when extrapolating the current measurements over the area of the blocks into which the section was divided. Figure 2 shows the division of the cross section into blocks in such a way that each block, except for those at the edges of the channel, contained one current meter position. The names by which the blocks are referred to are also given in the figure. In most cases the first letter in the name refers to the mooring name and the second to the current meter position (Top, Middle or Bottom) on the mooring.

Transport for each block was calculated by multiplying the estimated area of the block by the 330° current component from the relevant meter. For blocks not containing meters and for those where the meter returned incomplete records, values from the nearest appropriate mooring were used.

Daily means were calculated for the whole area (Figure 3). The means over the twenty five-days of the deployment were calculated for each block and plotted (Figure 4). In this figure the height of each bar is proportional to the current and the area of the bar proportional to the transport.

WIND DATA

Local wind data was available at three-hourly intervals from two stations, Orlock Point and West Fruegh (Figure 1). Data was presented as speed (in knots) and direction. Daily means were calculated and the components every ten degrees were derived. Wind values at the two stations correlated well, as might be expected with speeds at Orlock Point generally higher (Figure 5). In this paper only the West Fruegh data, a stick plot of which is shown in Figure 6, are used.

RESULTS AND DISCUSSION

Figure 7 shows progressive vector diagrams (PVD) for the current meter data after a Gaussian filter has been applied. The variation in scales should be noted when making intercomparisons. Apart from the westernmost mooring (I) flow, especially in the upper layer is generally to the north north west, that is outward along the axis of the channel. In the case of I, flow in the upper layer is to the south south east and that in the lower layer to the west. At the end of the period southward flow can be seen in the upper layer as far east a mooring G. Figure 8(a and b) shows the variation of upper layer flow with time for both deployments, and the north/south component of wind (note that the wind data was only available up to 31 May). After the service no records were returned for the top meters of the G and E moorings. The dotted curves in Figure 8(a and b) show records for the middle and bottom meter from G and E respectively. The paucity of data after the service is clear from this figure. Again, the increased 'inflow' at the end of the first period is visible.

This widening of the inflow may go some way towards explaining observations of changes in the salinity field of the North Channel. Figure 9 shows a series of salinity profiles collected by MAFF, SMBA and DAFS between November 1984 and August 1985. Of these, three (e, f & g) from MAFF and DAFS cruises coincide with the period of the current meter deployment. The area of maximum salinity at the centre in Figure 9 (e & f, when southward flow was restricted to the I mooring, is in the centre of the channel but by the end of the period in Figure 9(g) when the inflow has broadened the high salinity water has been displaced to the east.

Previous studies of the wind/transport relationship used an equation of the form

$$U(t+\Delta t) = AW^2(t)\cos(\Theta(t)-\alpha)+U_o$$

where U(t), the residual flow (or in some cases the potential of the telegraph cable) lags the wind stress $W^2(t)$ by a time Δt with wind blowing from $\Theta(t)$. The wind is most effective at producing residual flow when blowing from angle α. A is a coefficient and U_o is the residual flow (or potential) which does not depend on wind forcing.

Figure 10 shows plots of daily mean transport and daily mean wind component at intervals of 30°. Although it is difficult to see, from these plots, a "best" wind direction α, the correlation with wind from 150° appears slightly better over the majority of the period. The notable exception is at the time of minimum transport on 31 March.

It would be expected that there would be some time lag between wind stress being applied and change in current and hence in transport. Previous work gives values of Δt of the order of hours or less; e.g. Bowden and Hughes (1961) 2 hours, and Prandle and Harrison (1975) a few minutes. However, the latter do point out that the resolution in time of the wind data (6 hours in their case) does not allow accurate determination of the lag. The daily mean plots of Figure 10 do not allow estimates of lag of the order of hours. However, the possibility of a longer time lag, allowing for the cumulative effect of wind on transport has been considered. This may also be equivalent to looking at the effects of winds further away from the area, which may take days to act. Figure 11 shows plots of the 150° wind component and transport for time lags of one to four days. The four-day lag gives reasonable correlation for most of the period.

Over the twenty-five-day period the mean transport was estimated to be $8.5 \times 10^4 m^3 s^{-1}$. This is larger than the estimates made by tracer and modelling methods but agrees well with Howarth (1982) value of $8 \times 10^4 m^3 s^{-1}$ outflow for his moorings A, B and C, when the wind was southerly. However, Howarth also quoted a net inflow transport of $2.2 \times 10^4 m^3 s^{-1}$ when the wind was northerly and explained this by pointing out the high correlation between the current at his centre mooring B and the wind. There is no equivalent station in the present study as Howarth's station B was further north than all our stations, but this reversal in flow is seen in moorings H and C as discussed previously. The fact that Howarth is extrapolating his southward flow over a far wider area than in our case, explains the southward transport. His easternmost station, again further north than the present ones, showed southward flow over the 45 d of his record which is not seen at station E in our study.

The minimum daily mean transport in the March-April period was $0.6 \times 10^4 m^3 s^{-1}$ on 31 March and the maximum of $3.65 \times 10^5 m^3 s^{-1}$ occurred the previous day.

Correlation between wind and current at individual meters was also studied. The inclusion of the wind data in Figure 8 allows a more detailed study of wind current correlation. This figure shows that certain 'events appear all the way across the channel'. For instance, the southward maximum at H and I has corresponding decreases in northward flow at the other moorings on 31 March and there is a northward maximum at I, H and F on 24th May. However the southward maximum at E with corresponding minima in northward flow at F and A seems to lead the equivalent minimum at G, C, H and I by a day. (This may be due to the averaging of data.)

Some of these phenomena have corresponding wind changes. For instance, there is a southward maximum on 11 April and northerly wind for a period from the 18 April when the flow is at it's broadest.

CONCLUSIONS

A series of current meters has provided good coverage of the North Channel and has allowed an estimate to be made of the daily mean transport. Graphs have shown that, although correlation with the wind is not necessarily as clear as suggested in previous work, there is certainly some wind/transport relationship. Howarth's conclusion that there is better correlation in the "middle" of the channel than at the edges was not confirmed, although his "middle" station was in 150 m of water and not in the deepest part of the channel (compare the present station G in nearly 280 m). Other differences between the results in this paper and his may also be due to the different coverage of the region and the number of near-bed observations included in our transport estimates.

In order to get better estimates of "best" wind angle (α) and time lag (Δt), calculations of mean transport every three hours would need to be made. These could then be used with the three-hourly wind data.

In this paper no account has been taken of other current forcing sources such as pressure gradients. Tide gauge data will shortly be available from IOS (Bidston) from Portpatrick and Belfast. With this additional information allowing for estimation of these contributions to the currents, our remarkably good data set might be analysed to reach further conclusions on the flow pattern and wind/transport relationship in the area.

ACKNOWLEDGEMENTS

The authors wish to thank David Ellett (SMBA) and Tony Martin (DAFS) for supplying the salinity profiles shown in Figure 9.

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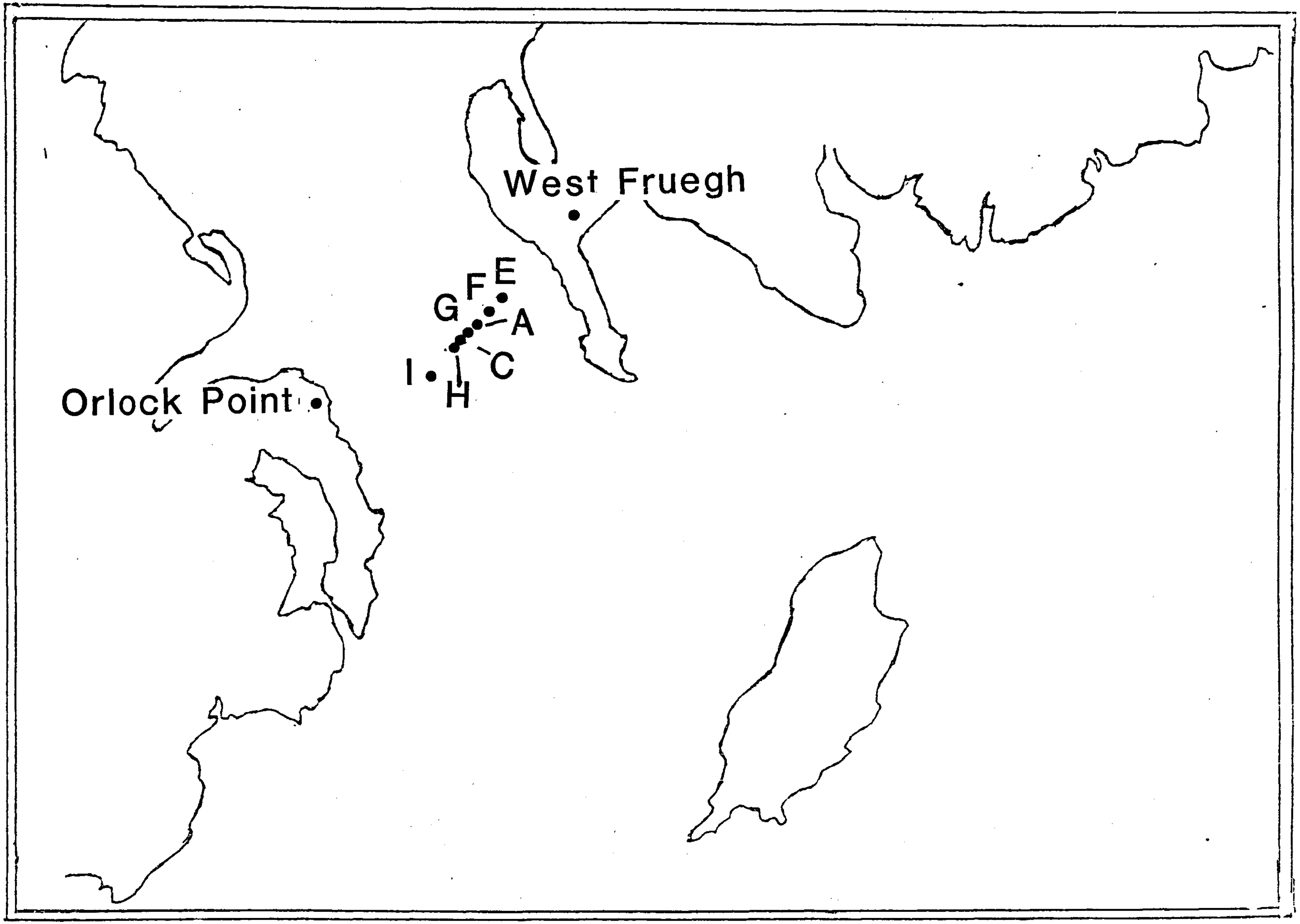

Figure 1. Current meter mooring positions and wind data station positions.

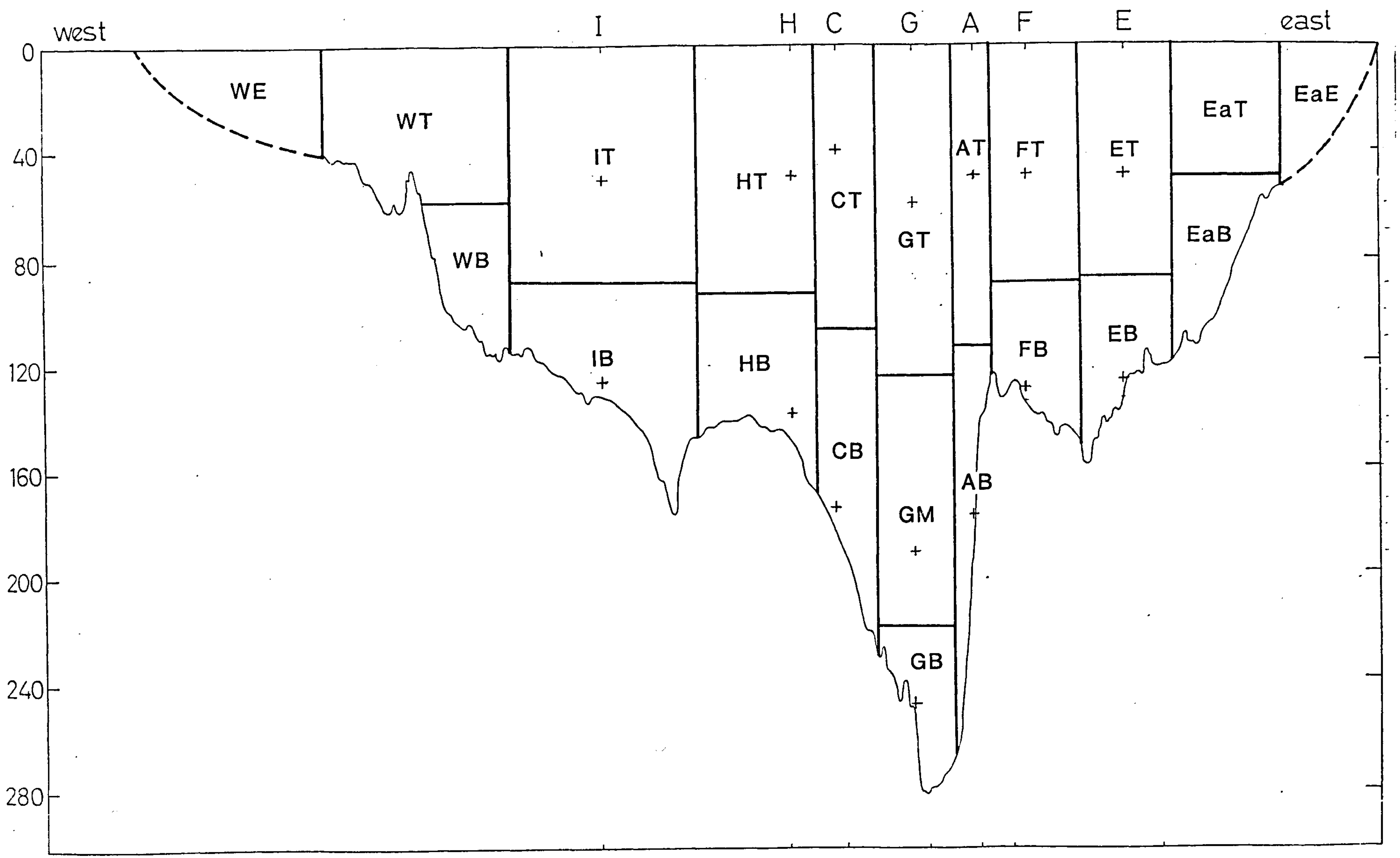

Figure 2. Bottom profile of North Channel with blocks used in transport calculations.

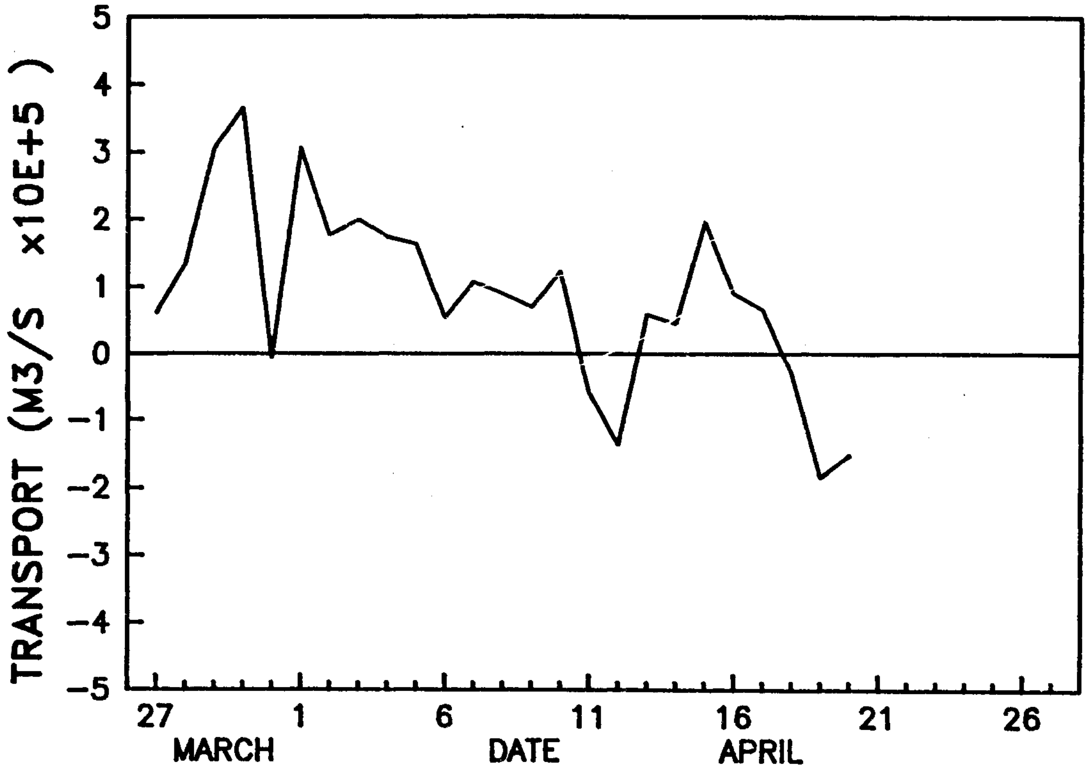

Figure 3. Daily mean transport values.

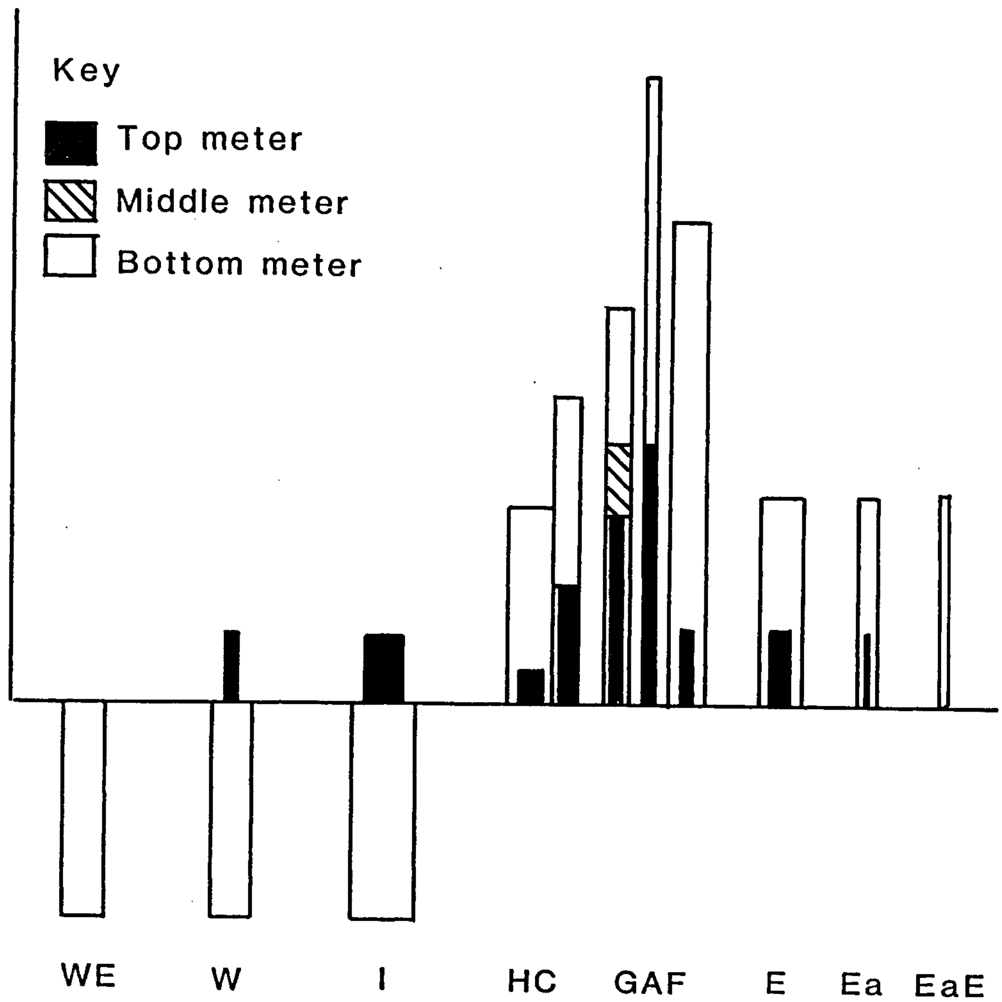

Figure 4. Twenty-five day mean transport for individual blocks.

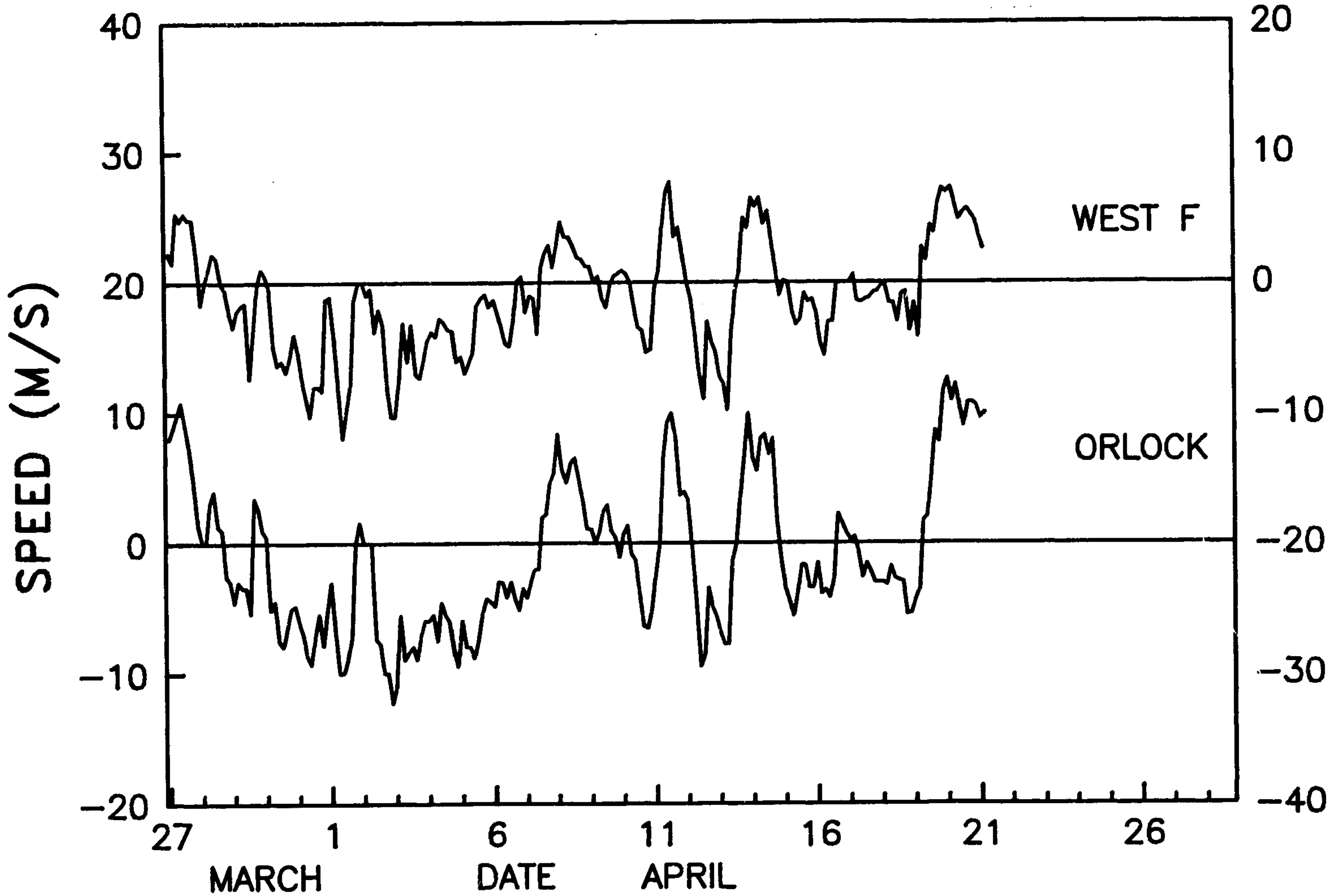

Figure 5. Wind data (3 hourly) for Orlock Point and West Fruegh.

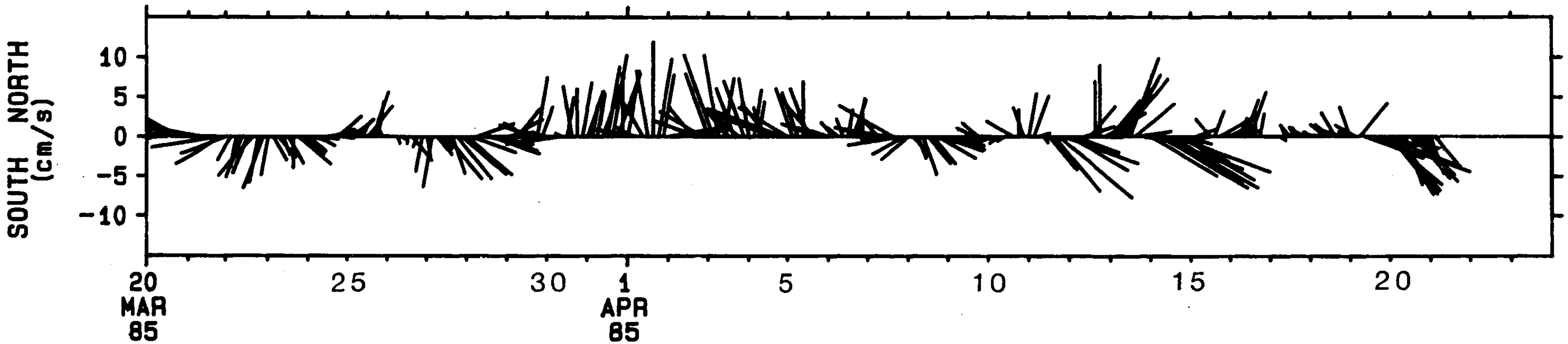

Figure 6. Stick plot of West Fruegh Wind data.

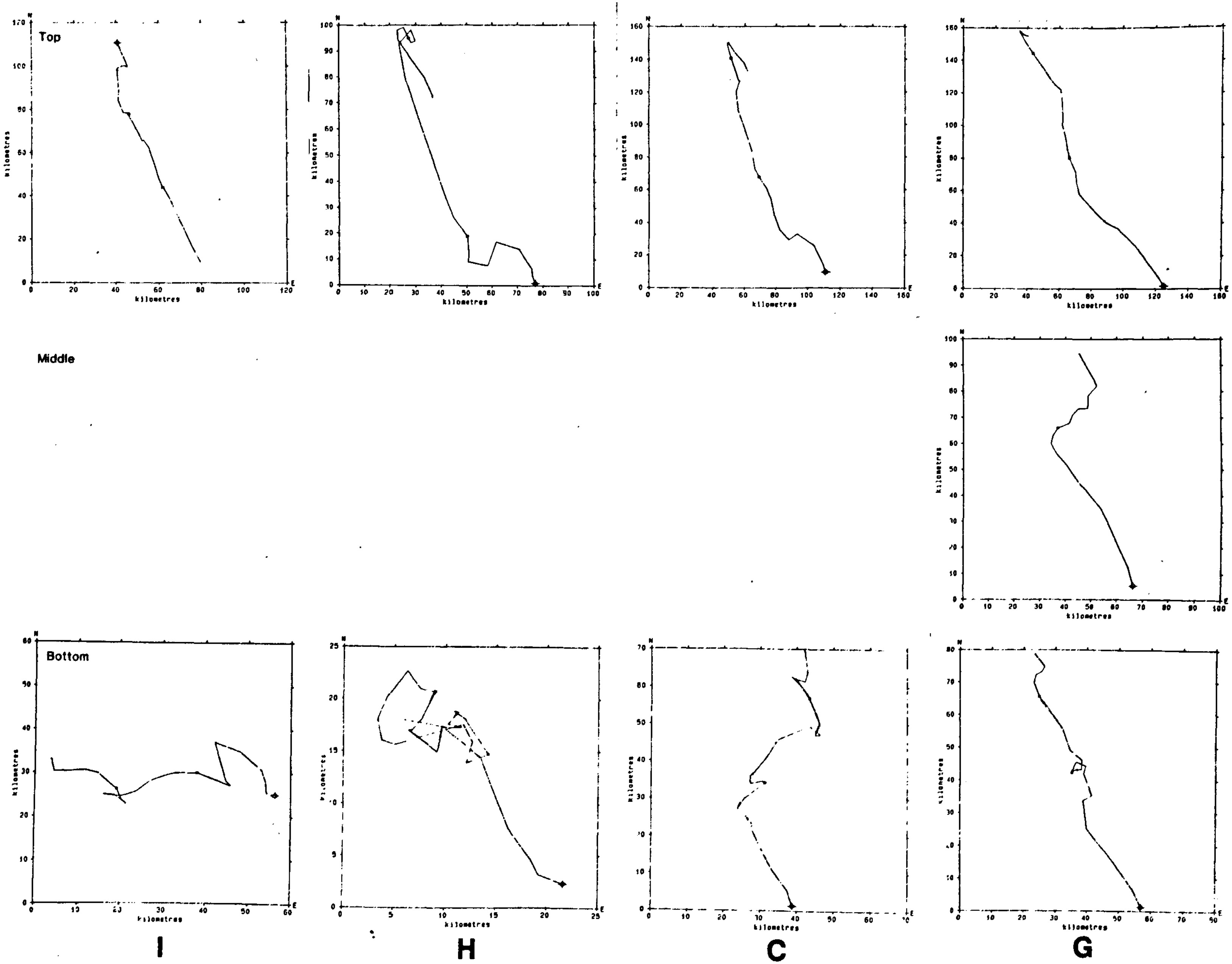

Figure 7. Progressive vector diagrams for current meters in the North Channel.

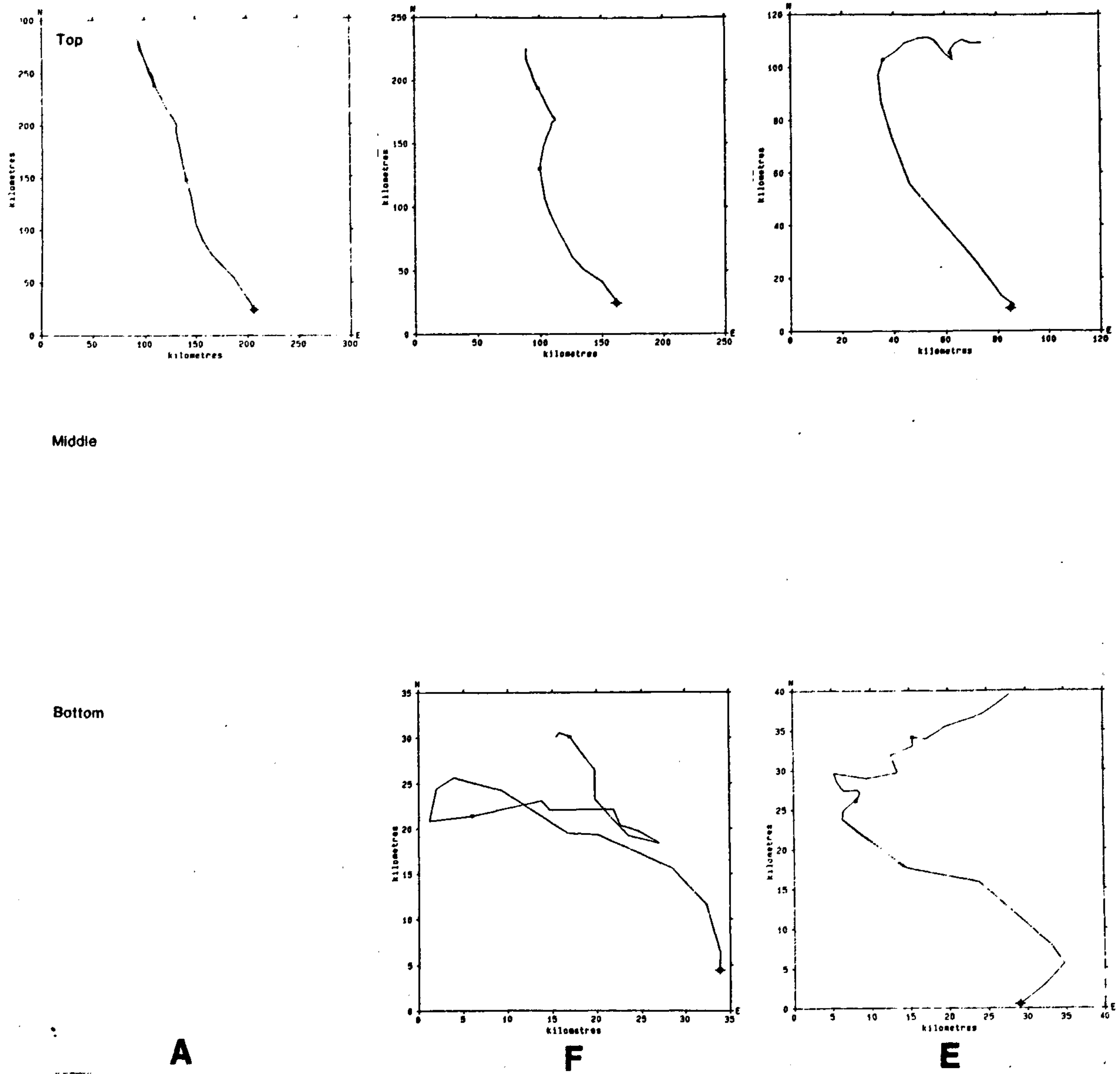

Figure 7. Continued.

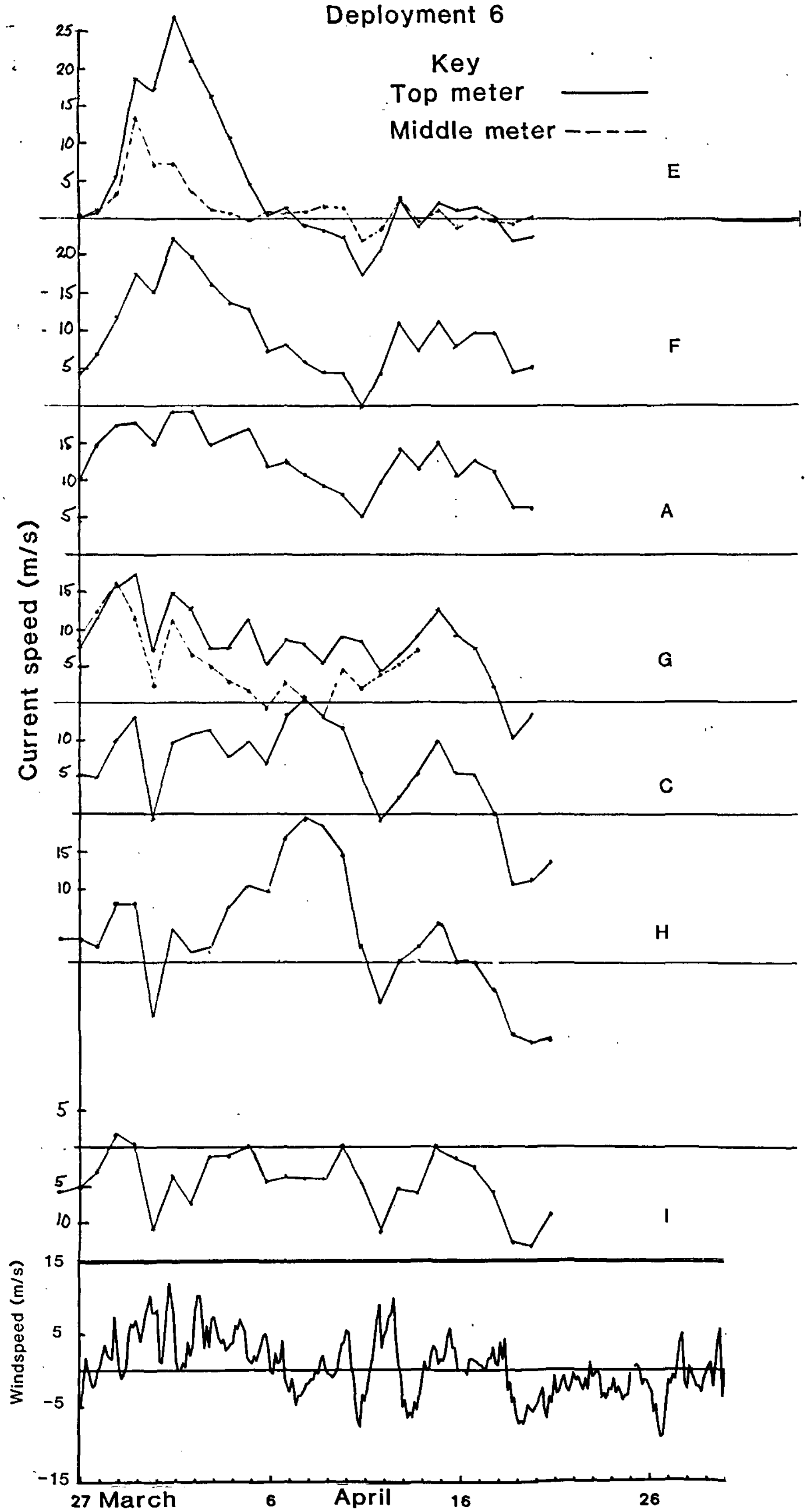

Figure 8. One hundred and fifty degree components of current for the top current meters and northerly component of wind.

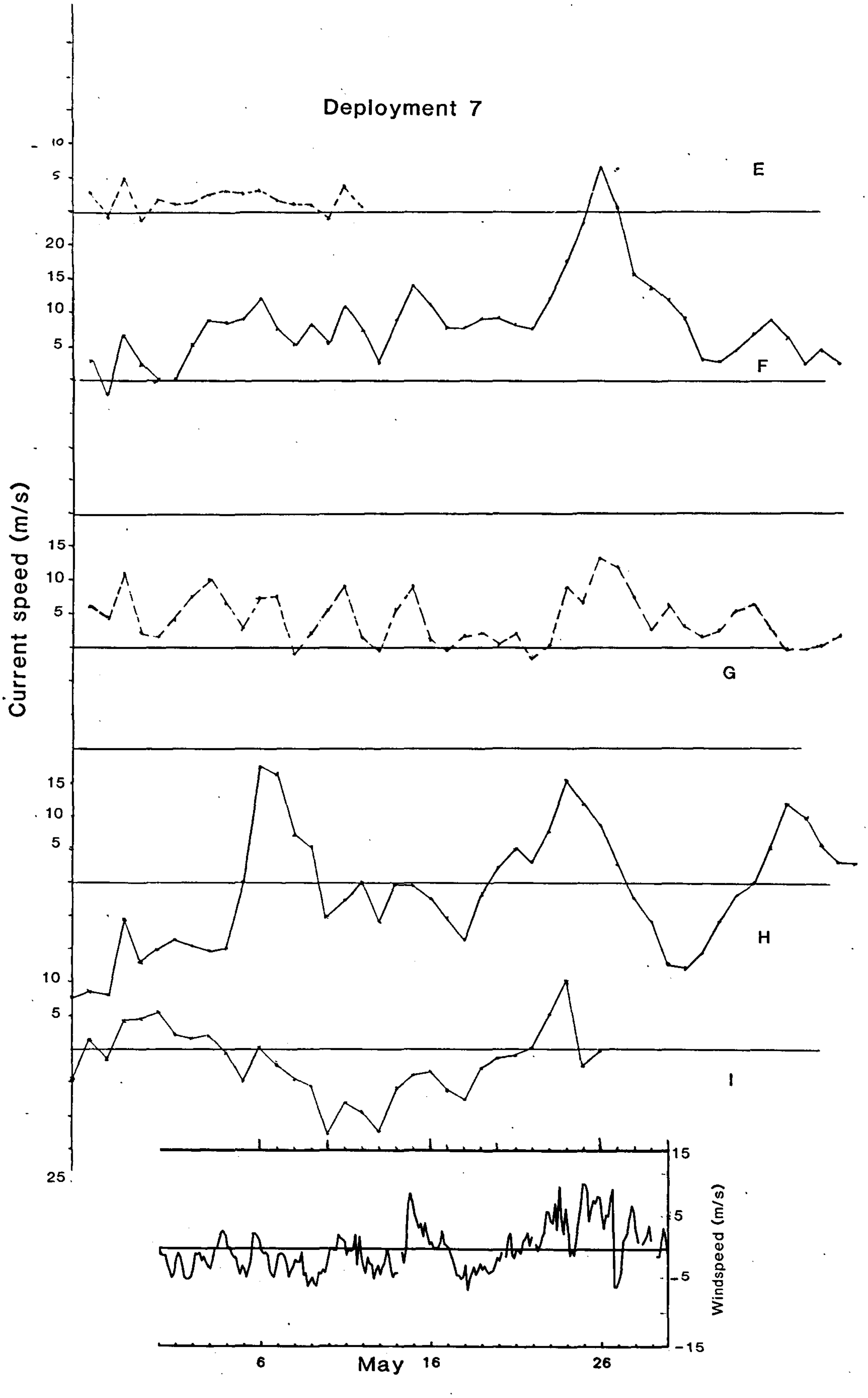

Figure 8. Continued

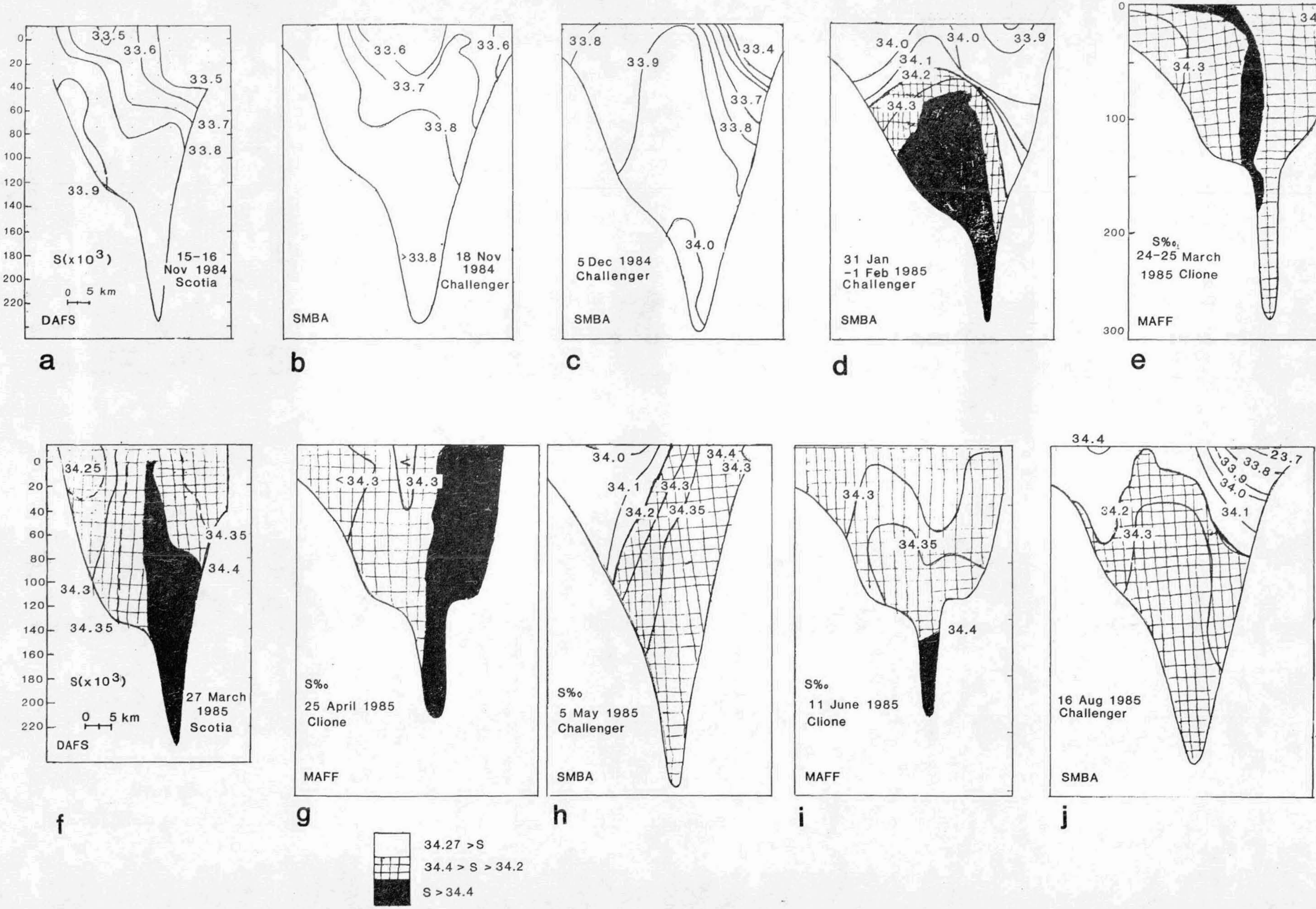

Figure 9. Salinity profiles November 1984 to August 1985.

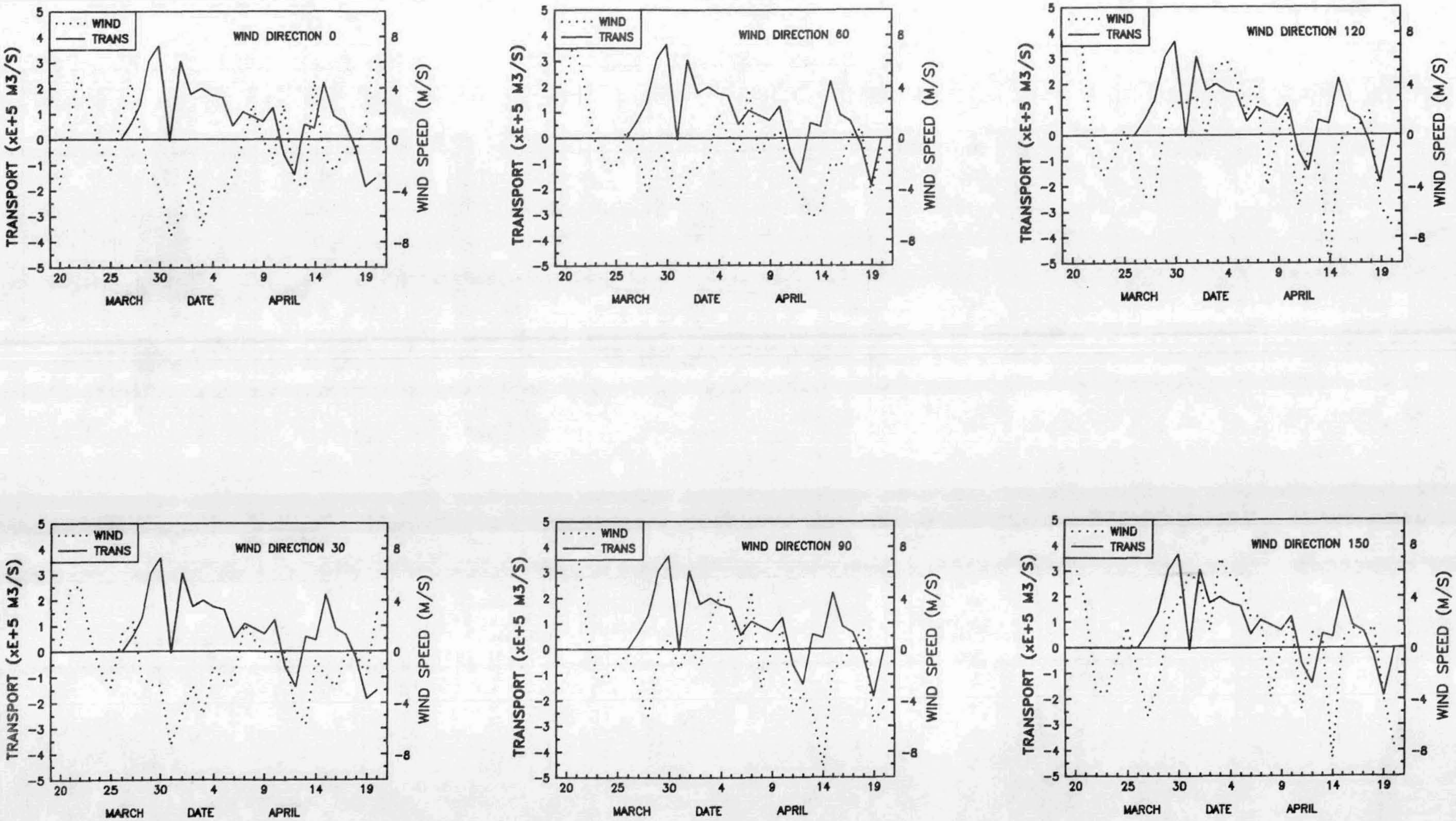

Figure 10. Transport and wind components every 30°.

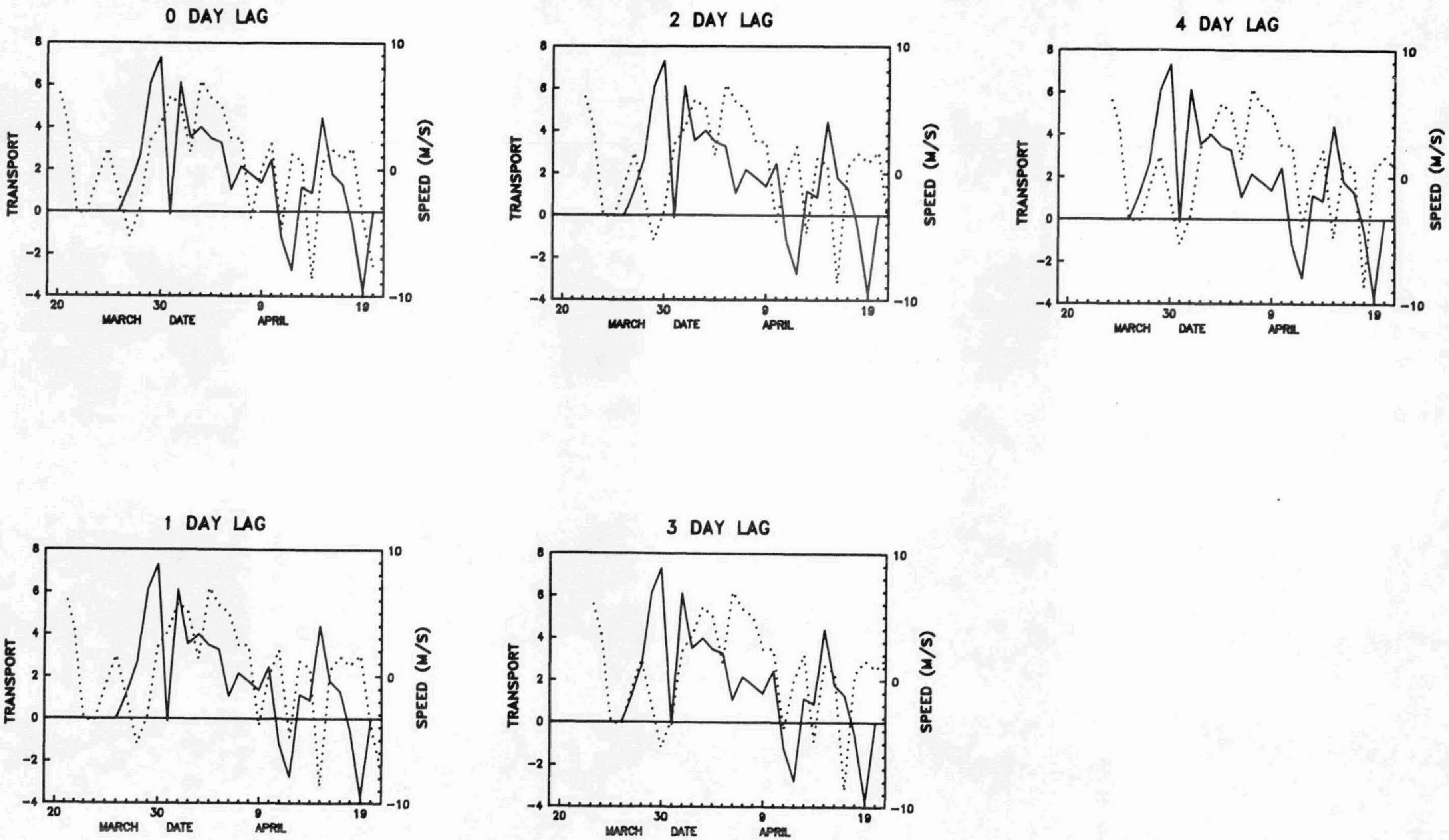

Figure 11. Transport and 150° wind component with lags of one to four days.