THE IRISH COASTAL CURRENT: A SEASONAL JET-LIKE CIRCULATION

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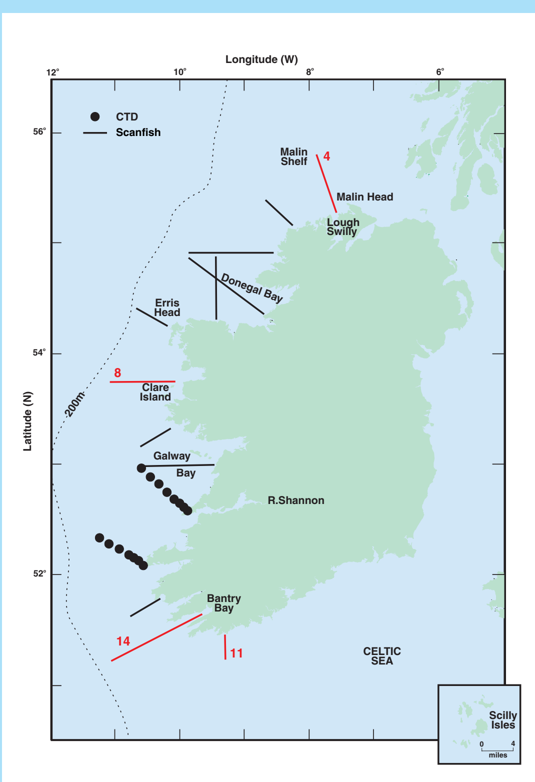
Introduction

Adjacent to the continental slope (200 m contour) and exposed to Atlantic weather systems (average monthly wind speeds between 12 m s^{-1} (January) and 7 m s^{-1} (June)), the waters of western Ireland exhibit hydrographic and biological properties characteristic of coastal and Atlantic regimes.

Argos buoy deployment from R.V. Celtic Voyager

A combination of relatively deep bathymetry and weak tidal amplitudes (< 0.3 m s^{-1}) means the water column stratifies thermally during summer (May – October). This occurs where there is insufficient tidally-generated turbulent energy to maintain mixing against the input of surface buoyancy through solar heating. However, near headlands and in shallow water tides may approach 1 m s^{-1} causing localised water column mixing. The conventional view of summer circulation is of a relatively quiescent dense (cold and salty) pool of bottom water beneath a warm and largely wind driven surface layer.

Recent work in the Celtic Sea (Horsburgh *et al*., 1998; Carrillo, 2001; Brown *et al*., 2002; Young *et al*., 2002) described a summer circulation dominated by fast (> 0.2 m s^{-1}), narrow (10-20 km wide) baroclinic jets associated with the margins of cold dense pools of bottom water trapped beneath the thermocline. These 'cold pool jets' flow in a cyclonic sense (dense water to the left in the northern hemisphere) and are essentially impervious to wind events. Limited evidence (drifters & current meters) indicated that circulation extends around the south-western tip of Ireland, but a description of the northward extent and continuity was elusive.



Surveys

From 26 July – 3 August 2001 a series of Scanfish (a towed undulating CTD (Brown *et al*., 1996; Fernand, 1999) and CTD sections were performed (above), representing the first comprehensive hydrographic survey of the coastal waters of western Ireland. Within the raw temperature and salinity data the horizontal distance between successive 'V' shaped Scanfish profiles was between 150 & 800 m depending on water depth.

Density and Velocity Structure

In the southwest (section 14; below left) temperature dominated stratification. Inshore (110 – 73 km) it was relatively diffuse, with a maximum surface to bottom temperature difference of 4 °C and little change in salinity. Close to where the bathymetry gradient changes (x ≈ 70 km) a comparitively sharp bottom density front was characterised by temperature and salinity changes of appoximately 1.5 °C and 0.3, respectively. Offshore (65 – 30 km) the strong surface themocline deepened, becoming more diffuse towards the shelf edge.

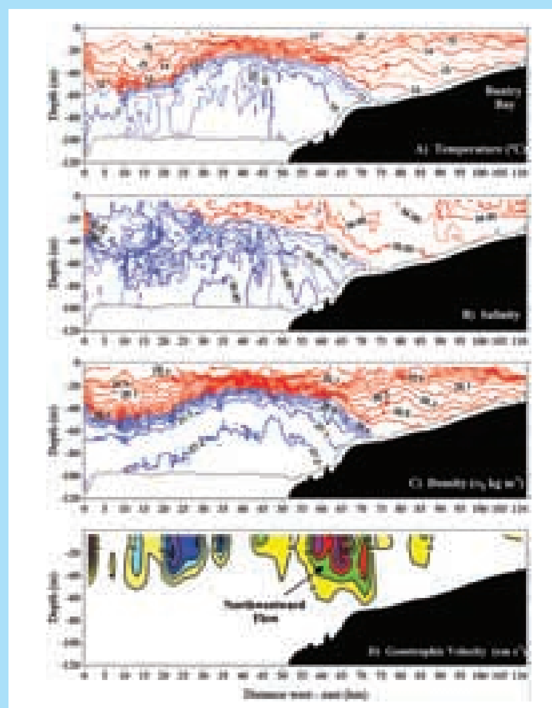
Computed geostrophic velocities normal to the section were calculated relative to an assumed level of no motion at the sea bed. Associated with the bottom fronts was a region of strong northwestward flow. At this resolution a series of comparatively small scale perturbations were present on the pycnocline, probably resulting from high frequency processes such as internal waves and thus not likely to be dynamically significant at low frequency (sub-tidal and sub-inertial) timescales (i.e. days).

Off Clare Island (section 8; below right) thermal stratification also controlled water column structure. The thermocline inshore was comparatively diffuse, with bottom fronts at 30 - 35 km along the section. West of a pinnacle (x = 22 km) the thermocline gradient sharpened. Salinity stratification was similar, with higher salinity deeper waters reflecting Atlantic influence and strengthening the bottom frontal region, associated with which was a distinct northward flow (>14 cm s^{-1}).

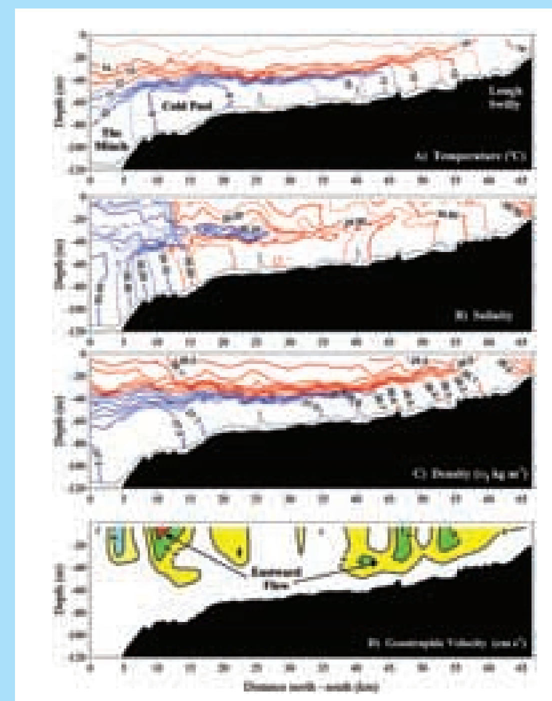
This jet-like flow was clearly seen in contemporaneous velocity data from a ship mounted 153.6 kHz broad band acoustic Doppler current profiler (ADCP), set to a resolution in the vertical of 4 m (bin size) and in the horizontal of approximately 250 m (1 minute averages).

In the north (section 4; below centre) thermal stratification again dominated, with a weak surface front (x = 50 - 55 km) and pronounced bottom fronts. To the north of the section a distinct pool of cooler saline Atlantic water coincided with the deep channel of The Minch. Two bottom frontal zones and associated eastwardly flowing jets of order 10 cm s^{-1}.

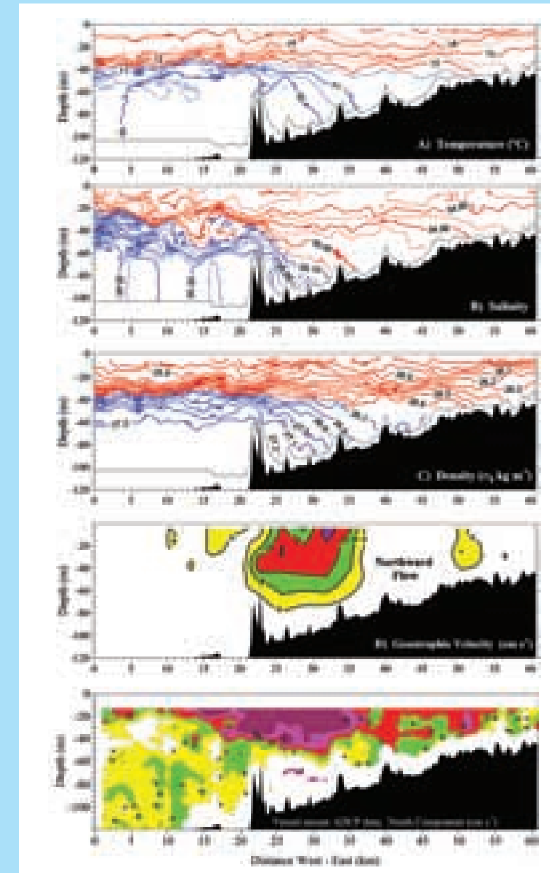
Section 14



Section 4



Section 8



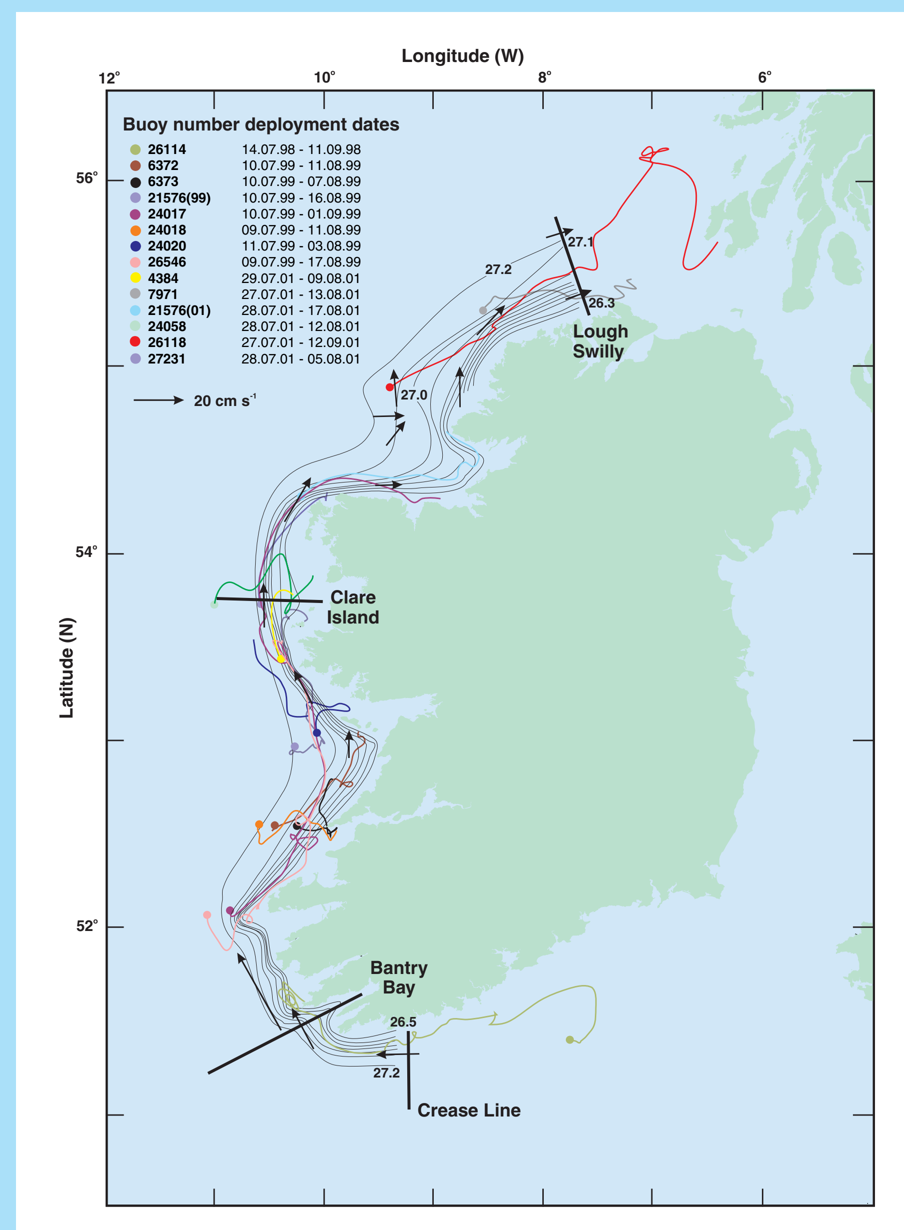
Regional Circulation

Satellite tracked drifters, with holey sock drogues 5.5 m long and 1.5 m diameter and centred at 30 m, were deployed at locations denoted by ● (right). In 1999 seven drifters were situated between latitudes 52 & 53°N. Trajectories of all but 24018, which stranded onshore, were northward parallel to the coast at mean speeds between 3.5 and 10 cm s^{-1}. The southern instruments (26546 & 24017) moved furthest describing similar paths across Galway Bay, with 24017 travelling 450 km at a mean speed of 10 cm s^{-1} (~8.5 km day^{-1}) and finishing in Donegal Bay. Residual flow near the River Shannon was weak and directionally variable.

In 2001 six drifters were deployed to the north of latitude 54°N. With the exception of 24058 (grounded) the overall movement was again parallel to the coast and northward at average speeds between 7.5 and 13.1 cm s^{-1}. Instruments 4384, 27231 and 21576 described a similar pathway to 24017 during 1999, with 21576 skirting Donegal Bay. To the west of Erris Head, 27231 moved at an average speed of 21 cm s^{-1} for the 5 days of its deployment. Of the two northern most instruments, 7971 became trapped near Malin Head whilst 26118 stagnated at the northern limit of its trajectory before moving south and beaching.

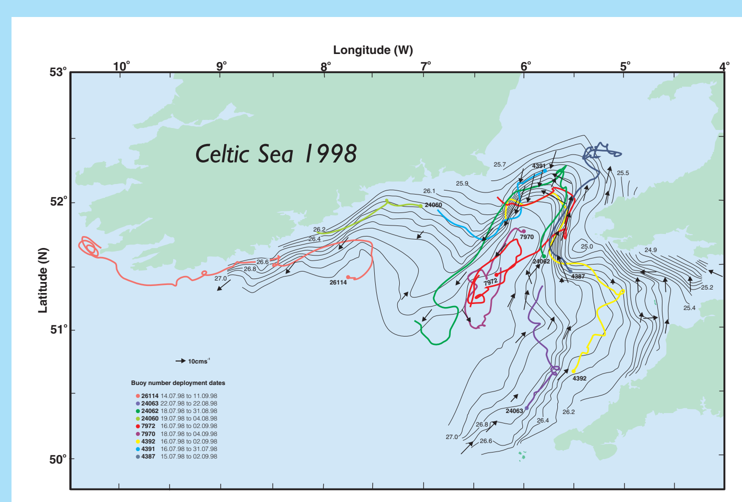
Direct wind influence was discounted as a forcing mechanism as no statistically significant correlations were found between the mean daily fluctuations in drifter and wind velocity components.

Filtered drifter trajectories are superimposed on contours of bottom density (σ_t (kg m^{-3})) derived from the Scanfish survey and illustrate the strong correspondence between drifter tracks and density gradient/bottom fronts. Included is a synthesis of flow (⟶ cm s^{-1}) derived from geostrophic estimates and representing the velocity at the core of the flow. Only velocity components normal to the sections can be computed, so the maximum possible geostrophic flow is underestimated if sections cross density gradients obliquely.



A Continuous Pathway

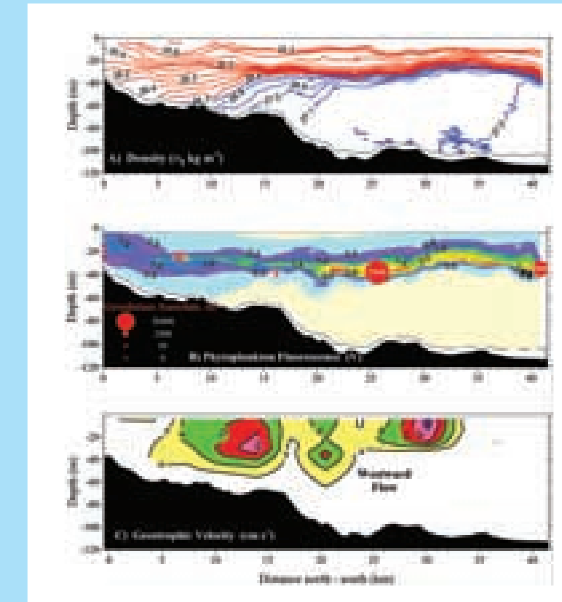
Overall, the summer circulation of the inshore waters of western Ireland is dominated by intense and predictable baroclinic jet-like flows associated with bottom fronts bounding a cold saline pool. A continuation of the summer density driven circulation of the Celtic Sea (right) this coastal current extends from the Celtic Sea to the Malin Shelf, before apparently passing into the Minch (Hill *et al*., 1997b) and along the western coast of Scotland.



Phytoplankton Dynamics

The coastal current may be implicated in the occurrence of harmful algal events that can require prolonged moratoria on the harvesting of shellfish in the bays of western Ireland. For example, *Gyrodinium aureolum* is associated with large mortality in shellfish and has been observed at locations from northwest France, the Scilly Isles and along the Irish coast bordering the Celtic Sea and Atlantic margin.

Section 11



Throughout the summer strong phytoplankton growth is associated with the base of the thermocline where light and the nutrients associated with deep waters are sufficient to support growth (section 11, above). It is likely that plankton are carried along the coast with the circulation and under certain wind conditions advected into the bays.

Summary

Our results add to a growing body of evidence (see references) that summer time circulation of the northwest European Shelf is dominated by organised flows located above bottom fronts that bound the margins of dense pools of water found in deep basins and other areas of low tidal energy. Such results highlight that for management of the shelf seas it is crucial to consider the appropriate time scales and physical processes. If models are to become reliable and believable management tools for biological and contaminant issues they must accurately represent the temperature, salinity and flow fields such as those presented here.

Acknowledgements

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