A REGIONAL HYDRODYNAMIC MODEL OF THE SOUTHERN BENGUELA UPWELLING

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To explore the environmental processes affecting fish recruitment in the Southern Benguela, an eddy resolving, coastal hydrodynamic model has been implemented in order to simulate the circulation over the main spawning and nursery grounds. Within the wide range of numerical models available, we selected the Regional Ocean Model System (ROMS). ROMS is a community model shared by a large user group and developed at Rutgers University and the University of California Los Angeles (Haidvogel *et al.* 2000).

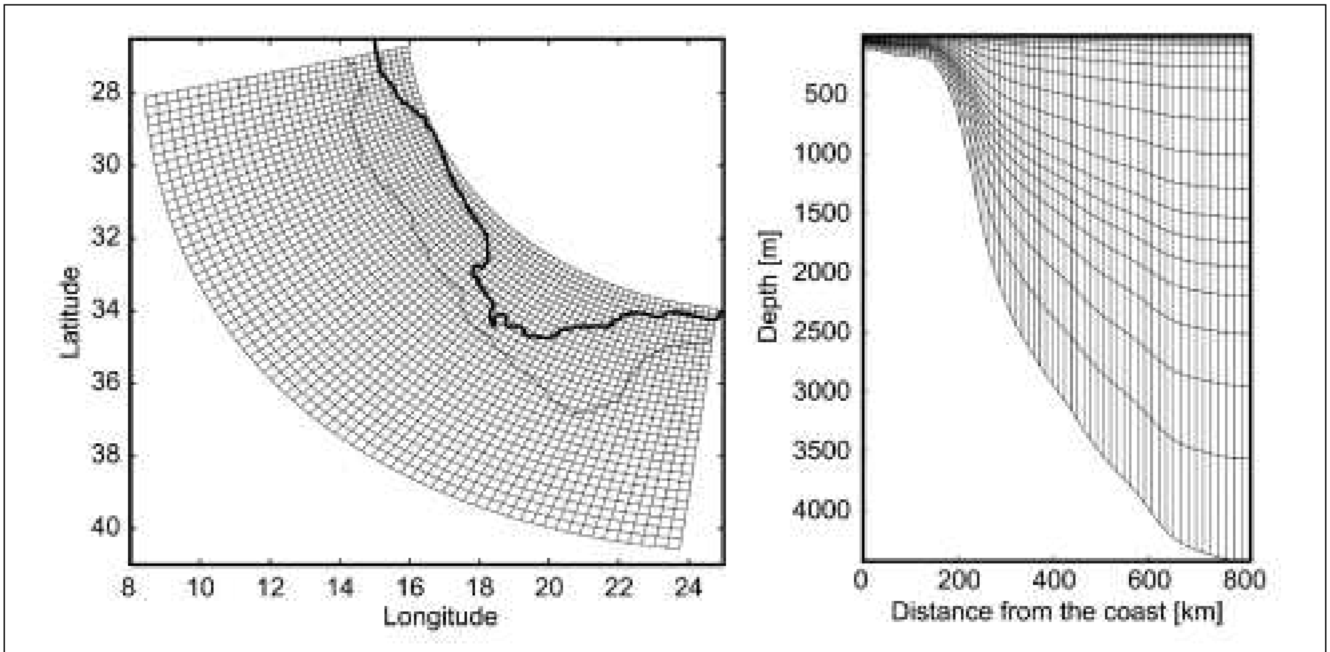

Fig. 1

ROMS incorporates advanced features allowing the efficient resolution of mesoscale dynamics. ROMS solves the free surface, hydrostatic, primitive equations of the fluid dynamics over variable topography using stretched, terrain-following coordinates in the vertical plane, and orthogonal curvilinear coordinates in the horizontal plane. Active open boundaries, connecting the regional model with the open ocean, are implemented (Marchesiello *et al.* 2001). A pie-shaped grid that follows the south-western corner of the African continent from 40°S to 28°S and from 10°E to 24°E was developed. The topography is derived from the ETPO2 database, and both a low-resolution and a medium-resolution grid are implemented (Fig. 1). Along the vertical plane, the twenty levels provide enhanced resolution at the surface while preserving an adequate resolution in the deeper layers. The model is forced with winds, heat and salinity fluxes extracted from the COADS ocean surface monthly climatology (Da Silva *et al.* 1994). At the three lateral boundaries, an implicit radiative boundary scheme, forced by a seasonal climatology computed from the AGAPE basin scale ocean model (Biastoch and Krauss, 1999), connects the model to the surroundings.

The highly energetic and meandering Agulhas Current flowing westward in the south-east corner of the domain necessitates the implementation of a specific open boundary scheme.

The medium-resolution configuration has a resolution varying from 9km at the coast to 18km offshore. Having a realistic topography, this configuration should adequately resolve the topographically-controlled features over the continental shelf. A high level of mesoscale activity is observed during a 10-year simulation, including the generation of Agulhas rings, and the shedding of cyclonic eddies starting from the southern tip of the Agulhas Bank, the Cape Peninsula and Cape Columbine (Plate 1). Off the West Coast, the upwelling front shows an important variability, developing a series of meanders, plumes and filaments in a realistic manner. In the southern part of the model domain, the cyclonic eddies that appear in the simulations in the lee of the Agulhas Bank are in agreement with observed features (Penven *et al.* 2001). The main discrepancy appears off the West Coast region during summer, where simulated SSTs are significantly lower than observed SSTs from satellites. In the monthly climatology used to force the model, the high frequency variability (from days to weeks) of the wind is smoothed out. This results in a continuous and persistent upwelling-favorable wind forcing, in contrast to the characteristic pulsing pattern of the local southeasterly wind, which results in a succession of relaxed and enhanced upwelling. It is thought that both the low temporal and spatial resolution of the climatological wind used to force the model contribute to intensify the input of cold water over the continental shelf in our simulations.

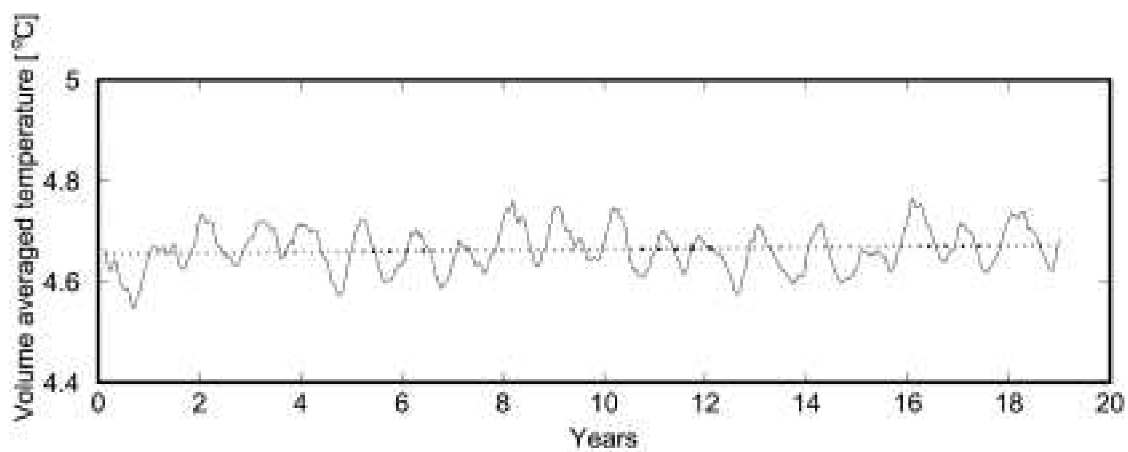

Fig. 2

Although the model is forced by repeated climatology, there are pronounced differences in the simulation outputs between individual years (*e.g.* the thermal structure and current fields of year 4 are significantly different from those of year 3; Fig. 2). The intense mesoscale activity is the main contributor to this inter-year variability (Penven 2000). This indicates that local, intrinsic oceanic instability processes are able to produce variations in the dynamics in the absence of added, forced variability by synoptic and inter-annual atmospheric fluctuations. How the inter-year variability observed in the model outputs compares to the inter-annual variability resulting from contrasted atmospheric forcing (such as a relaxed or intensified southeasterly wind regime) is still an open question.

Analysis of the 10 year model run is currently being carried further by focusing on the structure and variability of the West Coast upwelling, and on shear edge features along the Agulhas Bank. New experiments are in progress to investigate the response of the Peninsula jet and of the West Coast upwelling to high frequency wind forcing, as well as to an abrupt relaxation of the upwelling-favorable wind. This latter experiment is aimed at simulating the relaxation of the wind observed in December 1999, and investigating its impact on the successful transport of anchovy eggs and larvae to the West Coast nursery grounds (Roy *et al.* 2001).

Acknowledgements
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Figure Legends
Figure 1. The low-resolution horizontal (left) and vertical (right) grids used in the regional configuration of ROMS in the Southern Benguela.

Figure 2. Twenty year time-series of volume-averaged temperature using the low-resolution configuration.