A MODELLING STUDY OF THE SEASONAL EVOLUTION OF THE PHYSICAL STRUCTURE OF THE SOUTHERN NORTH SEA IN COMPARISON WITH OBSERVATIONS

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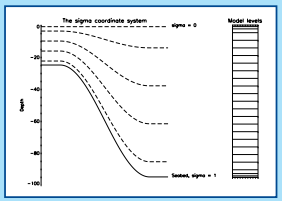
POM model description

- The physical model is a three-dimensional, primitive equation, σ co-ordinate, free-surface model based on the Princeton Ocean Model (Blumberg and Mellor, 1987) with Mellor and Yamada (1982) turbulence closure. The model domain encompasses the Southern North Sea from the Dover straights to 56.5°N (Figure 1). Details of the model physics are provided in Young (2002). Spatial cell dimensions are 1/20° in longitude and 1/30° in latitude giving a resolution of approximately 3.3 km x 3.7 km.
- Twenty-five sigma layers were used in the vertical, arranged as follows: σ = (0, -0.01, -0.025, -0.05, -0.1, -0.15, -0.2, -0.25, -0.3, -0.35, -0.4, -0.45, -0.5, -0.55, -0.6, -0.65, -0.7, -0.75, -0.8, -0.85, -0.9, -0.95, -0.975, -0.99, -1.0). This irregular spacing provides increased resolution in the high-shear surface regions and near-bed layers.
- Model depths were obtained by smoothing a fine resolution (1 nm) bathymetry provided by DHI Water and Environment, Denmark.
- Boundary conditions were taken from the Proudman Oceanographic Laboratory regional scale model (POLCOMS – S12).
- Meteorological forcing was obtained from ECMWF operational dataset.
- The initial temperature field was obtained from NASA Pathfinder AVHRR SST observations.
- River flow data were provided the UK National River Flow Archive and the Institute of Oceanography, Centre for Marine and Climate Research, University of Hamburg.

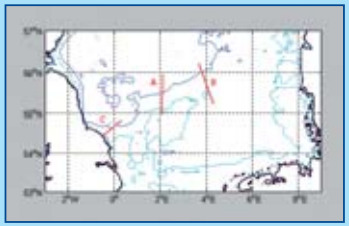
Figure 1: Model Area



Sigma Levels

Comparisons of model results with observations

Observations were obtained with a 'Scanfish' towed undulating CTD on research cruises of the CEFAS R.V. Corystes in the summer of 2001.



Locations of displayed Scanfish sections

Scanfish: towed undulator

Section A - Temperature

The observations show a sharp thermocline below a well-mixed surface layer. Neither of these features is well produced by the model (and this problem is common throughout the model domain). Simulation of bottom temperatures and horizontal temperature gradients however is quite accurate.

Section A - Salinity

Salinity in the surface layer shows a slight south to north rising gradient caused by the influence of higher salinity North Atlantic water flowing south past Scotland. This is evident in the model results at a reduced magnitude. The observations also show an area of lower salinity water below the thermocline in the centre of the section. This is not captured in the model simulation. Absolute values of salinity are also higher in the model than in the observations.

Section B - Temperature

The observations in section B show that mixing over the Dogger Bank is causing bottom water temperatures to be increased and bottom fronts to form between the well-mixed and stratified areas. The model simulates the absolute values of temperature and the horizontal temperature structure fairly well although again the thermocline does not show the sharp gradients seen in the observations.

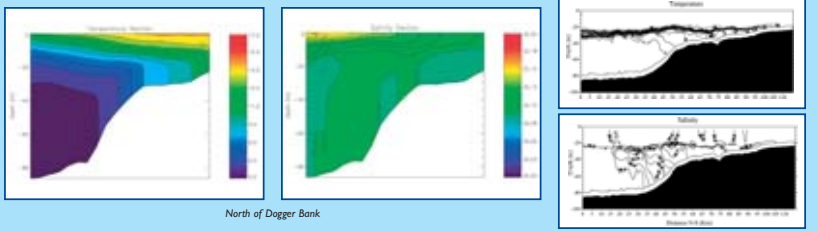
Section B - Salinity

Observations show a rising salinity gradient from south to north as previously discussed in section A. The model only captures this as a surface intrusion. The lower salinities south of the Dogger Bank are not seen in the model results.

Section C

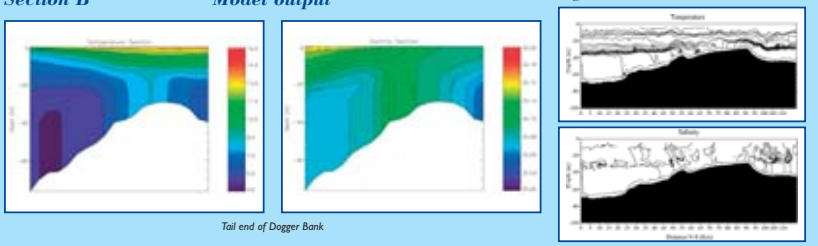
Section C reiterates the strengths and weaknesses of the model by showing good simulation of absolute values of temperature and horizontal temperature gradients but poor simulation of vertical structure. The steady horizontal salinity gradient seen in the observations is present in the model but the magnitude of the gradient is much reduced. The western (coastal) end of the model section shows the influence of fresh water input which is added throughout the depth of the water column.

Section A — Model output — High Resolution Observations



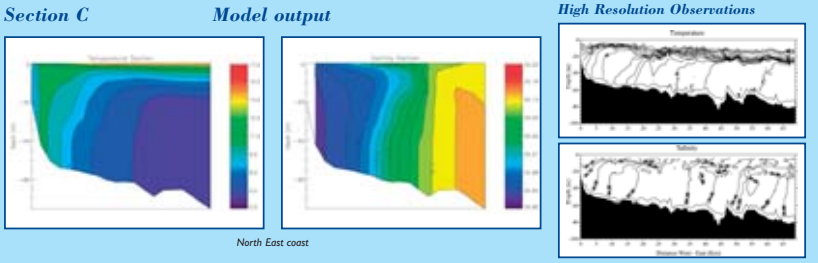
North of Dogger Bank

Section B — Model output — High Resolution Observations



Tail end of Dogger Bank

Section C — Model output — High Resolution Observations



North East coast

Conclusions

The main weaknesses of the current model are in the representation of the vertical water column structure and in the salinity implementation.

Work is in progress to improve the simulation of the surface mixed layer with the inclusion of surface wave breaking TKE (Craig and Banner, 1994). The literature suggests that this should provide a mechanism for generating a more realistic mixed layer depth than the using solely the Mellor-Yamada turbulence closure method (Mellor & Yamada, 1982).

Simulation of sharp temperature and salinity gradients in 3D sigma coordinate models is a common problem. A recent change from 15 to 25 vertical levels has produced some improvements however computer resources currently restrict further increases in vertical resolution.

The salinity implementation is still very much 'under construction' and the most likely explanation for the errors in the model salinity predictions is that the initial conditions are not in balance with the river forcing and boundary conditions. The results are taken from a run six months after initialization with fields taken from the POLCOMS S12 regional scale model. If poor initial conditions are the main factor then results taken after a longer spin-up period would show more salinity variations caused by local river forcing.

References

Blumberg, A.F. and G.L. Mellor, 1987: A description of a three-dimensional coastal ocean model. *Three Dimensional Coastal Ocean Models*, N.S. Heaps, Ed., AGU 1-16.

Craig, P.D., and M.L. Banner, 1994: Modelling wave-enhanced turbulence in the ocean surface layer. *J. Phys. Oceanogr.*, 24, 2546-2559

Mellor, G.L., and T. Yamada, 1982: Development of a turbulence closure model for geophysical fluid problems. *Rev. Geophys. Space Phys.*, 20, 851-875.

Young, E.F., 2002: Tidal validation of a three-dimensional, primitive equation model for the Irish and Celtic Seas region. *The Centre for Environment, Fisheries and Aquaculture Science, Lowestoft, Internal report.*

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