SEDIMENT TRANSPORT MODELLING IN THE POLCOMS

Laurent O. Amoudry, POL, laou@pol.ac.uk
Alejandro J. Souza, POL, ajso@pol.ac.uk

INTRODUCTION

Sediment transport and morphodynamic models are essential to the coastal engineering and policy making communities. We present here a three-dimensional sediment transport model implemented within the Proudman Oceanography Laboratory Coastal Ocean System (POLCOMS).

HYDRODYNAMIC MODEL

The physical model is based on a three-dimensional baroclinic model and solves the incompressible, hydrostatic, Boussinesq shallow water equations of motions. The governing equations can be expressed and solved both using Cartesian or spherical polar coordinates. The equations are split between depth varying and depth averaged velocities. The vertical gradient of turbulent stresses and fluxes are replaced following the turbulent viscosity and gradient diffusion hypotheses.

Turbulence modelling is performed via coupling with GOTM, setting the default model as that of Canuto et al. (2001).

SEDIMENT TRANSPORT MODEL

An unlimited number of sediment classes is possible with user-defined values for the median sediment grain, the dry sediment density, the critical erosion bed shear stress and the erodibility constant.

The sediment bed is described by a constant user-defined number of layer of spatially varying thickness, sediment class distribution, porosity and age.

Bed shear stress calculations:

- log-law bottom drag expression for currents.
- Madsen (1994) or Soulsby (1995) formulations for wave-current combinations.

Suspended load model:

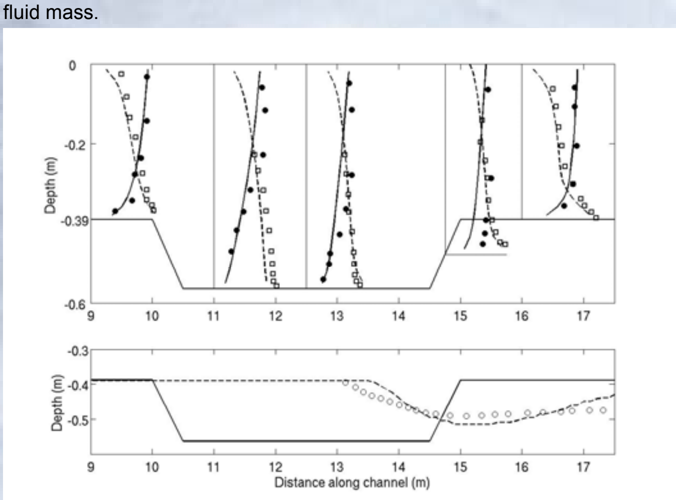
- Advection-diffusion equation.
- PPM technique for settling term.
- Continuous deposition.
- Erosion rate varies linearly with excess bed shear stress.
- Sediment diffusivity identical to buoyancy diffusivity.

Bed load model:

Soulsby and Damgaard (2005) expressions or simple power law.

Morphodynamic modelling

Routines update both the location of the sediment bed and the top bed layer thickness following the conservation of sediment mass among the bed, erosion, deposition, and bed load transport. The location of the sediment bed is updated with the barotropic component to enforce conservation of fluid mass.



Model (lines) and data (symbols) comparison for “initial” flow velocity and suspended sediment concentration (top panel), and for the trench migration (bottom panel).

VALIDATION

We use the trench migration experiment reported in van Rijn (1987) to test the ability of the model to reproduce suspended sediment concentration profiles and morphological evolutions.

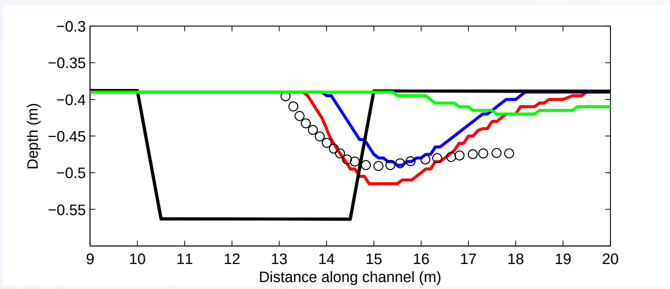
The setup consists of a 30 meter long, and 0.5 m wide straight channel in which a 0.2 m thick bed of well-sorted sediment of median diameter 160 μm is installed. Three different trenches were excavated and their migration downstream was observed after 15 hours. The upstream flow is steady with a depth-averaged velocity of 0.51m/s and a depth of 0.39 m.

The channel is discretised using a 0.1 m resolution in both horizontal directions and 20 levels vertically. The channel bed slope and a constant bed roughness are determined so that the flow rate remains uniform along the test section. Both the flow velocity and suspended concentration are then allowed to reach an “initial” steady state solution. This solution is then used as starting point for the morphodynamic computation employing a morphological factor of 10.

TURBULENCE MODELLING IMPACT

The trench migration case has been investigated using several different turbulence closures.

Little differences on the velocity and suspended concentration profiles were observed between closures using two balance equations to describe turbulence. A one equation model failed to reproduce the initial profiles.



There are significant differences for the trench migration using the default Canuto et al. (2001) closure (red), a traditional k-ε closure(blue) and a k-ω closure (green).

FUTURE WORK

- Estuarine suspended sediment dynamics.
- Model-data comparisons using flume studies.
- Implementation of sediment transport in Liverpool Bay

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GOTM: General Ocean Turbulence Model, www.gotm.net.

Proudman Oceanographic Laboratory

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