A HIGH RESOLUTION BATHYMETRY (1 KM) OF THE IRISH AND CELTIC SEAS FOR USE IN HYDRODYNAMIC MODELS.

by J. Brown, A.E. Joyce, J.N. Aldridge, E.F. Young, L. Fernand and J.M. Rees

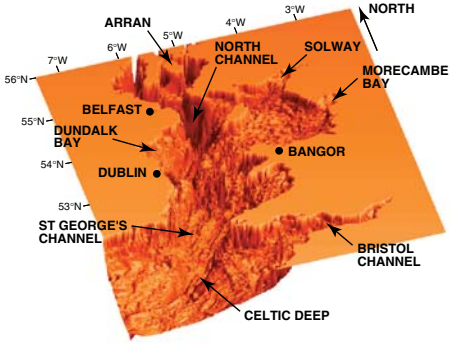
CEFAS
The Centre for Environment, Fisheries & Aquaculture Science

Introduction

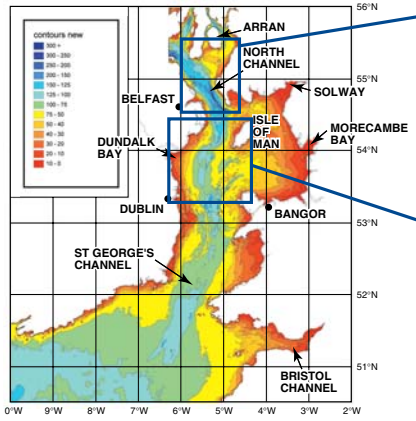
Successful marine environmental management requires the ability to understand and predict the physical mechanisms which control chemical and biological processes. In this, high resolution hydrodynamic models provide an important tool in the assessment and forecasting of environmental change, contaminant transport and fisheries recruitment. Good quality tidal models form the basis for such work and, in part, their success depends on the quality of bathymetric data. The 1995 Irish Sea Science Co-ordinator's Report[1], jointly commissioned by the UK and Republic of Ireland, identified a particular need for data to improve hydrographic models. Partly, this referred to a requirement for good quality high resolution observational data against which models can be validated. It also recognised the need for accurate high resolution bathymetric data for models, the next generation of which are being developed at resolutions of order 1 km.

Existing Bathymetries

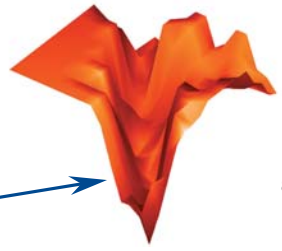
Existing model bathymetries stem from the 1970's when, typically, each grid box of shelf seas models covered a horizontal area of between 12 and 35 km^2. Largely, bathymetries were derived from standard Admiralty navigation charts. These offer comparatively poor resolution, reflecting the shallowest point in a region, as required for navigation purposes, rather than a depth representative of that throughout a model grid box. Present 'higher resolution' bathymetries (grids of order 4 km^2) were largely constructed by interpolation from coarser grids. Consequently, existing bathymetries offer a range of disparate resolutions in different areas and omit features that play an important role in determining the density structure and flows in a region.



New 1 km Bathymetry; 3-D Representation.



New 1 km Bathymetry; 2-D Representation.



North Channel of the Irish Sea at 8 km resolution. Used in many existing shelf seas models.

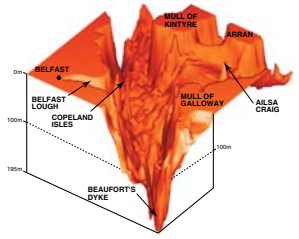
8km ⟹ 1km

Western Irish Sea at 8 km resolution.

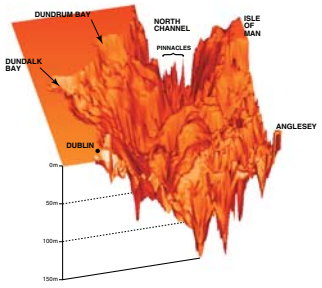
8km ⟹ 1km

New Bathymetry

Using data from Admiralty fair sheets, which give an accurate high resolution measure of depth direct from survey data, supplied by the UK Hydrographic Office, a bathymetry of the Celtic and Irish Seas has been constructed at a grid resolution of 1 x 1 km (strictly speaking 1/120° latitude by 1/60° longitude, a grid containing approximately 126000 data points). Where modern high resolution surveys were unavailable (largely the western Celtic Sea) data were digitised from Admiralty charts, as, largely, were those for the eastern Irish Sea. Fortunately, in these regions the bathymetry is comparatively gentle.



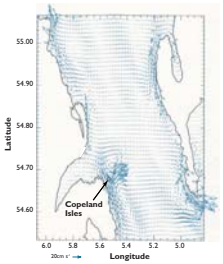
New 1 km resolution bathymetry of the North Channel.



New 1 km resolution bathymetry of the western Irish Sea.

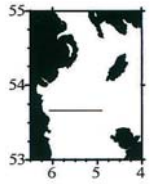
Data use

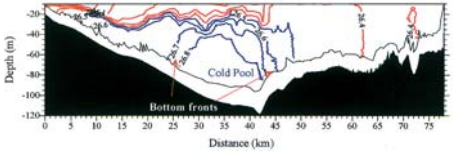
A recent modelling study[2] demonstrated the need to resolve the complicated bathymetry of regions such as the North Channel at a resolution of order 1 km to properly represent flow variability. This requirement is clearly seen in the complex horizontal structure of the tidal residual currents (right). For example, the strong gyre at the mouth of Belfast Lough arises from tidal interaction with the Copeland Isles and surrounding seabed, features generally not represented in existing bathymetries. Also, the region of southward flow centred at ~ 54.6°N 5.35°W perhaps helps explain why current meter observations in this region[3] suggest inflow into the Irish Sea on the western side of the Channel.



Density flows

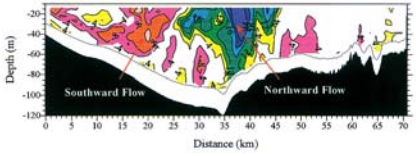
The next generation of shelf seas models beginning development, are intended to represent flow fields associated with persistent density differences (fronts). Recently, direct observations in the Irish Sea, North Sea, Celtic Sea and The Minch have demonstrated the existence of strong and persistent 'jet-like' flows whose location and strength is closely linked to the nature of bathymetry[4, 5, 6, 7 & 8], which necessarily must be accurately represented in model simulations. In this respect, the requirement for high resolution bathymetry has been demonstrated in the North Sea[9]. It should be noted that the natural length scale for deformation of frontal features is of the order 3-5 km, requiring models of greater resolution accurately describe flow fields.





Section (see left) of density (σ$_t$ kg m^{-3}; above) and north/south current flow (cm s^{-1}; below) across the western Irish Sea (7 July 1996). Isolated below a warm surface layer is a pool of cold water bounded by narrow (< 5 km) bottom fronts. Associated with these are strong north and south flows.

Direct measurements of flow in the western Irish Sea (above & right) show persistent 'jet-like' flows associated with the narrow bottom fronts that bound the cold pool of dense bottom water isolated below the seasonally warmed surface layer. The jets are ~ 10 km wide with peak speeds exceeding 20 cm s^{-1}, and the anti-clockwise current field dominates the summer (May-September) circulation. The positions of the fronts and associated flows are essentially constant and are determined by tidal interaction with bathymetry. Successful models will resolve such flows. Present modelling of the features[10] shows that coarse resolution bathymetry generates diffuse bottom fronts which occur over significantly larger horizontal scales than observed. Additionally, models using data derived from existing bathymetries over-estimate the northern and southern extent of summer stratified waters. In part, this can be attributed to inadequate representation of the area of pinnacles at the southern end of the North Channel (left). Their interaction with tidal flow generates the necessary turbulent energy to mix the water column.



Summary

Future management strategies will require a reliable predictive capability for spill response, licensing purposes, determining contaminant movement and understanding ecosystem response. Success will be judged by the ability to replicate high resolution data. In this, realistic estimates of bathymetry are required, which may also include parameterisation of bottom friction by sediment type.

Access to the Data Set

Contingent on permission from the Hydrographic Office, it is intended that the data be lodged at the British Oceanographic Data Centre and that it be available for research and emergency response purposes on condition that the appropriate copyright conditions are fulfilled and that DETR and MAFF support for the work is acknowledged.

References

1. Boelens, R.G.V., 1995. An integrated science programme for the Irish Sea: Synthesis and Recommendations. Third Report of the Irish Sea Science Co-ordinator.
2. Young, E.F., Aldridge, J.N. and Brown, J., 1999. Development and validation of a three-dimensional curvilinear model for the study of fluxes through the North Channel of the Irish Sea. Continental Shelf Research, In press.
3. Brown, J. and Gmitrowicz, E.M., 1995. Observations of the transverse structure and dynamics of the low frequency flow through the North Channel of the Irish Sea. Continental Shelf Research, **15**, 1133 - 1156.
4. Brown, J., Hill, A.E., Fernand, L. and Horsburgh, K.J., 1999. Observations of a seasonal jet-like circulation at the central North Sea cold pool margin. Estuarine, Coastal and Shelf Science, **48**, 343 - 355.
5. Hill, A.E., Brown, J. and Fernand, L., 1996. The western Irish Sea gyre: a retention mechanism for the Norway Lobster (Nephrops norvegicus)? Oceanologica Acta, **19**, 357-368.
6. Hill, A.E., Brown, J. and Fernand, L., 1997a. The summer gyre in the western Irish Sea: shelf sea paradigms and management implications. Estuarine, Coastal and Shelf Science, **44** (Supplement A), 83 - 95.
7. Hill, A.E., Horsburgh, K.J., Garvine, R.W., Gillibrand, P.A., Slesser, G., Turrell, W.R. and Adams, R.D., 1997b. Observations of a density-driven recirculation of the Scottish coastal current in The Minch. Estuarine, Coastal and Shelf Science, **45**, 473-484.
8. Horsburgh, K.J., Hill, A.E. and Brown, J., 1998. A summer jet in the St George's Channel of the Irish Sea. Estuarine, Coastal and Shelf Science, **47**, 285 - 294.
9. Proctor, R. and James, I.D., 1996. A fine resolution model of the southern North Sea. Journal of Marine Systems, **8**, 285 - 294.
10. Horsburgh, K.J., 1999. Observations and modelling of the western Irish Sea gyre. Ph D Thesis, University of Wales Bangor.

Acknowledgements

This work was funded by DETR under contract CW0753 'Further Identification and Acquisition of Bathymetric Data for Irish Sea Modelling.' and an earlier Department of the Environment contract EPG 1/9/61. Funding to construct the bathymetry to the north and west of 54° 20'N and 4° 20'W, respectively, was provided by the Ministry of Agriculture and Food. Bathymetry reproduced with permission of the hydrographic office of the United Kingdom and the Controller of Her Majesty's Stationary Office.

The Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Lowestoft Laboratory, Pakefield Road, Lowestoft, Suffolk NR33 0HT, UK http://www.cefas.co.uk