Shelf Slope Observations

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Introduction

NUI, Galway are lead partners in two tasks in WP2 concerned with shelf-slope observations, namely making measurements during the OMEX II campaign and also to review and re-analyse existing hydrographic data in order to provide a data base in which OMEX II measurements may be placed into context and to provide data for flux calculations.

Measurements of the flow fields in the shelf slope region are needed to quantify the processes which exchange material, such as Carbon and nutrients, across the shelf edge. Along the shelf edge of the northeast Atlantic, the shelf edge current has been identified as a major dynamic feature (e.g. Huthnance and Gould; 1989, Barton; 1989). Along the Iberian margin, this feature is found in winter as a warm, saline poleward flowing current. (Haynes and Barton; 1990, Frouin et al.; 1990). CTD sections across the slope reveal the streaky, filament nature of the current which is between 25-40 km across (Frouin et al.; 1990) and satellite imagery show that the flow may progress around the NW corner of Spain into the Cantabrian Sea (Haynes and Barton; 1990). The limited horizontal extent to the poleward flow was found in direct measurements of the current reported by da Silva (1996), which showed the poleward current reaching depths of 300-400m over a water depth of 910m but was less apparent at similar depths over a water depth of 2300m. The winter time poleward flow appears to be forced by the large scale meridional pressure gradient in the north east Atlantic when the summertime southward trade winds have weakened or reversed. During the wind driven upwelling summer season, an equatorward slope/shelf current is generally found associated with the band of cool upwelled water at the Iberian margin.

Another major feature of the Iberian margin are the presence of upwelling filaments during the summer as have also been observed along the eastern Pacific boundary in the California Current system. These filaments appear as major features in July and subsequently grow until they reach their maximum extent in September (Haynes et al.; 1993). Analysis of satellite imagery (Haynes et al.;1993) reveal that the filaments grow to about 200-250 km in length and there are generally 5-6 filaments found along the Iberian margin. The formation of the filaments may be due to instabilities in the southward flowing current associated with the upwelling and/or with the topographic features such as capes found along the shelf edge.

Moorings

Moorings have been deployed as part of the OMEX 2 line (Figure 1). NUI, Galway have occupied the two shallowest stations at nominal depths of 700m and 160m. On the shelf, in an exact water depth of 156m at 42^o 40.94'N 9^o 28.58W, a bottom mounted ADCP was used, utilising the new Flotation Technologies Trawl Resistant Bottom Mount (TRBM). At 680m depth, a sub-surface mooring was deployed at 42^o 40.1'N 9^o 34.4'W with 4 current meters (CMs) located at water depths of 660, 580, 380 and 230m. Both moorings were deployed on CD105 (June 1997) and were due for recovery on CD110 in January 1998, and then re-deployed.
On the recovery cruise, however, it was found that the sub-surface mooring had been moved about half a mile up-slope and the mooring would not return to the surface although contact with the acoustic

release was possible. It is assumed that the mooring has been disturbed by fishing activity. Bad weather allowed no time for dragging operations and this must be done on a subsequent cruise. No deployment of the replacement mooring could be made because of the bad weather on the CD110 cruise.
Further problems have occurred with the bottom mounting for the ADCP. The mounting was trawled up by a fishing boat on the 16th December, 1997 a week before the RRS Charles Darwin arrived in the area to recover the package. The package was recovered from the fishermen and subsequent analysis of the ADCP records indicated that the mounting turned over during descent to the bottom. Flotation Technologies claim that their TRBM will not turn over during freefall descent (it's biggest selling point) and also will 'self right' within 50m of descent which obviously it did not. NUI, Galway purchased the TRBM in good faith considering it the best option for use in the region. Analysis of the ADCP showed that the mounting was hit four times before eventually being trawled up indicating the level of fishing activity present off Vigo. It is hoped to re-deploy the instruments in 1998.

Historical Analysis

Current meter data has been collated from many sources for statistical analysis and to review the previous observations and general dynamics of the Iberian margin. In total over 40 current meter (CM) years of Eulerian data has been collected as well as buoy tracks. Sources of data have been from BODC, SISMER (Bord-est data set), IH data sets and from Des Barton (UWB). Unfortunately, no data has been obtained from the MORENA project as yet, but data is expected in the near future. Analysis includes estimations of current means, monthly mean currents, tidal components, sub-tidal variance and current stability (the ratio of the vector to arithmetic mean current over one month periods using daily averaged data). Data coverage (Figure 1) is reasonably good in the southern portion of the Iberian margin but within the OMEX box (42-43^{o}N) there is minimal data sets to analyse. The inclusion of the MORENA data will help in this regard. The data from IH provide good coverage of the shelf region south of the OMEX box.
Mean currents for two depth ranges, shallow depths (<300m) and that level (600-1400m) influenced by the Mediterranean Water (MW) outflow, are shown in Figure 2. It should be noted that these means may be seasonally biased as many timeseries are less that a year long and so may reflect either summer or winter conditions, rather than an annual mean. For locations over deeper water, currents in the upper half of the water column show a general off shelf mean flow up to 5 cm s^{-1}, particularly in the southern Iberian margin. In the slope/shelf break region, small (1 cm s^{-1}) on-shelf means are found at the IH mooring locations near 41^{o}N. For CMs at depths <300m, but in the lower half of the water column, poleward mean flow is found off-shelf with small southward flow measured on-shelf over 100m water depth. At the level influenced by MW, flow appears essentially constrained topographically with poleward flows of O(5 cm s^{-1}). The exception is at the Bord-est line near 38^{o}N which show flow into deeper water and this is an area which was identified by Bord-est as a region where MW leaves the margin region (Daniault et al.;1994).

Seasonality of currents in the upper layer (<300m and upper half of water column) is shown in Figure 3. In winter (January, Figure 3a), currents along the slope and shelf region are strong (up to 10 cm s^{-1}) and poleward. Means off-shelf are variable in direction. In spring (April, Figure 3b), currents are weaker (< 5 cm s^{-1}) with no preferred direction for mean flow. Summer currents show a southward trend in both slope and off-shelf regions and presumably is a result of the southward directed wind forcing and associated upwelling conditions. By October, however, upwelling has ceased and poleward flow along the slope region has resumed. For the available data here, mean monthly currents for October are generally greater than 5 cm s^{-1}.

Monthly current stabilities (R, expressed as a fraction) are shown in Figure 4a. As one might expect, current stability increased with the magnitude of mean monthly current vector - higher mean flows indicating more persistent flow in a preferred direction. Stability values were consistently high (>0.8) for mean monthly currents greater than about 6 cm s^{-1}. This was also found for the stability values calculated from the entire length of individual timeseries. Only a small correlation for higher mean stabilities with increasing values of h/D (where h=CM depth and D is the water depth) was found. Taking all CMs available, monthly values of R varied little throughout the year and were generally high (R>0.5), with minimal variation in R for CMs at different depth levels (Figure 4b). Taking only those CMs located over the slope/shelf region (D<1000m), the situation is somewhat different (Figure 4c). Values of R are generally lower (<0.6) and values for CMs with h/D > 0.5 are smaller than those CMs in the upper layer of the water column. A maximum in R was found in October for CMs in the upper layer (h/D <0.5) with a minimum apparent in spring and early summer.

There has been some analysis of the buoy tracks provided by Des Barton (UWB, Haynes and Barton; 1990, 1991) and it is hoped that buoy tracks from the MORENA project may be added to the database. Splitting the tracks (buoys drogued at 5m depth) into monthly components show the variable nature in the surface flow field (Figure 5). Buoys were released at late September and initially the general flow was northward but this ceased at the end of the month when southward wind stress increased (Figure 5a). During October and November flow was variable with southward drift observed in some tracks (Figures 5b,c), with eddy activity present in the OMEX II box area SE of the Galicia Bank. By December (Figure 5d), the two buoys that remained in the north of the region moved further north, presumably in the poleward saline flow, and traveled around the NW corner of Spain into the Cantabrian Sea.

Discussion

To date the current meter analysis has confirmed the general pattern of circulation at the Iberian margin. There are two factors influencing the slope flow in this region, the summer dominated upwelling regime of equartorward flow and the density driven poleward flow found when the trade winds weaken or reverse. This maybe seen in the short (12 day) current meter records of Haynes and Barton (1990) and also the surface buoy tracks of the same authors. These show a reverse in a general northward drift when the opposing wind stress (measured at La Coruna) increased. Conditions needed in the pressure gradients to reverse the wind driven flow are, as yet, quantified and this is a subject which needs further examination within the OMEX project. Monthly variation in current stability, R, may reflect a balance or domination of one of these forcing processes. Generally value of R, calculated for the entire length of a timeseries, are high in the CMs located over deeper water and this is partly due to very high values associated with the flow of MW (4 of the 5 highest R values (R>0.9) are at the level of MW outflow). For CMs located in the upper layer (h/D <0.5) over the slope/shelf region, peaks in R are found in July, October and December with minimums in spring and early summer. The minimums a may reflect a period of change between the two dominant forcing mechanisms, when upwelling conditions maybe found intermittently. At times when one forcing mechanism is dominant e.g. in July (upwelling) or December (density driven flow) we might expect higher R values, as measured. There are, however, only a few monthly means with which to make averages and more measurements are need to clarify this.
Analysis will continue in the next phase of OMEX II and a data report is being compiled. An increase in the data base will come from more archive sources and from data being measured as part of the current experiment. Discussions have taken place with the OMEX physics modellers in how best to use the statistics generated for model validation. This task will also be undertaken in the next 12 months.

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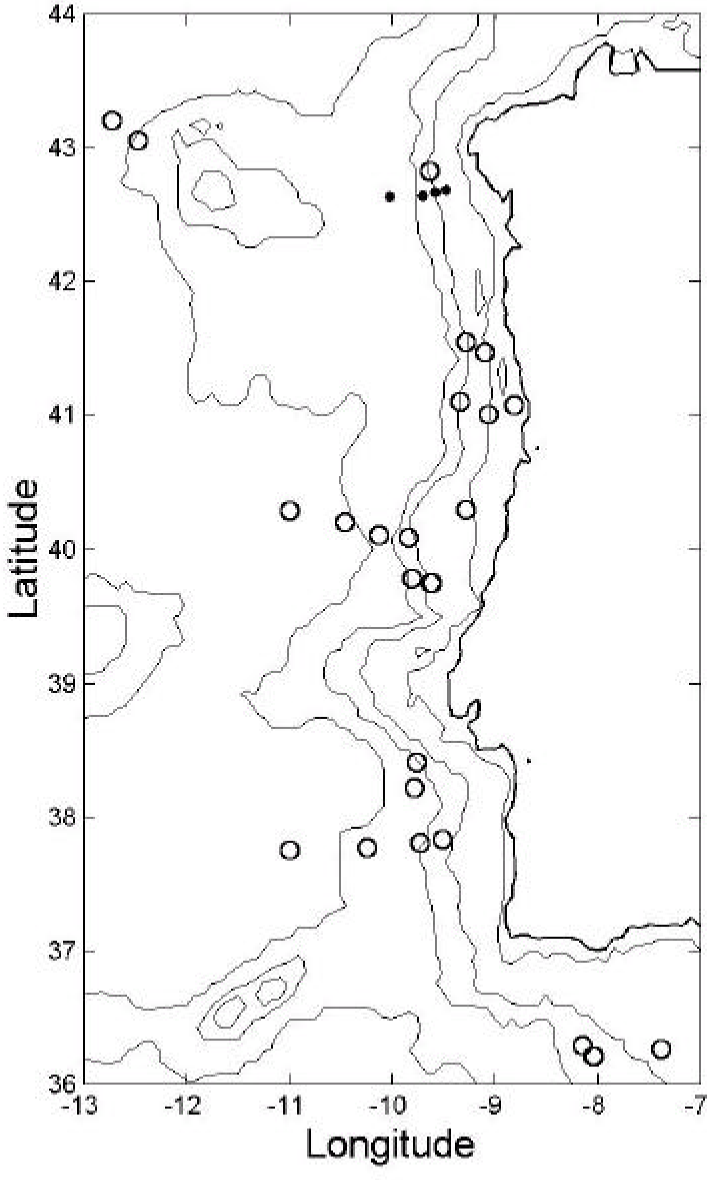

Figure 1. Position of archived CM data sets (o) and the OMEX 2 mooring line stations (.).

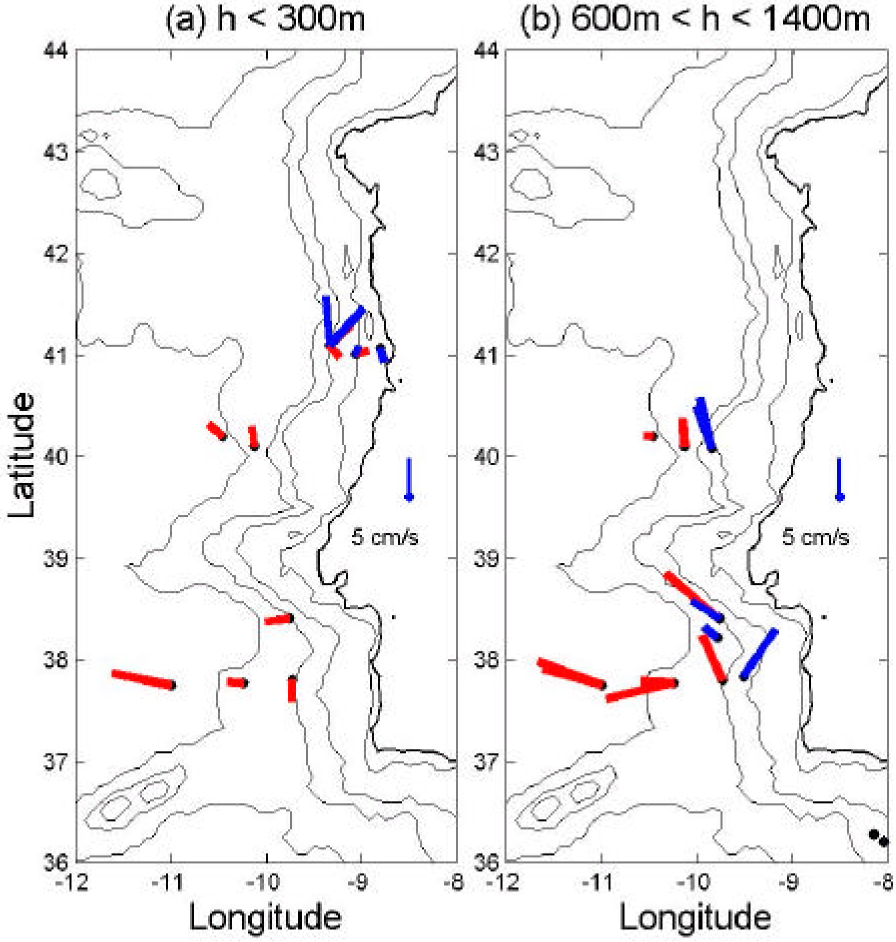

Figure 2. Mean current vectors for data in two depth ranges from archived data sets. Red = h/D < 0.5, Blue, h/D >0.5

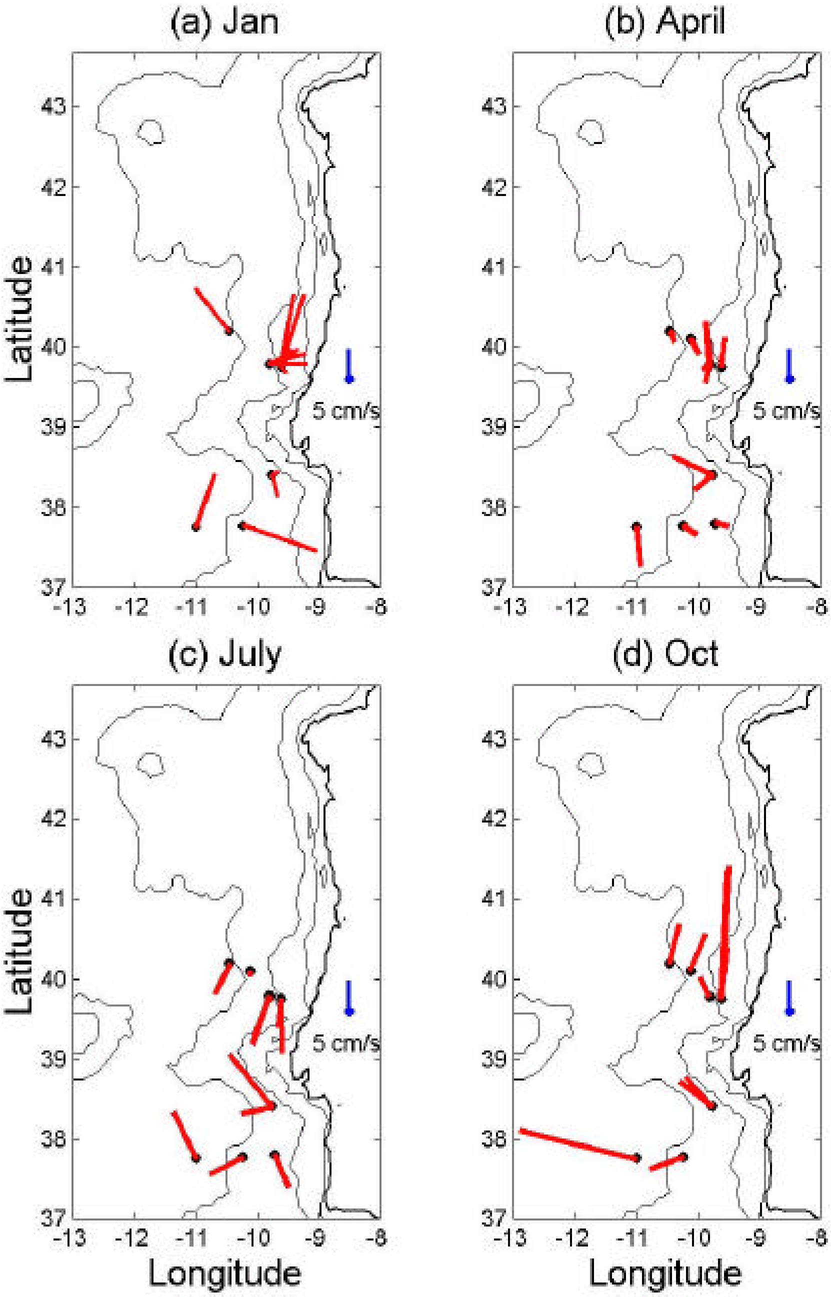

Figure 3. Monthly current means for CMs < 300m depth

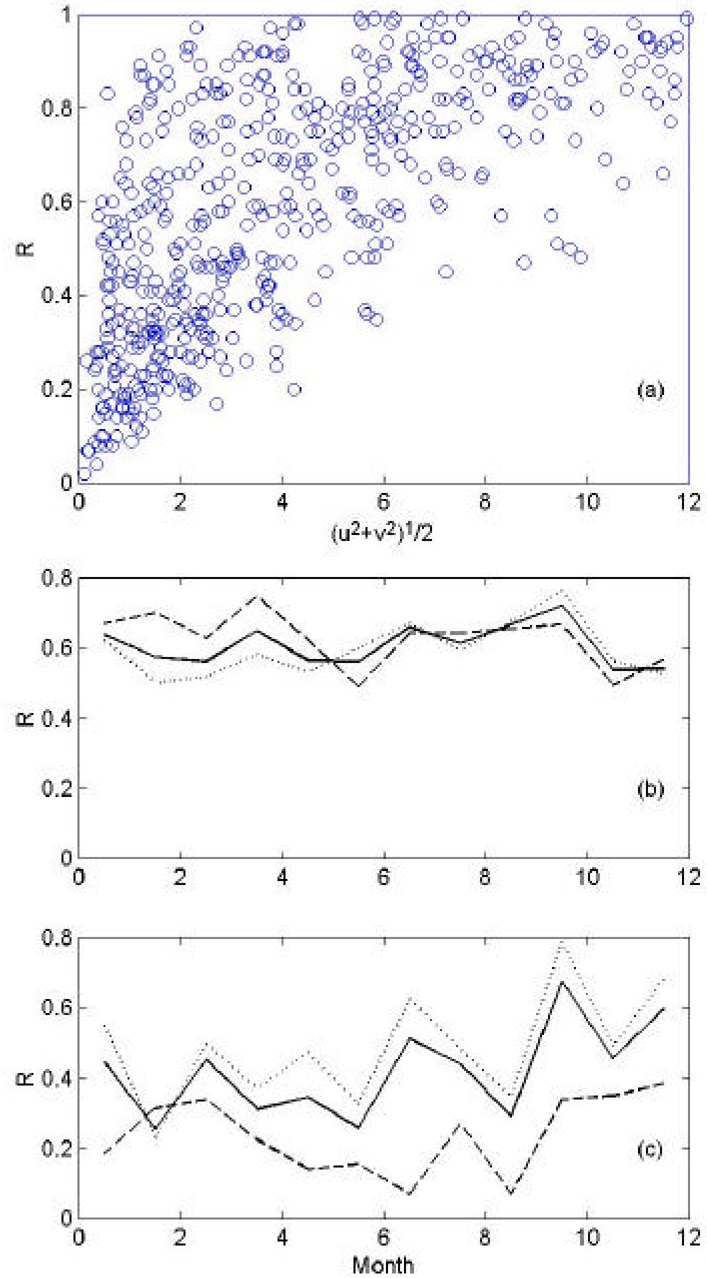

Figure 4. (a) Monthly Stability (R, all months) against current magnitude and timeseries R for (solid line-all), (---) h/D > 0.5, (...) h/D < 0.5 for (b) all CMs and (c) in water depth < 1000m.

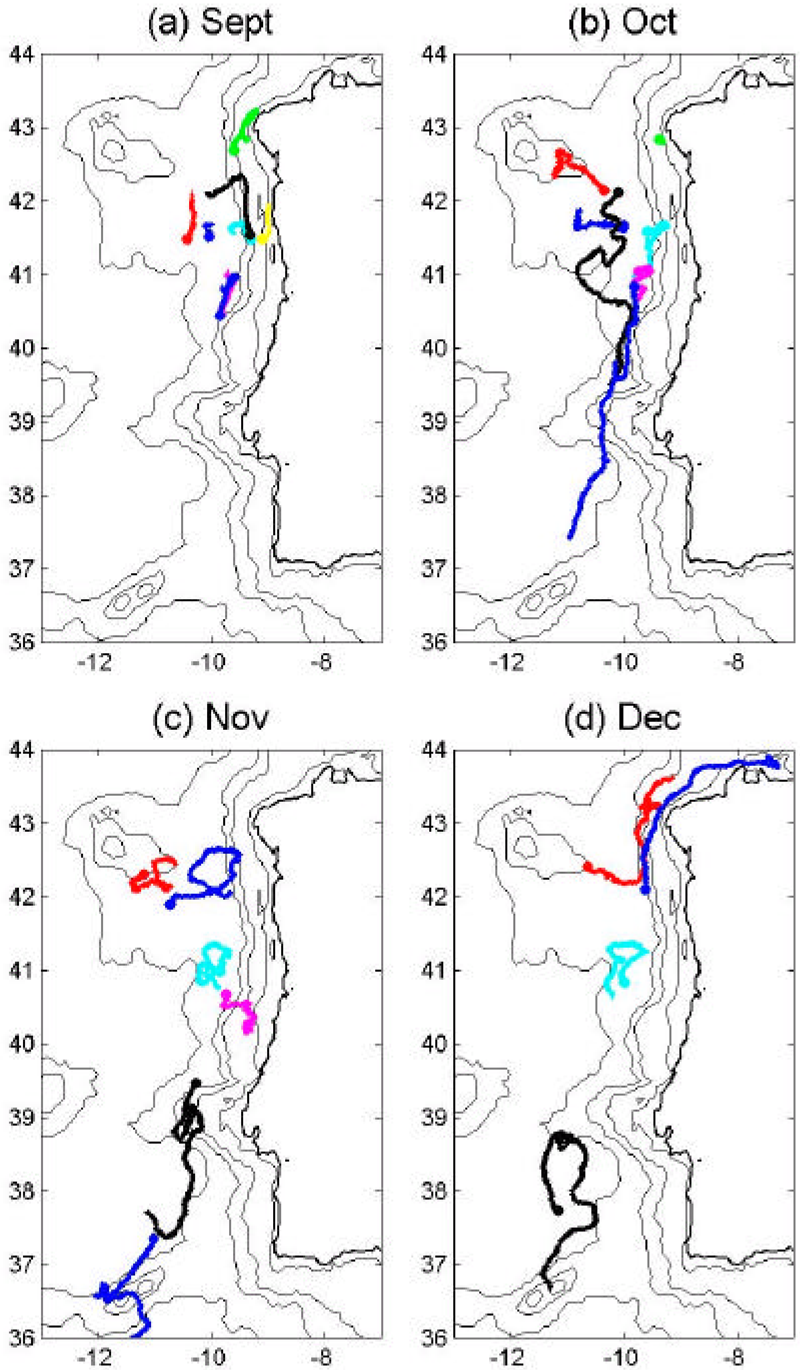

Figure 5. Monthly buoy tracks (5m drogue, Haynes and Barton; 1990).