Estuarine to Shelf Sea Modelling with the General Estuarine Transport Model (GETM)

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General Estuarine Transport Model

- Three dimensional, hydrostatic, free surface, baroclinic
- Explicit mode-splitting, Arakawa-C grid
- Horizontal coord.: Cartesian, spherical or curvilinear
- General vertical coordinates
- Turbulence closures from GOTM (http://www.gotm.net)
- TVD & FCT advection schemes for $u$, $v$, $\theta$, $S$, $C_i$
- Stable drying and flooding algorithm
- Fully parallelised (domain decomposition)
- Public Domain (http://www.bolding-burchard.com/getm)
Turbulence modelling

- Statistical turbulence closure models: Derived by Reynolds decomposition of Navier-Stokes equations, empirical closure on level of second moments
- Two-equation models: $k-\varepsilon$ model, $k-\omega$ model, Mellor-Yamada model, Umlauf and Burchard (2003) generic model
- Stability calculation based on steady-state Richardson number ($Ri_{st} = 0.25$)
- Algebraic second-moment closure
- All closures tested in 1D model framework GOTM (General Ocean Turbulence Model, http://www.gotm.net)
Liverpool Bay: tidal straining

Observed and simulated temperature and dissipation rate

[Graphs showing temperature and dissipation rate variations over time and depth, with color scales indicating values.]

Simpson, Burchard, Fisher, Rippeth [2002]
General vertical coordinates

upper $\gamma$-coordinates, $d_u = 5$, $d_l = 1.5$

lower $\gamma$-coordinates, $d_u = 1.5$, $d_l = 5$

symmetric $\gamma$-coordinates, $d_u = 1.5$, $d_l = 1.5$

symmetric $\gamma$-coordinates, $d_u = 5$, $d_l = 5$
1D simulation North Sea

Simulation FLEX 76

Depth [m]

Julian Day 1976

T [°C]
1D simulation North Sea

Layer distribution for 10, 20, 40 and 80 layers:

Conclusion by Burchard and Beckers [2004]:
For fixed number of layers adaptive grids may be more accurate.
Drying: Numerical mechanism

- Very shallow ($D < 0.1 \, \text{m}$): pressure-friction balance $\Rightarrow$ log-law

- Pressure gradient correction when following situation:

$$
-H_{i,j} + D_{\text{min}}
$$$$
\zeta_{i,j}
$$$$
-H_{i,j}
$$$$
\zeta_{i+1,j}
$$

Virtual sea surface elevation

Actual sea surface elevation

Bathymetry approximation
North Frisian Wadden Sea

Velocity and turbulence in intertidal area

Burchard and Bolding [2002]
East Frisian Wadden Sea

VERTICALLY INTEGRATED VELOCITY

Stanev et al. [2002]
Lake Geneva: Inter-basin exchange

Umlauf and Lemmin [2005]
Lake Geneva: Inter-basin exchange

- a) wind speed
- b) wind direction
- c) 47.15 m measured modeled
- d) 11.15 m measured modeled

Umlauf and Lemmin [2005]
Lake Geneva: Inter-basin exchange

Umlauf and Lemmin [2005]
ETM in river Elbe

Burchard et al. [2004]
ETM in river Elbe

Burchard et al. [2004]
North Sea - Baltic Sea - 1 nm
Surface temperature and salinity around Denmark

http://www.frv.dk/
Extentions under construction

- Vertically adaptive grids
- Two-way nesting
- Lagrangian tracers
- Biogeochemical modelling
- Selection of various Kalman filter formulations

Wishes:

- Non-hydrostatic pressure
- Sea ice model
- . . .