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# Modelling processes influencing shelf edge exchange of water and suspended sediment

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**Abstract**

The major processes, and the associated models, which describe shelf edge exchange, and across-shelf movement of suspended sediment are briefly reviewed, and illustrated using results from numerical models and references to the literature. The across-shelf exchange of sediment due to internal tide, along-shelf flow, wind and wind wave effects (primarily swell) is examined. Calculations show the importance of the internal tide in suspending sediment at the shelf edge with wind waves influencing the nearshore suspension, and wind driven flows leading to sediment advection.

Barotropic and baroclinic processes in shelf edge regions lead to significant meanders and eddy generation, and associated exchange. This is briefly discussed with reference to the recent literature, and illustrated in terms of barotropic instability. The role of eddies in transporting suspended sediment is briefly discussed and illustrated in the case of an isolated eddy.

Ocean–shelf water exchange due to dense overflows (cascading) is described, and the role of entrainment and small-scale topography upon this process is illustrated in a number of calculations. The influence of large-scale topography, namely submarine canyons upon the movement of dense water bottom plumes into the ocean and the resulting eddies is briefly discussed and illustrated with reference to the recent literature.

Future modelling involving shelf–ocean models with irregular grids and non-hydrostatic capabilities is suggested as an important development topic.


*Keywords:* Shelf edge; Sediment; Internal tide; Eddies; Cascading

## 1. Introduction

Until recently large-scale ocean circulation and shelf sea modelling have progressed in parallel with little interaction between the two. However with the advent of more powerful computers, the

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finite difference grids in ocean circulation models have been refined and their geographic extent expanded to the extent that they no longer cover just oceanic areas but also encompass the shelf edge region. Similarly, shelf models with their traditionally finer grid but more limited geographical extent have recently expanded their domain to cover the shelf edge and part of the adjacent ocean. Consequently, both types of model must now take account of shelf edge processes, and can start to examine the importance of a range of processes that control ocean–shelf exchange.

One particularly important problem at the shelf edge is its role in oceanic mixing, and this together with the influence of internal waves and non-linear interaction upon mixing is covered in a companion paper (Davies and Xing, 2004). A second important problem is concerned with exchange between shelf and ocean in particular the long-term offshelf export of sediment and carbon from the shelf to the ocean. In this paper, we concentrate upon some of the processes influencing the exchange between shelf and ocean, and recent progress in their modelling. For a more extensive review of processes and related measurements, see Huthnance (1995).

Initially, we consider the development of a three-dimensional model for temperature, salinity and sediment transport in the shelf edge region and the range of parameterizations used to represent sub-grid-scale mixing in such a model. These parameterizations range from the use of a two-equation turbulence energy model, to one involving a Richardson number dependent viscosity and diffusivity. In subsequent sections, the model is used to examine sediment transport on the Iberian shelf and off the west coast of Scotland under a range of tidal, and wind forced conditions. The influence of including wind wave effects in particular swell is briefly considered.

The role of an along-shelf flow upon cross-shelf exchange and the effect of meanders and eddies due to both barotropic and baroclinic instability is briefly considered in terms of references to recent work, and demonstrated by a number of numerical calculations. The movement of sediment due to an isolated eddy is discussed and illustrated using the three-dimensional model developed in the first part of the paper. The influence of dense overflows (cascading) upon shelf–ocean exchange is briefly reviewed in terms of recent papers and demonstrated using a cross-sectional model. Calculations show that entrainment and small-scale topographic features have an important role. The importance of large-scale topography, namely submarine canyons, is briefly discussed in terms of recent papers. In a final concluding section, the range of shelf edge processes is reviewed and suggestions as to the future direction of shelf–ocean model development and data sets for model validation is made.

## 2. Numerical model

### 2.1. The three-dimensional hydrodynamic model

Although the model will be primarily used in cross-shelf form, its three-dimensional application has been considered in the literature (Xing and Davies, 2001a) and for completeness the three-dimensional equations are given here using Cartesian co-ordinates in the horizontal and a normalized $\sigma$ co-ordinate in the vertical, where $\sigma=(\eta+z)/H$. The continuity and momentum equations are given by

$$\frac{\partial \zeta}{\partial t}+\nabla\cdot\left(\int_{-1}^{0}(H\vec{V})\,\mathrm{d}\sigma\right)=0, \tag{1}$$

$$\frac{\partial Hu}{\partial t}+\nabla\cdot(Hu\vec{V})+\frac{\partial Hu\omega}{\partial \sigma}-fHv = -gH\frac{\partial \zeta}{\partial x}+BPF_x+\frac{1}{H^2}\frac{\partial}{\partial \sigma}\left(K_m\frac{\partial Hu}{\partial \sigma}\right) + HF_u, \tag{2}$$

$$\frac{\partial Hv}{\partial t}+\nabla\cdot(Hv\vec{V})+\frac{\partial Hv\omega}{\partial \sigma}+fHu = -gH\frac{\partial \zeta}{\partial y}+BPF_y+\frac{1}{H^2}\frac{\partial}{\partial \sigma}\left(K_m\frac{\partial Hv}{\partial \sigma}\right)+HF_v. \tag{3}$$