General Estuarine Transport Model (GETM)

*History and Future Outlook*

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Prehistorical remarks

Some (negative) experience of a $z$-coordinate-based Wadden Sea model (Burchard, 1995) has been used for the development of GETM. It came out that resolution of the sea bed with step-like structures has several disadvantages for resolving near-bed flows.

Grid layout for channel flow (left) and resulting eddy viscosity (dots, right)
Arcachon shock

During a workshop in Arcachon in May 1997, there was a sudden need for a 3D Wadden Sea model for the EU-project PhaSE, since 1D and 2D models did not provide a sufficient basis for dynamics of benthic organisms.

However, such a (free) model was not on the market by that time. Solution: Write it yourself!
### Why a new 3D model?

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1. GETM Users Workshop, Båring Hojskole, Denmark, June 6-8, 2004 – p. 6/23
A new Wadden Sea model had been developed within a few months (Burchard, 1997), including a $k-\varepsilon$ turbulence closure model, momentum advection, drying and flooding, and mass conservation.
Oosterschelde light

Mussel beds (observed, above) and growth (simulated, below)

First ecosystem application of GETM in the framework of EU-project PhaSE, work carried out by Peter Herman and Francois Lamy, NIOO.
GOTM & GETM

In 1998 `mixedlayermodel.f` became GOTM and `mudflat.f` became GETM. GETM calls GOTM by means of the following line:

```fortran
CALL do_turbulence(kmax, dt, D(i,j), u_taus, u_taub, z0s, z0b, h,
                   NN1d, SS1d, P, B)
```

GOTM homepage in 2004 (left) and GOTM developers in 1999 (right)
BBH

In 1999, the Bolding & Burchard Hydrodynamics GbR was founded in Varese (Italy) with the purpose of applications for EU-projects. This was also fuelling the GOTM & GETM developments, specifically through the early FRV-cooperation.
FRV: Baroclinicity needed!

Within short time, the following features had to be coded:

- High-resolution advection schemes
- Pressure gradient formulations
- Stratificational input into turbulence closure

Extensively used test case: Lock exchange:

Lock exchange without (left) and with (right) TVD limiter.
FRV: Curvilinear needed!

Within short time, orthogonal curvilinear horizontal coordinates had to be coded:
FRV: Curvilinear tested!

Curvilinear grid layout (first tests):

Pers. comm. Karsten Hansen, Farvandsvæsenet
GETM Report 2002

FRV Baltic Sea applications

SSS on June 1, 1997, $\Delta x = \Delta y = 3$ nm

$x / \text{nm}$

$y / \text{nm}$

$S / \text{psu}$

- 35
- 30
- 25
- 20
- 15
- 10
- 5
- 0

Baltic Sea Research Institute Warnemünde
FRV Baltic Sea applications

$T$ across Doggerbank W/E section I, 97/09/01

$\Delta x = \Delta y = 6 \text{ nm}$

$\Delta x = \Delta y = 3 \text{ nm}$
GETM users

- Emil Stanev (Oldenburg): Wadden Sea
- Manuel Ruiz Villarreal (A Coruña): Tidal Elbe
- Lars Umlauf (Lausanne): Lake Geneva
- Frank Wolk (Hamburg): Lagrangian tracers
- Adolf Stips (Ispra): Baltic Sea/North Sea
- Elisaveta Paneva (Ispra): Black Sea
- Bjarne Büchmann (Copenhagen): Baltic ...
- Joanna Staneva (Oldenburg)
- Eirwen Williams (Menai Bridge): Menai Strait
- Marie Maar (Copenhagen): Doggerbank
Parallelisation

As part of the FRV cooperation, GETM has been parallelised. It was an extremely tedious work to implement the exchange of halo data in a complete and correct work.

Now, GETM is fully parallelised using the domain-decomposition technique and MPI (Message Passing Interface).

More information will be given in the presentations of Karsten Bolding and Bjarne Büchmann.
GETM is being implemented at Farvandavæsenet as operational forecast model with focus on the Danish EEZ, running on a LINUX-Cluster. More information in the presentation by Bjarne Büchmann.
EU-projects

MaBenE Managing Benthic Ecosystems, building up of GETM as integrated model environment for coupled benthic-pelagic ecosystem modelling, focusing on benthic filter feeders, with applications to Limfjorden (DK) and Oosterschelde (NL).

Oceanides Monitoring illegal oil spills, coupling GETM with an oil spill model including transport and weathering.
GETM as research tool

Adaptive grids, example from GOTM. This is in the process of being included into GETM (Beckers and Burchard, in prep.).

Burchard and Beckers [2004]

1. GETM Users Workshop, Båring Hojskole, Denmark, June 6-8, 2004 – p. 21/23
Known problems

Most eminent problem: Pressure gradient problem generally known for bottom-fitted coordinates.

Strategy for fixing: Smoothing of bathymetry, high horizontal resolution, generalised vertical coordinates, ...

Further problems: limitations due to structured grid, strategy: two-way nesting, curvilinear grids ... Open boundary conditions, strategy: implement better ones
Future extentions

- Interactive coupling to pelagic and benthic ecosystems (started)
- Extended source code documentation (in progress)
- Improved open boundary conditions (projected)
- Surface wave module (projected)
- Periodic boundary conditions (projected)
- Two-way nesting (projected)
- Thermo-dynamic ice model (planned)
- Non-hydrostatic processes (dreaming of)
- …