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RESIDUAL DRIFT REGIMES IN THE NORTHERN NORTH SEA IN APRIL-MAY 1973

by

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INTRODUCTION

In April-May 1973 the Fisheries Laboratory, Lowestoft and the Marine Laboratory, Aberdeen established 13 moored current meter stations in the northern North Sea (Figure 1). Lowestoft deployed current meters at positions 1-6 and Aberdeen at stations A-G. Unfortunately, losses of rigs meant that little or no information could be obtained from stations 4-6 or from station A. Details of the station positions and meter record lengths are given in Table 1.

Apart from elucidating features of current flow in this area these records are of additional interest since they closely overlap with the JONSDAP 76 plans. (Bolle et al 1975). Indeed, it seems to us that several features of these data need to be borne in mind in the planning of not only the current measuring aspects of JONSDAP 76, but also the chemical and biological surveys in the vicinity of the main operational area. Furthermore, in due course these data will provide a very useful comparison with the data which will accrue from JONSDAP 76.

THE HYDROGRAPHIC BACKGROUND

(a) Along the Scotland-Denmark Section

Figure 2 shows two aspects of the vertical character of the water mass distribution along the Scotland-Denmark line of moored stations as the Lowestoft stations were laid and recovered. The most striking feature of the data is the development of the thermocline by late May over the whole section.

(b) At depth over the whole northern North Sea

The salinity distribution during the period of the exercise over the whole of the northern North Sea is best represented by parts of the bottom salinity charts for May and June 1973 produced by the ICES Service Hydrographique and these are reproduced as Figure 3. (The corresponding temperature charts do not have any pertinent features and so are not shown, while the bottom salinity distribution for April does not, we feel, have a very satisfactory coverage of stations in either time or space). We think, in fact, that the contrast between the bottom salinity distributions in May and June, taken together with the vertical profiles of Figure 2, provide a reasonable indication of the changing hydrographic situation at all depths during the period of the current measuring exercise.

For example, Figure 3(a) suggests that in May east-west salinity gradients are present in the vicinity of stations B and C whilst all the other moorings occupy regions of north-south gradients. This is fairly typical of the general situation found in this series of monthly charts, although the 35.10°/oo isohaline lies very close to the east Orkney coast. In February it was 35 miles away, in June (Fig. 3b) 20 miles off, and these values bound the zone in which it usually appears. Consequently mooring B at 20 miles off the Orkney coast lies in May in water that is atypical of the area (35.30°/oo at times) and hence to some extent the results reported here may not be representative of the long-term regime at that station. However, from our assessment of the results at stations B and C and the general meteorological situation during May it seems that in the second half of that month the situation off Fair Isle and Orkney returned to "normal". Certainly by 30 May, when the stations were recovered, "normal" conditions prevailed with mooring B in mixed coastal water (35.15°/oo) and mooring C in higher salinity water (35.29°/oo), as is depicted in the June bottom salinity chart. (Figure 3b).

VARIABILITY IN THE RESIDUAL CURRENT REGIMES

In Figure 4 the residual components of drift calculated from most of the records obtained and the daily mean air pressure in the operational area have been plotted against time. Whilst it is not possible to see the detailed changes of trend at this scale this figure effectively compares the general character of the records from station to station and provides the general meteorological background to the exercise. It also serves as a reminder of the complexities that are being smoothed out in the derived data products of later figures. All the basic data are available for inspection on request.

Dooley (1974) has suggested that the fields of residual currents in the Fair Isle-Orkneys area are confined to very narrow zones and are vertically uniform. These zones moreover are not fixed geographically, and so variability in time within and near these zones is a consequence not only of temporal variations in the strength of the residual currents but also of spatial shifts in the areas influenced by a given regime. He also demonstrated the likelihood of a continuous flow of water which passed from the area of station B through stations 1 and E and in which the direction changed gradually from south to east-going and then at about 1°E to northeast-going. He felt that the alignment of this residual drift regime was governed largely by the bottom topography.

With these points in mind, 7-day mean residuals were calculated from the moored station data and then plotted in their true geographical context. (Figure 5). Mean winds for the same period at Dyce airport were also calculated and plotted in order to give an indication of the changing meteorological situation during the exercise. Clearly several discrete oceanographic "events" can be seen in this series of diagrams and it seems likely that some of them occur at the same time as changes in the local wind regimes. In particular, the very large residuals at stations B and C on 29-30 April (29 and 20 cm/sec respectively) occur at a time when an intense depression is present to the southeast of the Shetland Isles. (See Figures 4 and 5d.) However, this is the only time when the residual drift regimes at stations B and C do have a great deal in common. Indeed, during May the record at station B is more similar in character to those at stations 1, D, E and F than that at station C. We see this as clear evidence, first, of a spatial shift in the zone of Atlantic water moving into the northwestern North Sea in the Fair Isle-Orkney area between late April and May and, second, of the fact that the residual flows at station B are part of the same regime as those found at the stations further south. Small time-lags of the order of 1-2 days are apparent between station B and the more southerly stations. From this it can be inferred that fluctuations in residual currents are associated indirectly with macro-scale atmospheric changes and directly with local variations of the wind-stress field which also has a lag of the order of 1-2 days across the area.

The complexity of the situation in this area is further emphasized by the fact that whilst the presence of the depression off Scotland on 29 April coincides with the occurrence of very high residuals at stations B and C subsequent similar meteorological systems (eg Figure 4, May 1, 6 and 10 in air pressure time series) do not lead to further large inflows of Atlantic water at either of those stations. A possible explanation of this apparent anomaly is that the first depression produced a wind field in the region lying on the periphery of the North Sea west of the Shetland Isles quite different from those produced by subsequent depressions, and the meteorological-oceanographic links in that region may have an important bearing on conditions in the vicinity of stations B and C. Similarly, meteorological processes outside the North Sea <u>per se</u> may account for the "event" around 12 May (Fig. 4) when residual current strengths at stations B and D increased considerably without any marked change in the local weather pattern. Consequently attempts to relate meteorological and oceanographic events very simply and directly are not likely, on this evidence at least, to produce very meaningful results in this region. Similar conclusions were reached by Howarth (1975) in his examination of meteorologically induced currents in the Irish Sea.

Figure 5 (c-g) also suggests, incidentally, that at any particular station in the network the residual drift at depth is typical of conditions over the whole water column at that station and that the regime at station 2 (a Lowestoft station) has much more in common with the regimes found at station F (an Aberdeen station) than it does with the Lowestoft stations 1 and 3 that lie west and east of it respectively. This provides in part the field inter-calibration check that has been found to be so important when the records from instruments from different laboratories are being compared.

DISCUSSION

(a) In relation to the Dooley Hypothesis

From what has gone before it is clear that several features of our relatively long records support the general hypothesis concerning the circulation of part of the North Sea suggested by one of us. (Dooley 1974.) In particular, we have seen that the Fair Isle-Orkney inflow zone *per se* is relatively narrow, and that geographically its position varies in the short term. It also appears that the influence of the inflowing water is restricted, probably by its links with bottom topography, to a relatively small part of the north-western North Sea. A corollary to this last point that is apparent in our data is that station G appears to lie in a different oceanographic regime, not only to stations B, 1 and E, but also to the stations lying east of 2°E. In the latter case very variable and slow-moving (less than 1 mpd) residual drift are found and this finding agrees in principle with the results reported by DHI (1968) and Ramster *et al.*, (1973) from a line of stations occupied for short periods in May 1962 and September 1972 respectively.

(b) Relevance to JONSDAP 76

In Figure 6 we have added to a resumé of these results the proposed lines of moored current meters and the main area of operations for projects INOUT and FLEX respectively of the JONSDAP 76 exercise. Clearly, if our assessment of the character of the residual drift in the region of the April-May 1973 moorings is correct the FLEX box should be clear of any influence from the relatively narrow, fast-flowing, Fair Isle current. However, it must be stressed that as yet we have no field evidence that downstream of station D the inflow does move off eastwards parallel to the 100 m contour, apart from the general sense of the distribution of Caesium 137 in this area as reported by Kautsky (1973). Indeed, it is now readily apparent that only the organization of a large-scale co-operative project like JONSDAP 76 can attract to the region the large number of self-recording instruments that are needed to monitor properly the spatial distribution of currents there. Once this has been done reasonably successfully then for the first time we shall also be able to make satisfactory estimates of volume transport and flow entrainment in the various residual drift regimes.

(c) The links between the wind and the residual drift regime

There is some evidence in our data to support the idea that from time to time the dissimilar residual current systems found in our operational area change slightly in character in the same way. In Figure 7 such marginal changes occur at most stations at a time when the local wind regime appears to be the causal factor. However, it is very evident too that the overall mean current fluctuations in this area are of much greater magnitude and are likely to stem from more complex interactions taking place both within and outside the North Sea. As fisheries oceanographers we must be more concerned with the second of these sets of fluctuations and with ascertaining, for example, the causes of the very large drift that occurred at station B throughout most of the measuring period since such residual movements might well carry into the North Sea at particular times of the year considerable numbers of fish eggs and larvae from the region north of Scotland. In Dooley and Mackay (1975) the likelihood of such developments is discussed in more detail than is possible here. All in all, we feel that it is highly relevant for both hindcasts and forecasts of larval recruitment to this region that an attempt should be made soon to clarify the nature of the relationship that exists between the residual drift and the meteorological regimes over the whole of the shelf seas lying to the north and east of Scotland.

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Figure 1. U.K. moored current meter stations in the northern North Sea in April and May 1973.

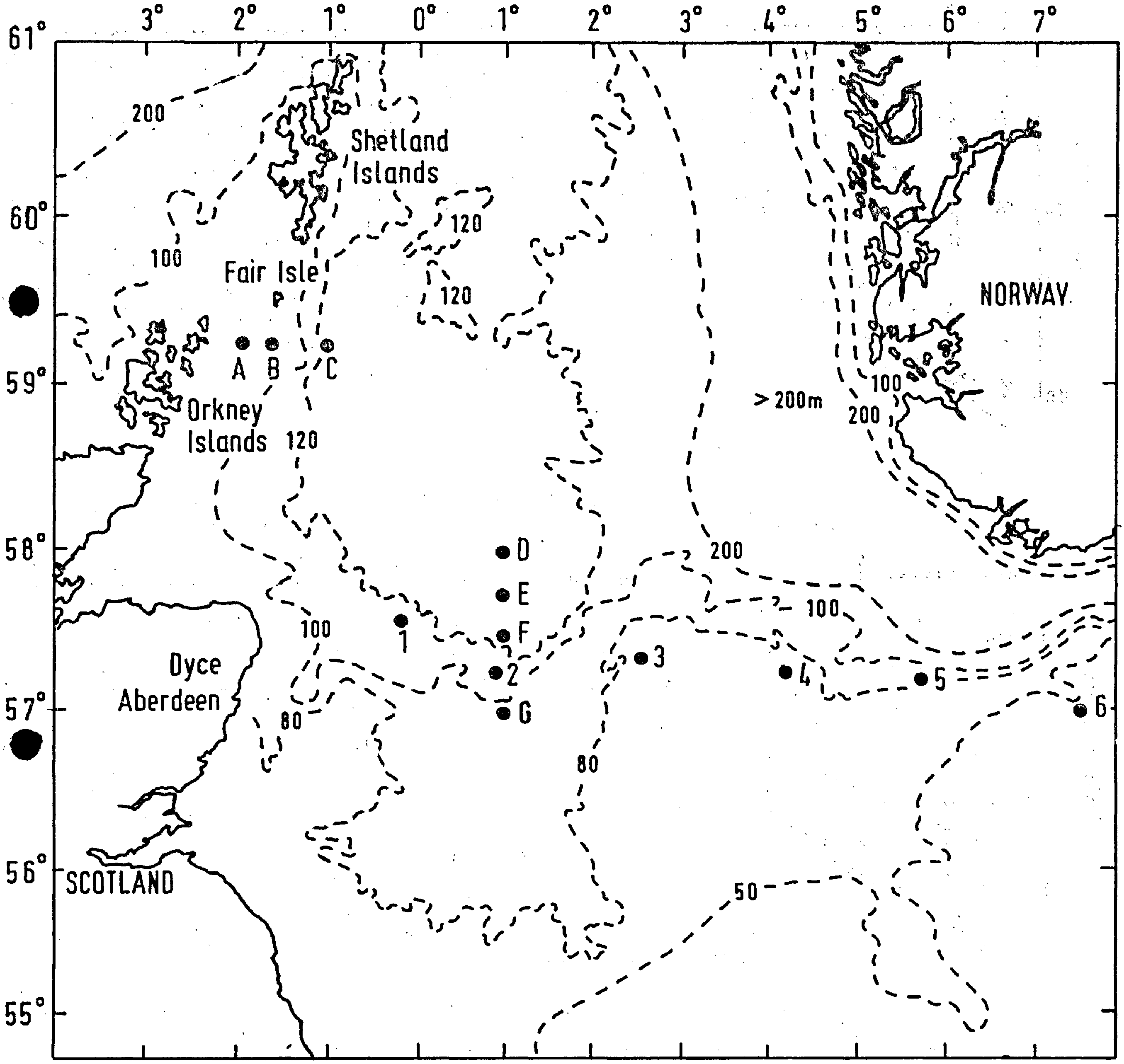
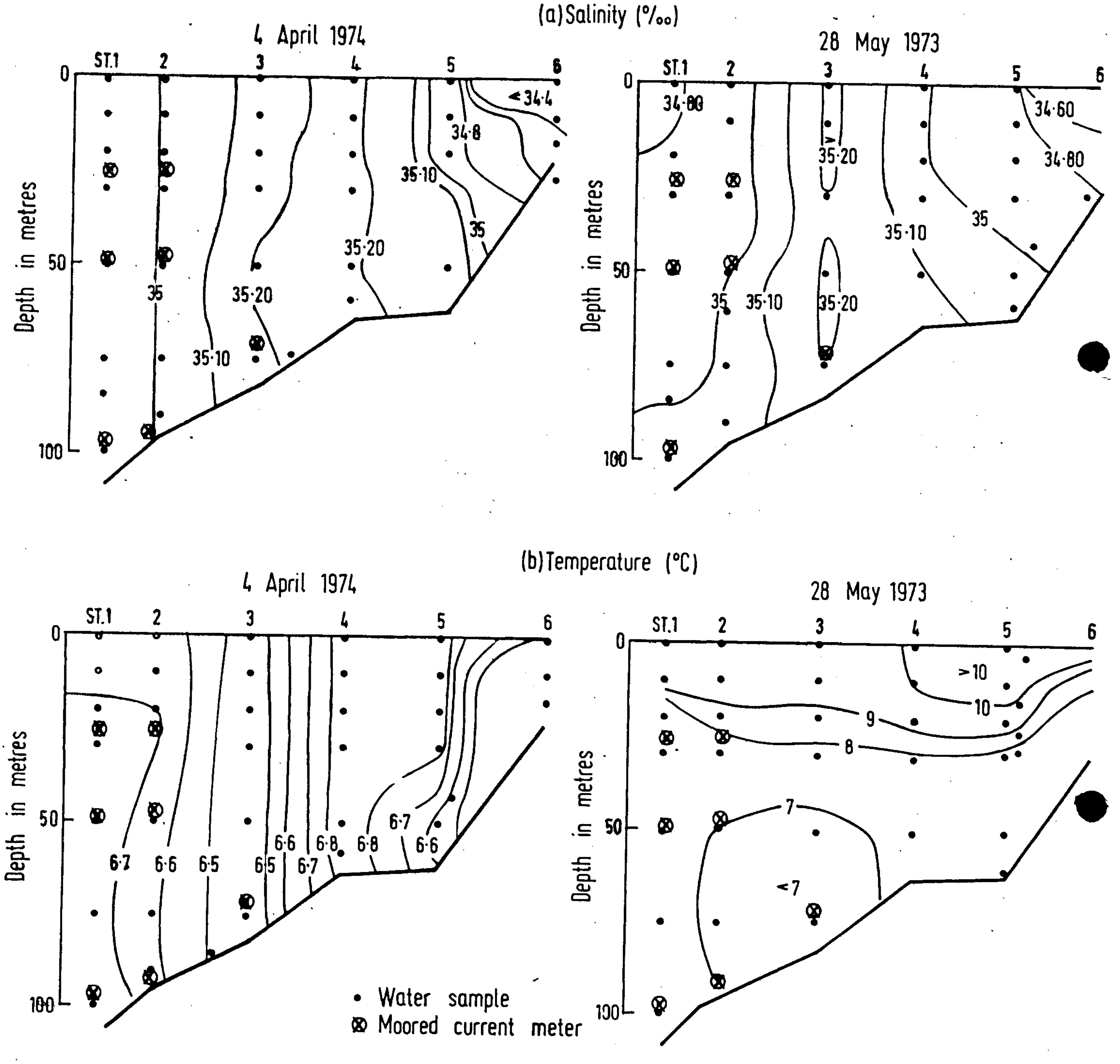


Figure 2. Salinity and Temperature sections between Scotland and Denmark, April and May 1973



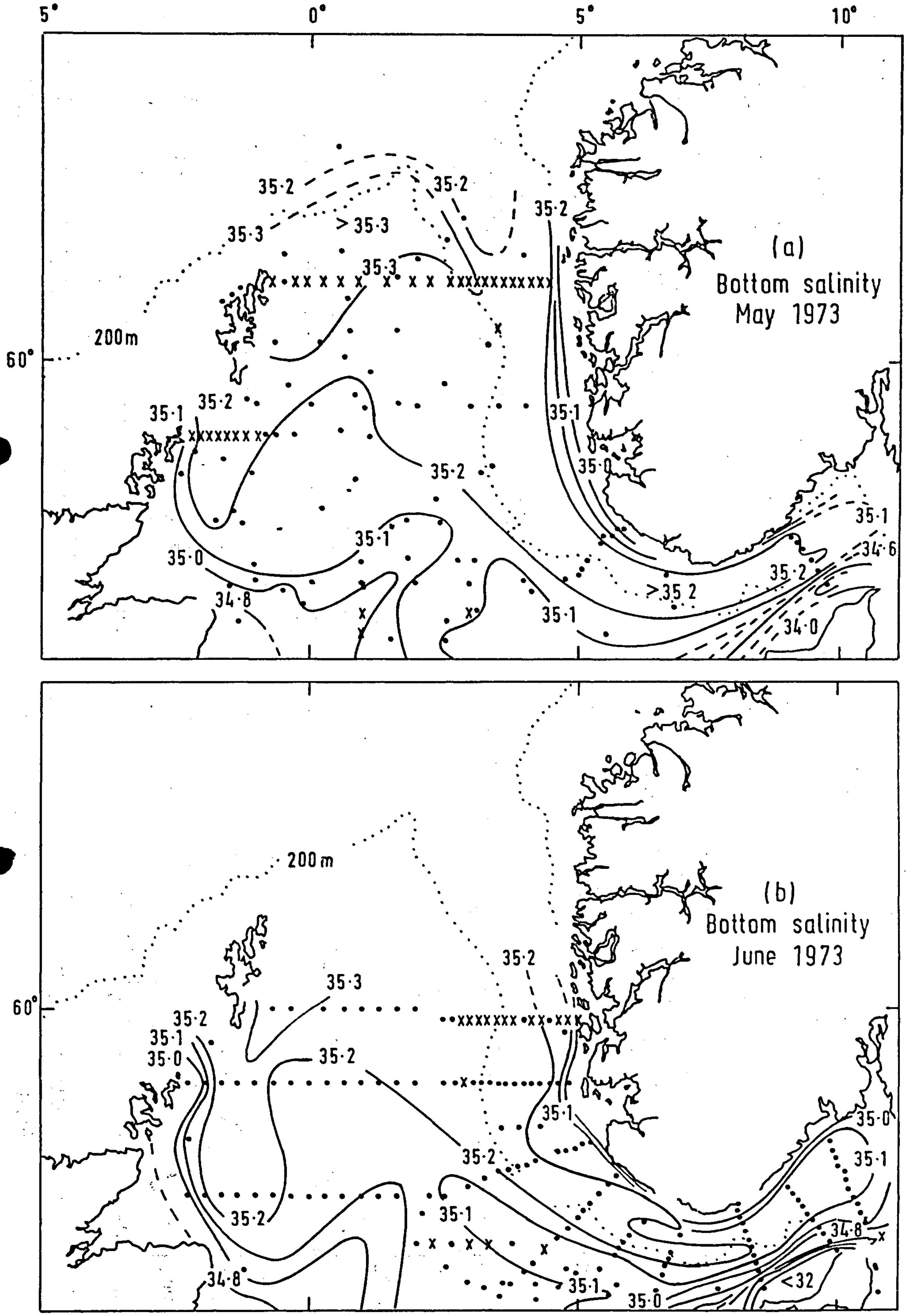


Figure 3 Bottom salinity in the northern North Sea in May and June 1973 (taken from ICES Service Hydrographique charts)

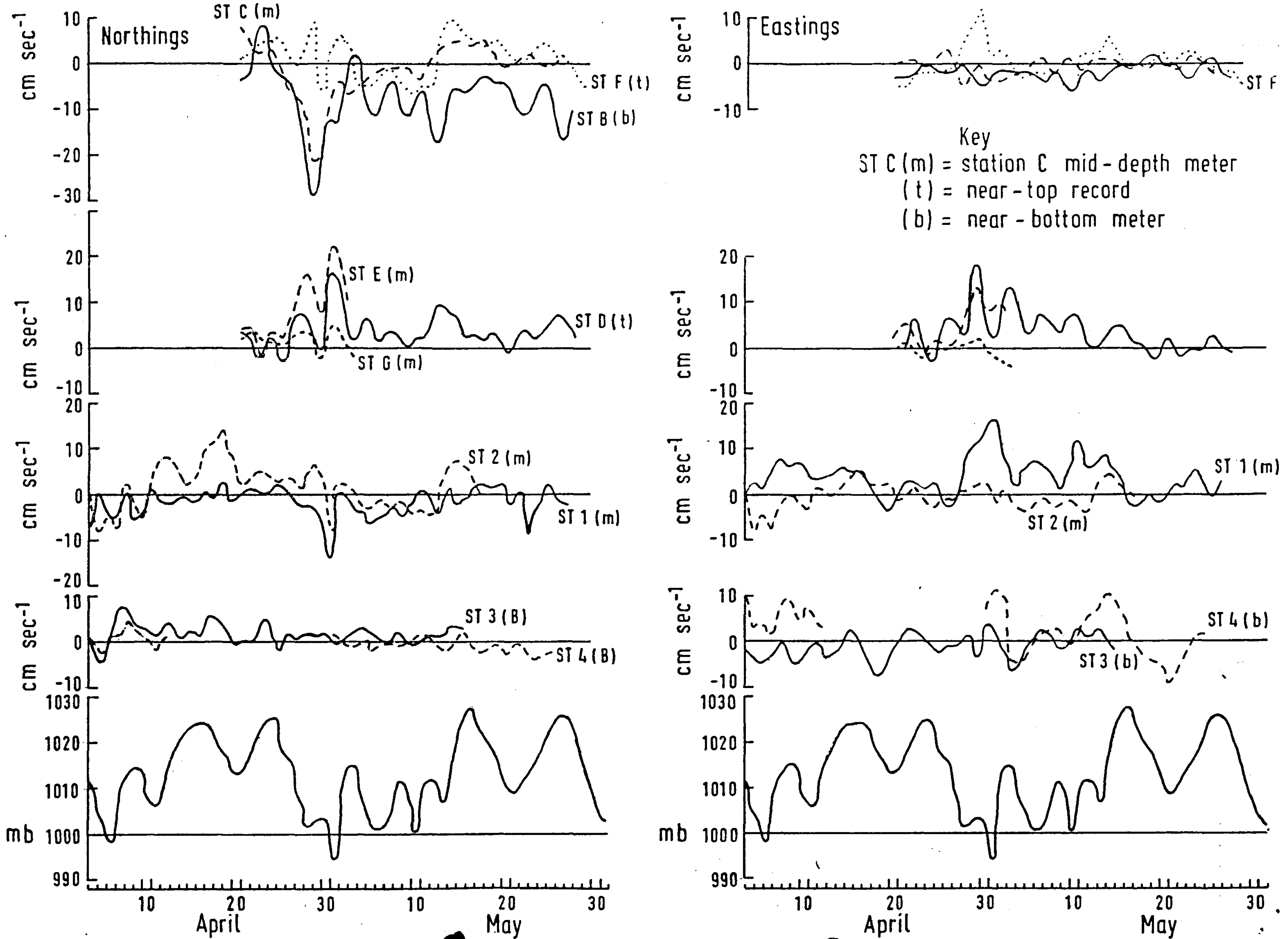


Figure 4. Components of residual drift a[illegible]the moored buoy stations and [illegible]ly mean air pressure in the operational area.

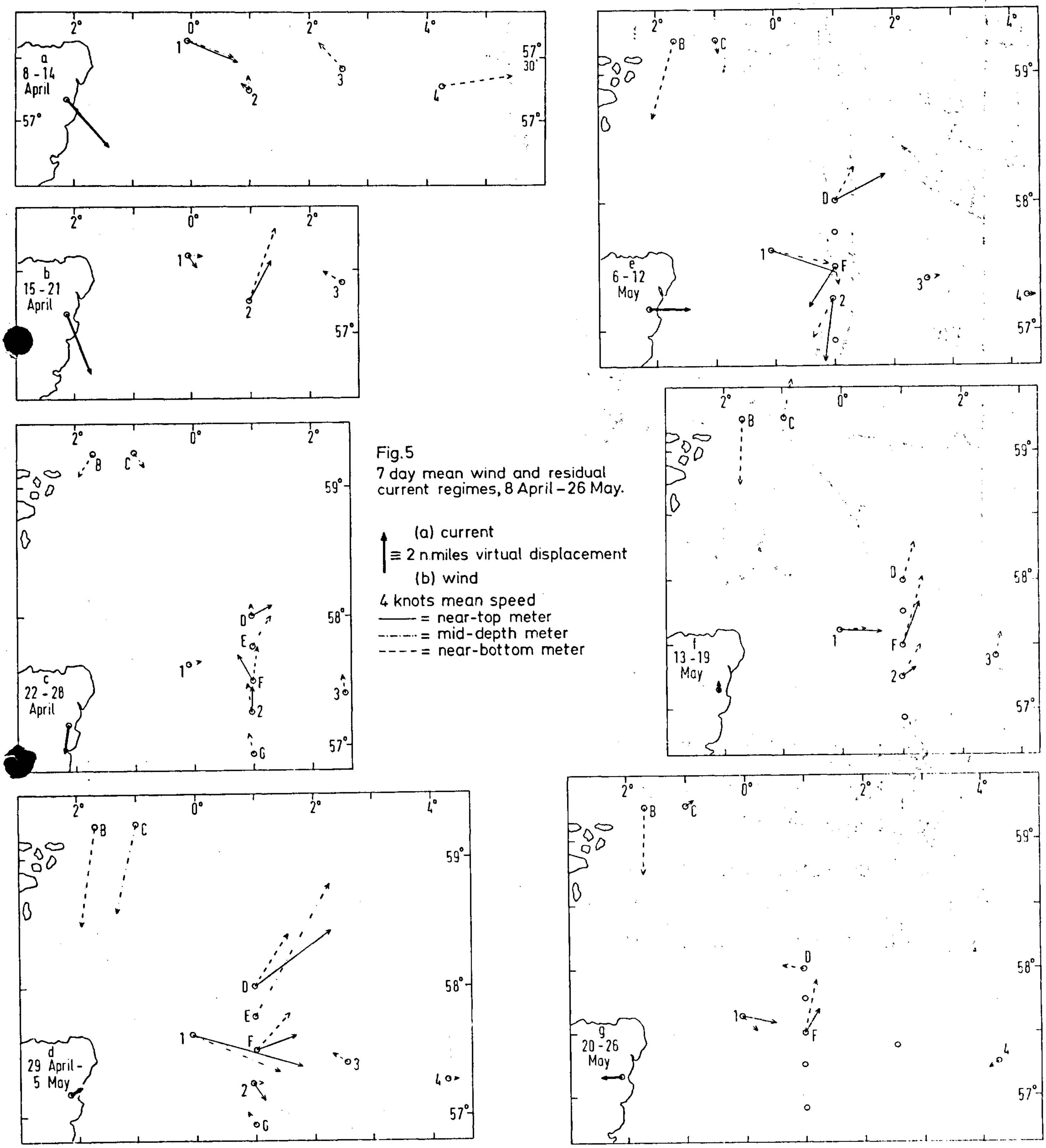
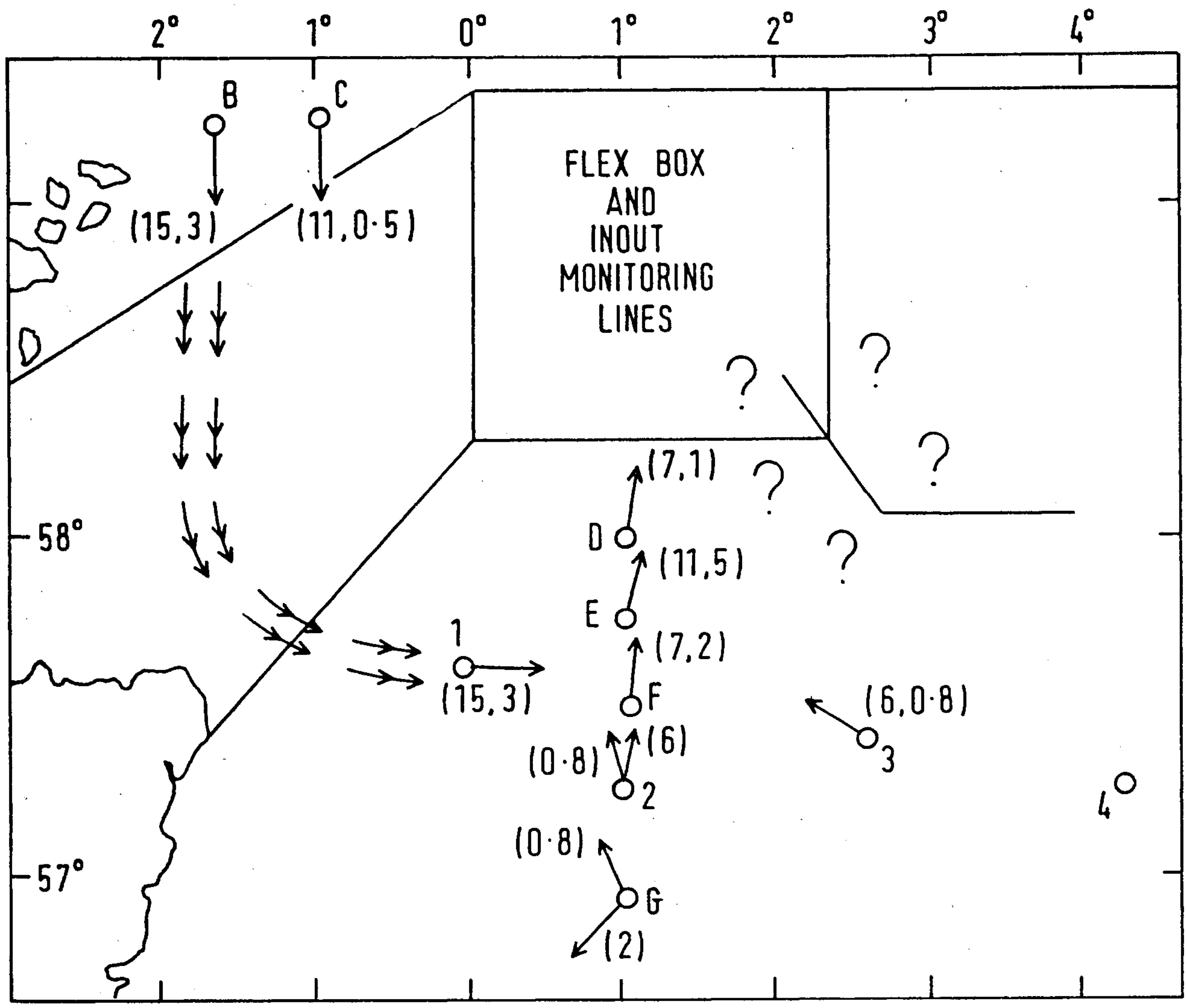


Fig.5
7 day mean wind and residual current regimes, 8 April – 26 May.

(a) current
≡ 2 n.miles virtual displacement
(b) wind
4 knots mean speed
——— = near-top meter
–·–·– = mid-depth meter
– – – – = near-bottom meter



KEY

Diagrammatic indication of mean and maximum residual drift.

(7,1) = Maximum displacement in nautical miles per day and mean displacement.

Suggested line of Fair Isle current.

Figure 6. Summary of results and relation to JONSDAP 76 plans.

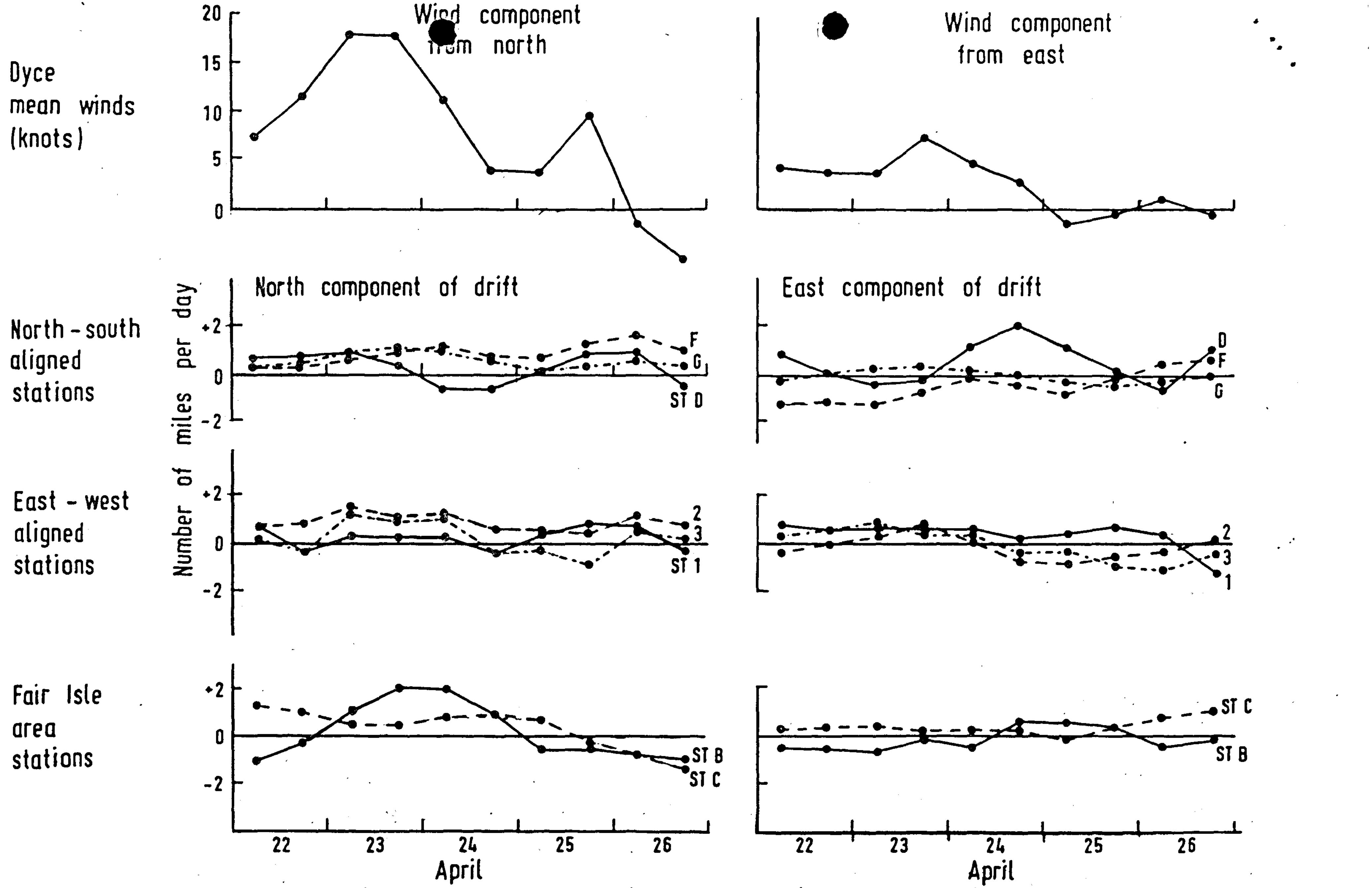


Figure 7. An example of the possible response of the residual drift regime to local wind systems, and of the generally similar marginal changes of residual drift character that occur over the region.

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Table 1. Station positions, periods of deployment and measuring depths

Station identification	Latitude	Longitude	Depth (M)	HT of Meter above bottom (M)	Period of measurement	
A	59° 16.91'N	01° 59.53'W	97	45	Nil	
B	59° 17.15'N	01° 41.25'W	79	54	Nil	
				18	19.4	30.5.73
C	59° 17.08'N	00° 59.50'W	124	68	19.4	30.5.73
D	58° 00.80'N	00° 58.17'E	146	110	20.4	31.5.73
				37	20.4	31.5.73
E	57° 45.12'N	00° 59.80'E	102	50	20.4	6.5.73
F	57° 29.28'N	01° 00.67'E	95	65	20.4	31.5.73
				5	20.4	31.5.73
G	56° 58.50'N	01° 02.00'E	92	48	21.4	6.5.73
I	57° 37.50'N	00° 07.00'W	106	84	4.4	27.5.73
				60	4.4	27.5.73
				12	4.4	22.4.73
2	57° 15.00'N	00° 59.00'E	93	73	4.4	21.5.73
				50	4.4	17.5.73
				12	Nil	
3	57° 25.00'N	02° 34.00'E	79	59	Nil	
				12	4.4	15.5.73
4	57° 17.00'N	04° 16.00'E	66	12	(3.4	12.4.73
					(1.5	26.5.73