Modelling buoyancy effects in the coastal zone

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- Mixing vs. stratification
- General Ocean turbulence Model (GOTM)
- Example: SIPS in Liverpool Bay
- Tidal asymmetry & residual transport
- General Estuarine Transport Model (GETM)
- Example: ETM in the Elbe river
- Can this be relevant for the Wadden Sea ?
- Dynamics of dense bottom plumes
- Example: Inflox events in Arkona Sea

k-ε model I

Turbulent Fluxes (velocity & temperature):

$$\langle \tilde{u}\tilde{w} \rangle = -\nu_t \partial_z \bar{u}, \quad \langle \tilde{w}\tilde{T} \rangle = -\nu_t' \partial_z \bar{T}$$

Eddy Viscosity / Eddy Diffusivity:

$$\nu_t = c_\mu \frac{k^2}{\varepsilon}, \quad \nu_t' = c_\mu' \frac{k^2}{\varepsilon}.$$

k:	Turbulent kinetic energy (TKE)	[J/kg]
ε:	Dissipation of TKE	[W/kg]

k-ε model II

k-ε model (*Launder and Spalding* [1972]):

$$\partial_t k - \partial_z \left(\frac{\nu_t}{\sigma_k} \partial_z k \right) = P + B - \varepsilon,$$

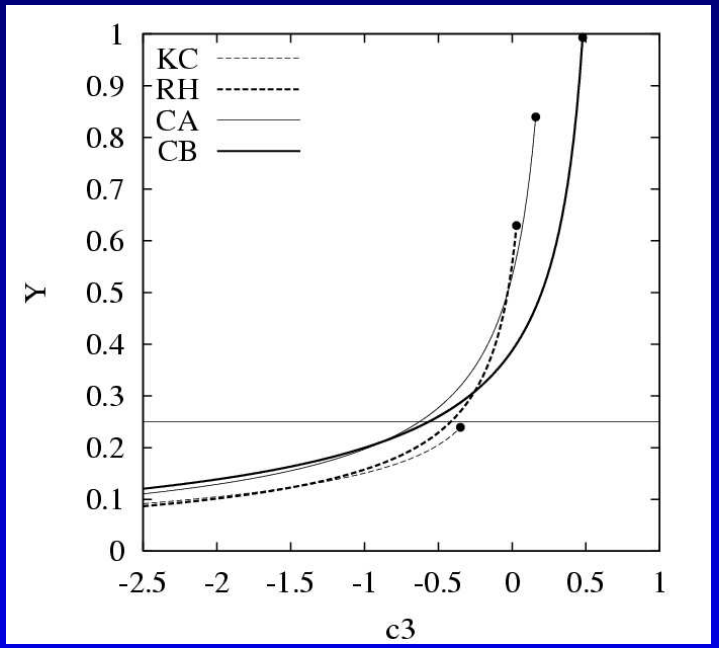
$$\partial_t \varepsilon - \partial_z \left(\frac{\nu_t}{\sigma_\varepsilon} \partial_z \varepsilon \right) = \frac{\varepsilon}{k} \left(c_{\varepsilon 1} P + c_{\varepsilon 3} B - c_{\varepsilon 2} \varepsilon \right).$$

P: Shear production of TKE [W/kg]
B: Buoyancy production [W/kg]

Total equilibrium (k-ε)

$$\dot{k} = \dot{\varepsilon} \Longrightarrow R_i = \frac{-\frac{g}{\rho_0}\partial_z \rho}{(\partial_z u)^2 + (\partial_z v)^2} = R_i^{st} = \frac{c_\mu}{c'_\mu} . \frac{c_{2\varepsilon} - c_{1\varepsilon}}{c_{2\varepsilon} - c_{3\varepsilon}}.$$

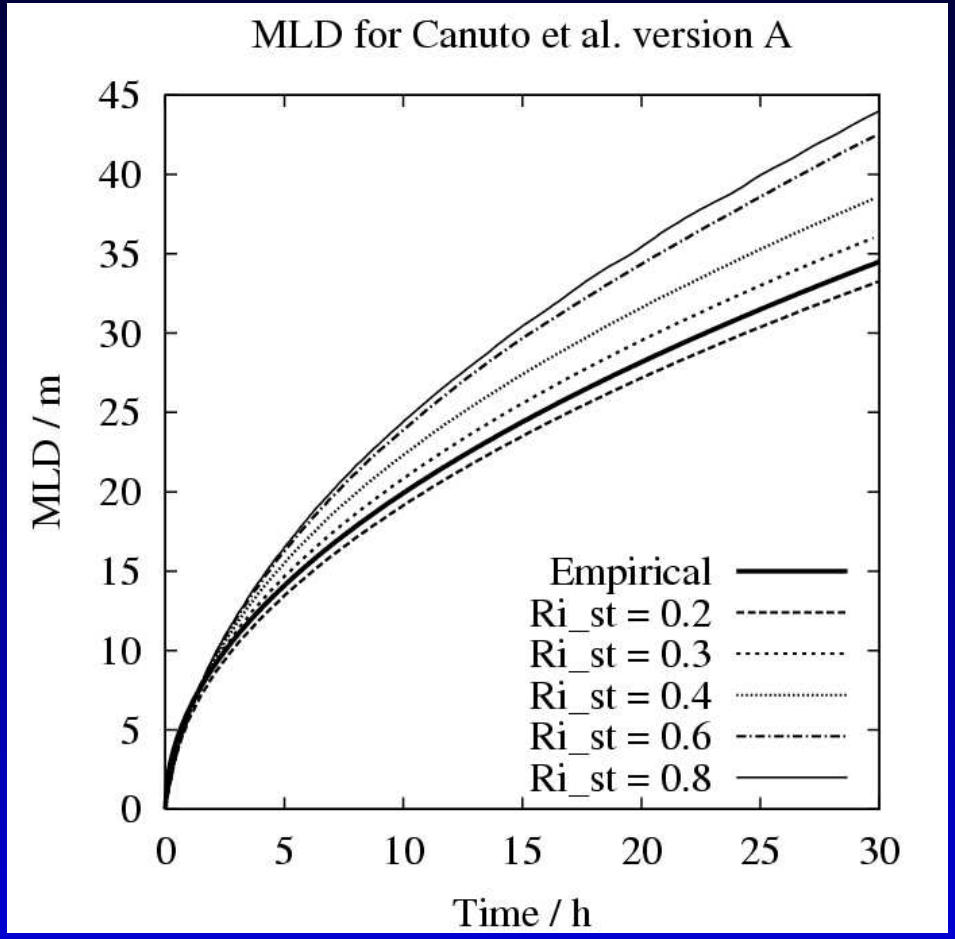
$R_i^{st} \approx 0.25$: Steady-state Richardson number.



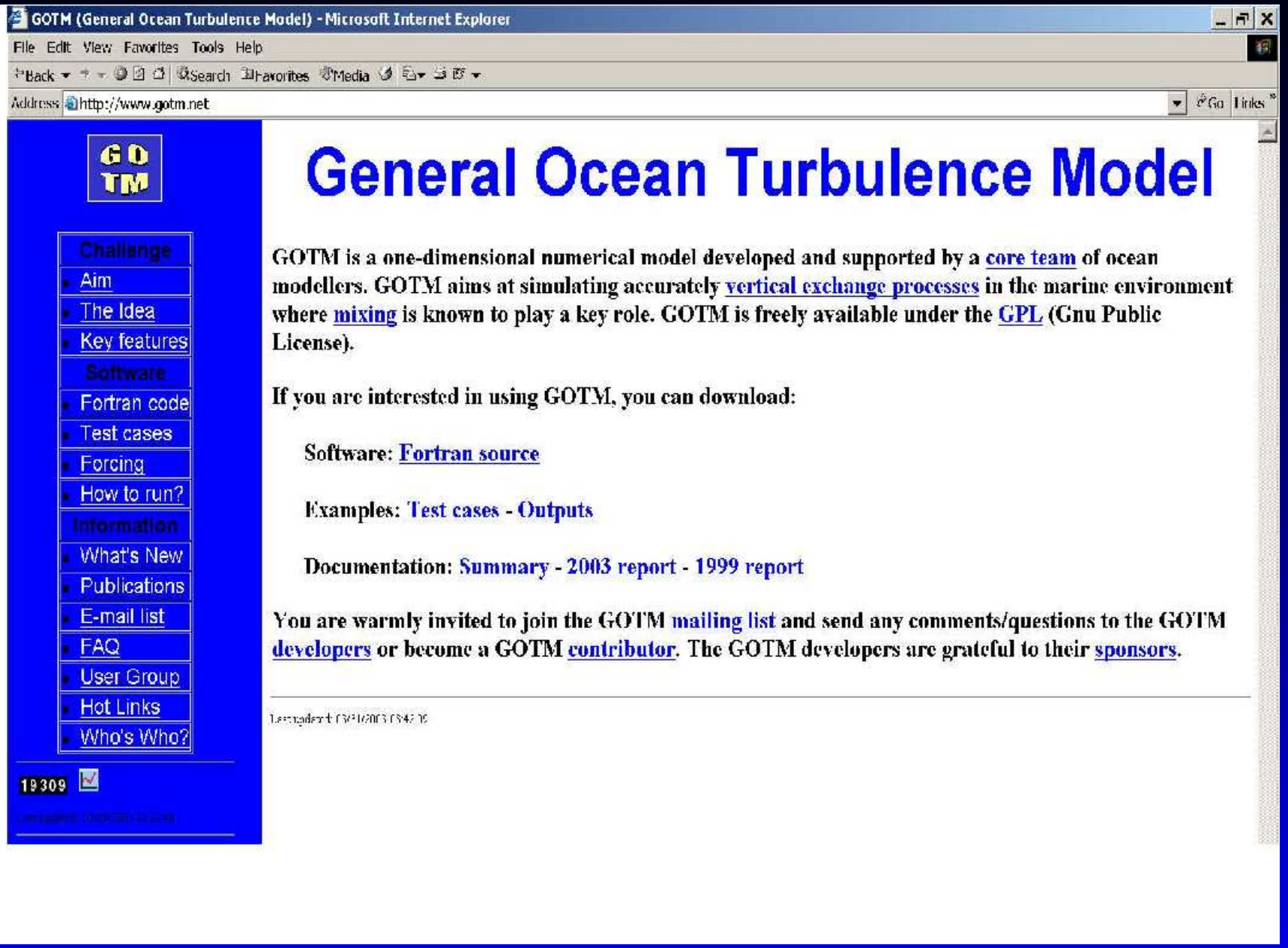
Burchard & Bolding [2001]

Kato-Phillips experiment

Wind-induced mixed-layer depth (MLD)

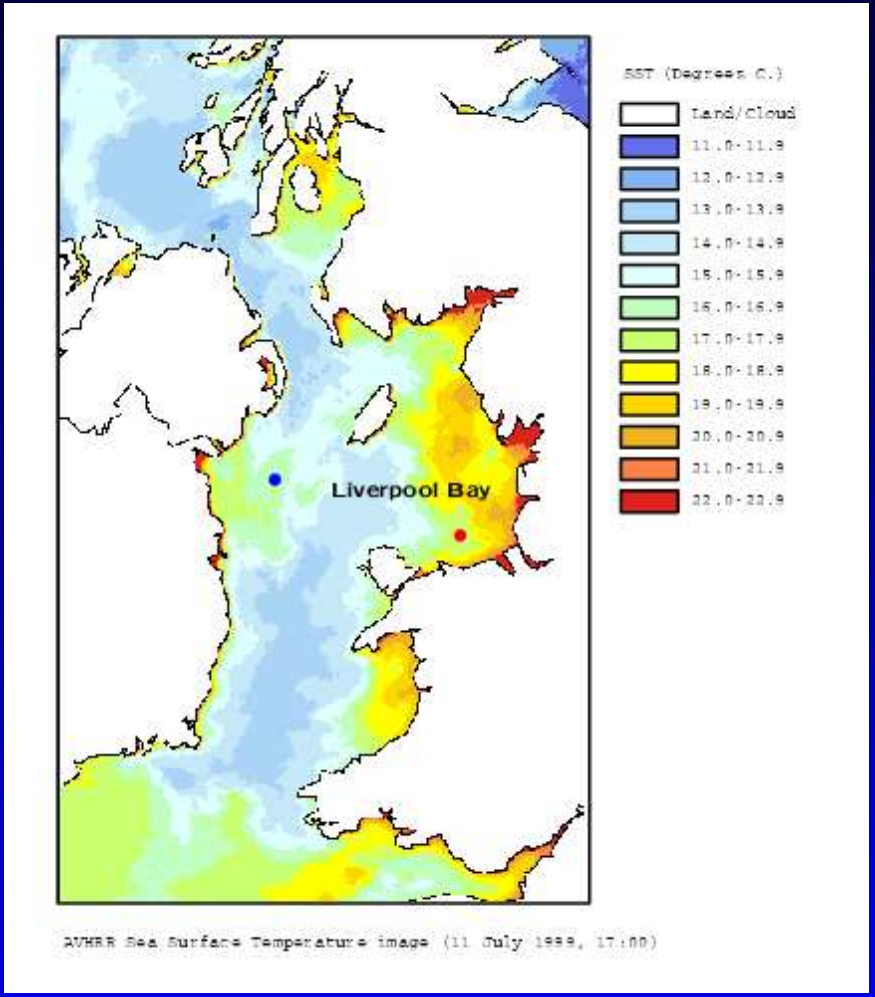


Burchard & Bolding [2001]


GOTM (General Ocean Turbulence Model) - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites Media
Address http://www.gotm.net
Go Links
GO TM
Challenge
Aim
The Idea
Key features
Software
Fortran code
Test cases
Forcing
How to run?
Information
What's New
Publications
E-mail list
FAQ
User Group
Hot Links
Who's Who?
19309
General Ocean Turbulence Model
GOTM is a one-dimensional numerical model developed and supported by a core team of ocean modellers. GOTM aims at simulating accurately vertical exchange processes in the marine environment where mixing is known to play a key role. GOTM is freely available under the GPL (Gnu Public License).
If you are interested in using GOTM, you can download:
Software: Fortran source
Examples: Test cases - Outputs
Documentation: Summary - 2003 report - 1999 report
You are warmly invited to join the GOTM mailing list and send any comments/questions to the GOTM developers or become a GOTM contributor. The GOTM developers are grateful to their sponsors.

Liverpool Bay

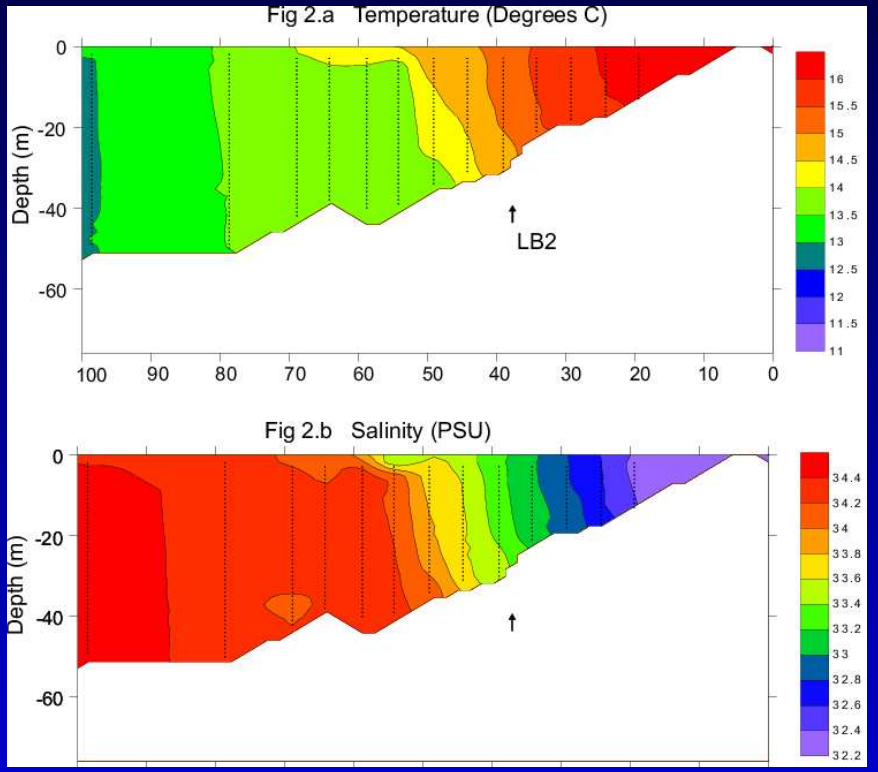
SST from space and location of station (●)



Courtesy to School of Ocean Sciences, UBW, Wales

Liverpool Bay

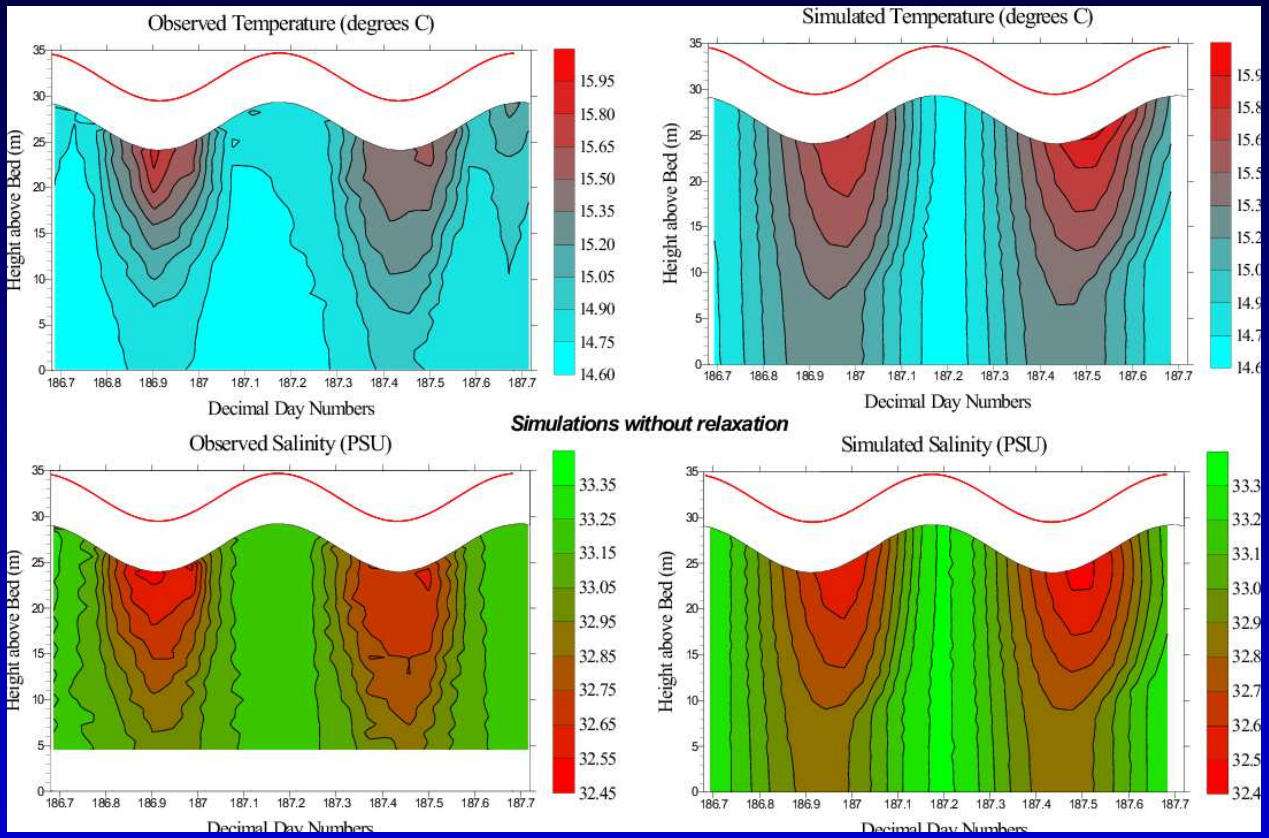
Section of Temperature and Salinity



Rippeth, Fisher, Simpson [2001]

Liverpool Bay

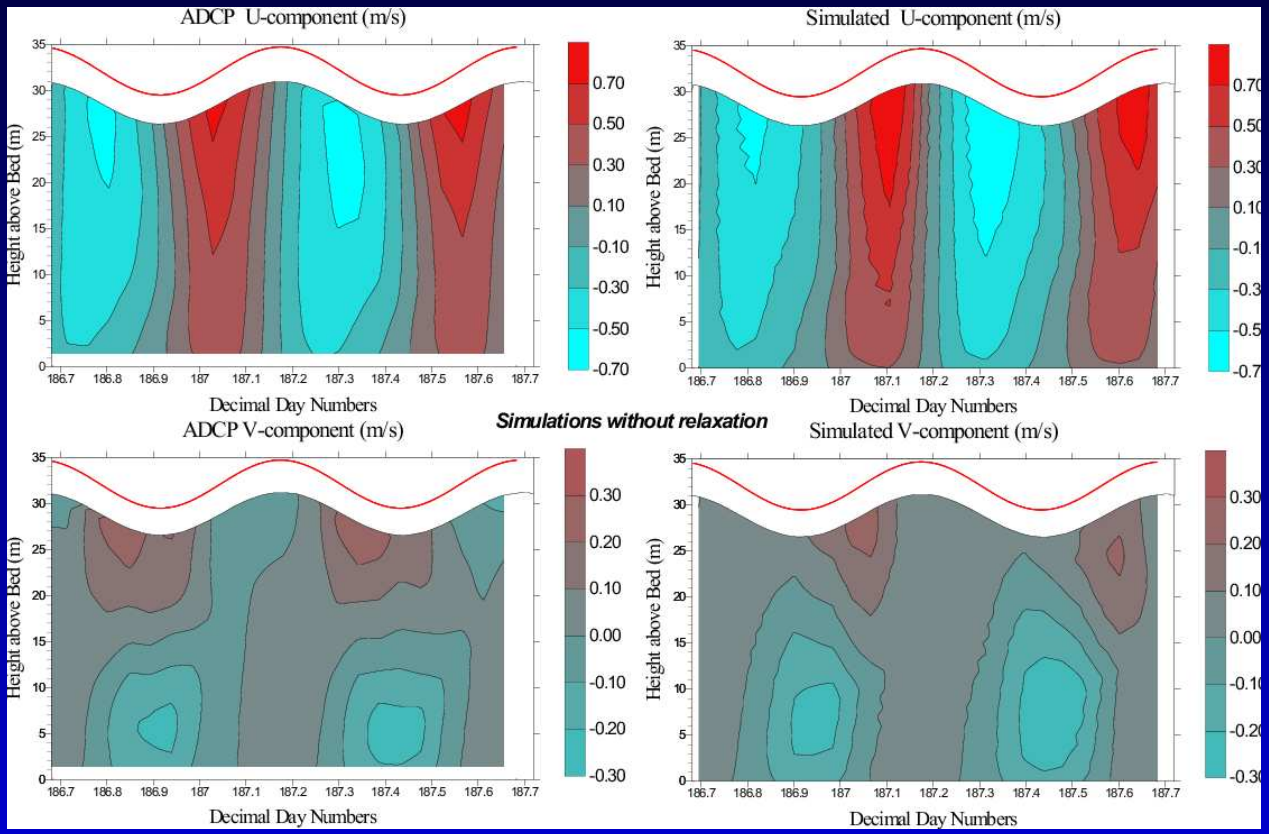
Observed and simulated temperature and salinity



Simpson, Burchard, Fisher, Rippeth [2002]

Liverpool Bay

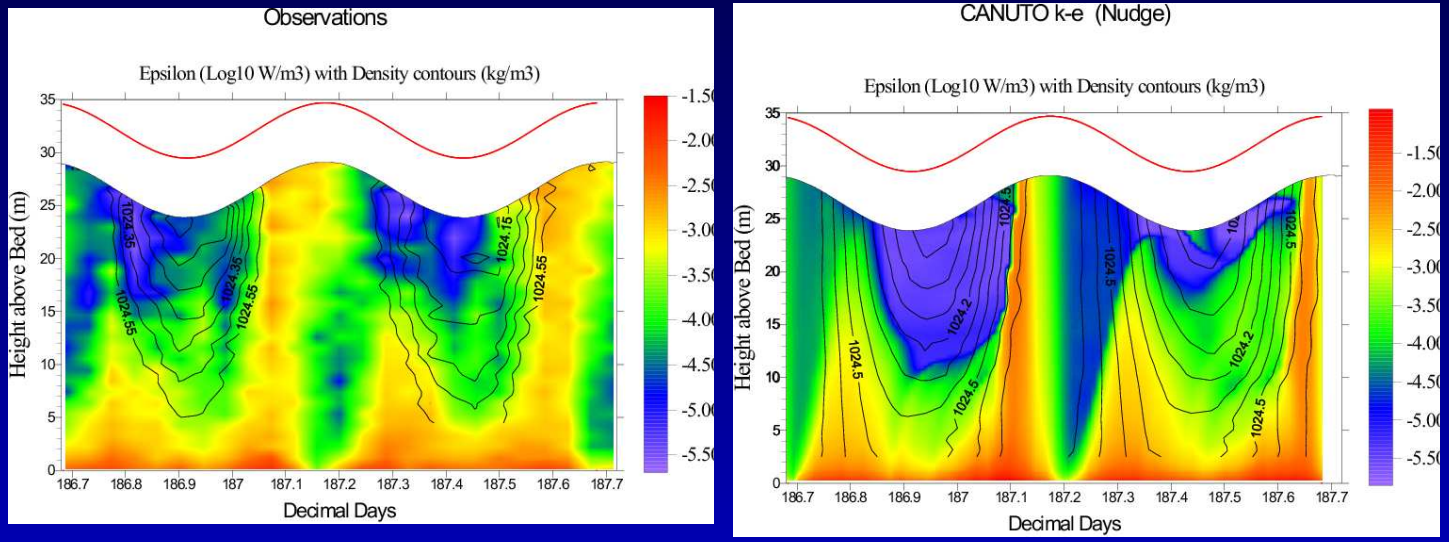
Observed and simulated current velocity



Simpson, Burchard, Fisher, Rippeth [2002]

Liverpool Bay

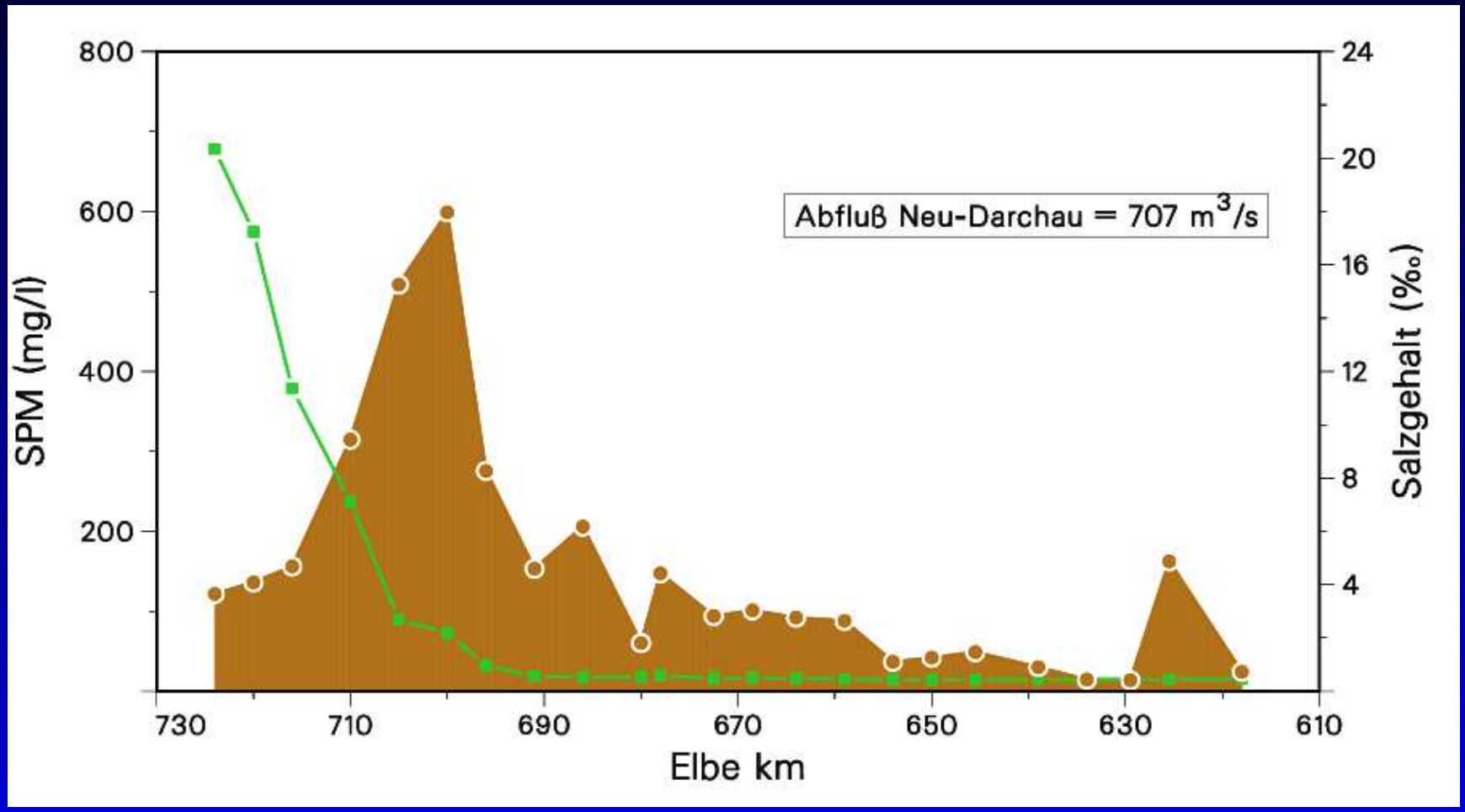
Observed and simulated dissipation rates



Simpson, Burchard, Fisher, Rippeth [2002]

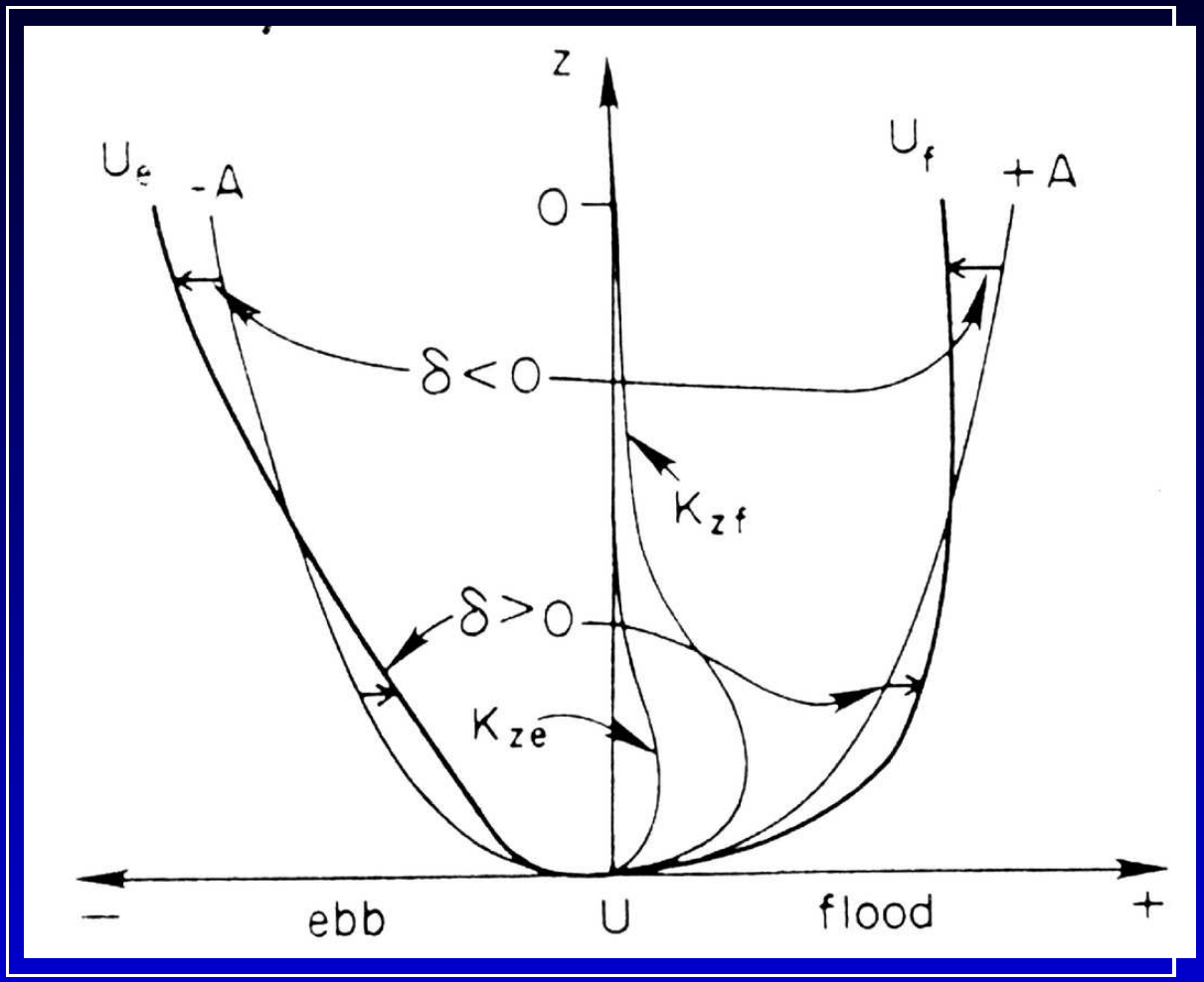
Estuarine Turbidity Maximum

SPM observations in the tidal Elbe



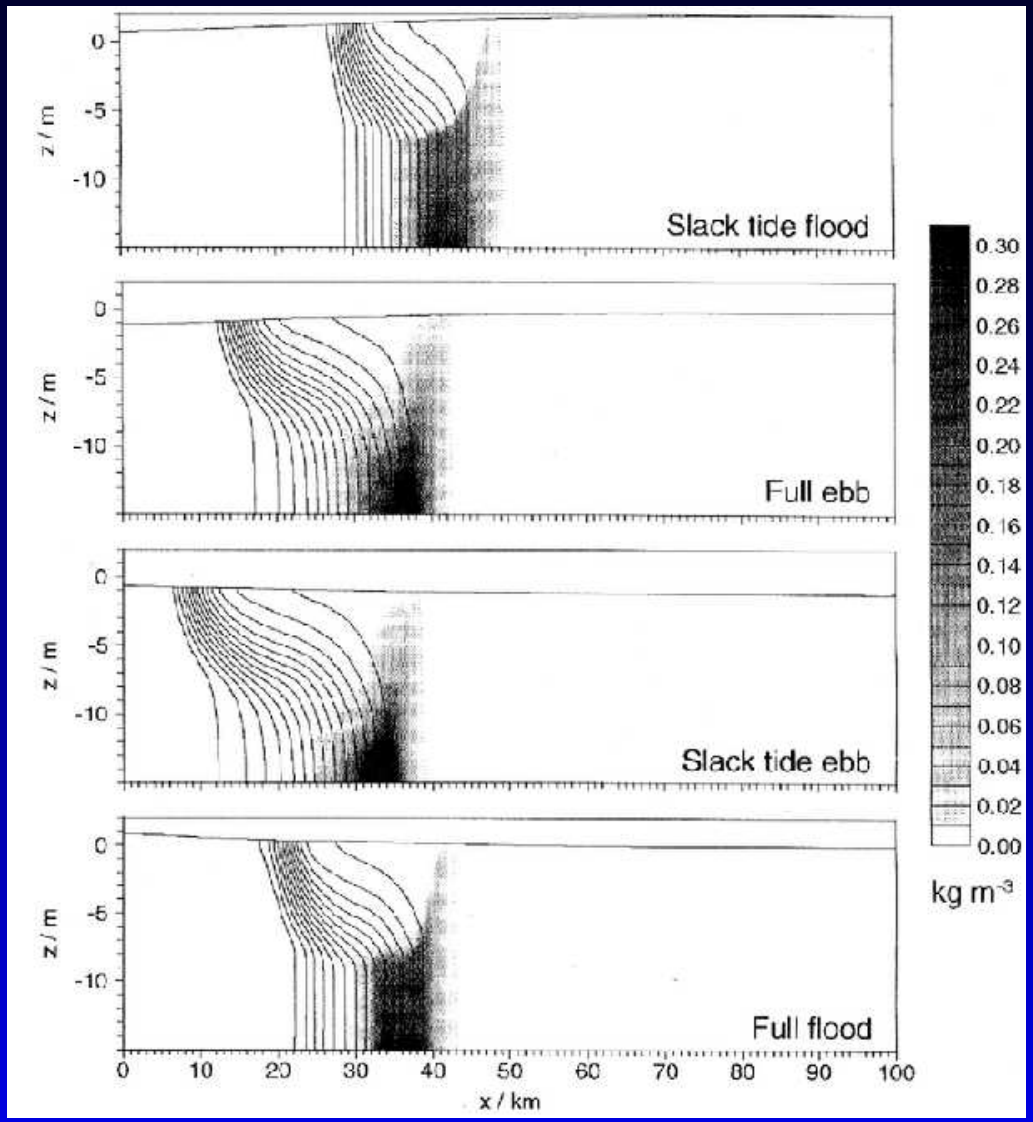
Pers. comm. Jens Kappenberg

ETM: Conceptual model



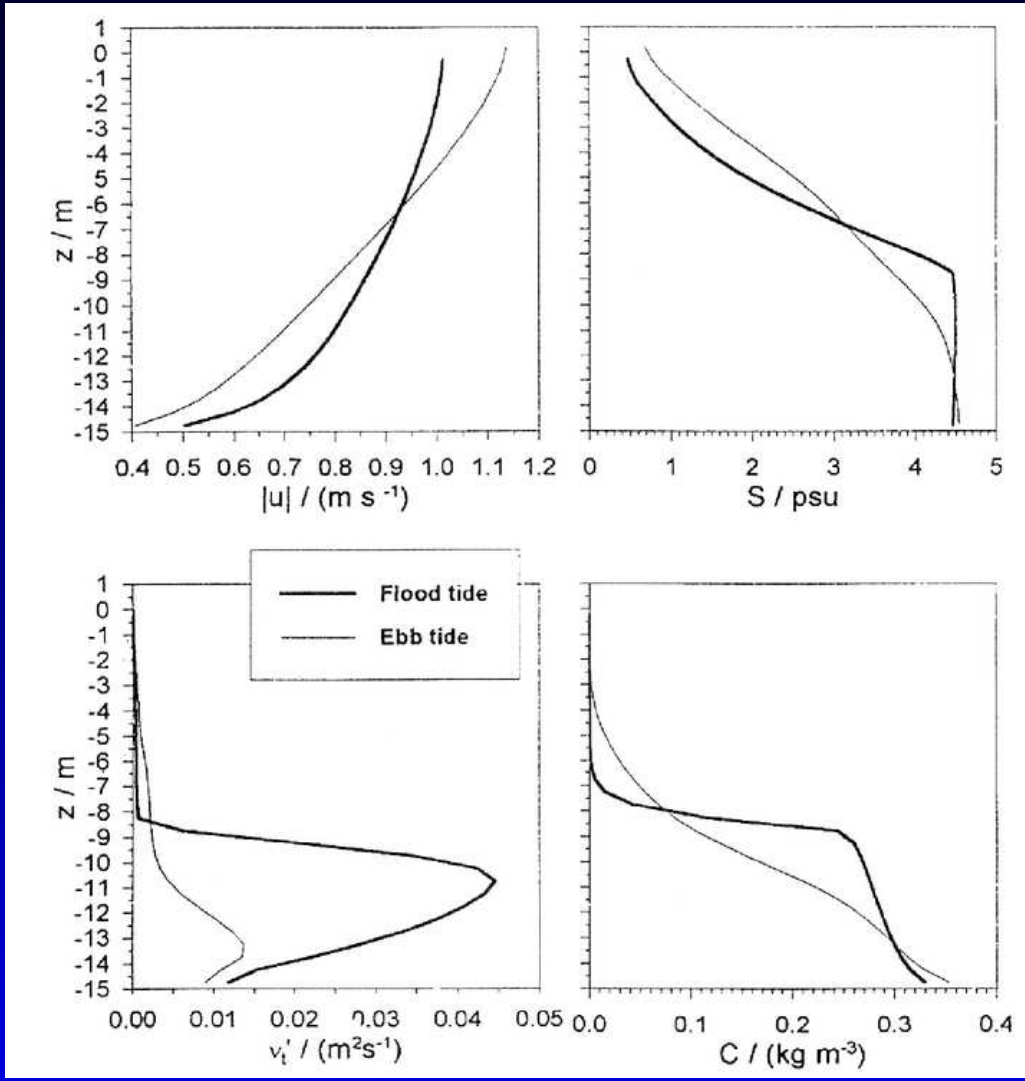
Jay & Musiak, 1994

ETM: Computer simulations



Burchard & Baumert, 1998

ETM: Computer simulations



Burchard & Baumert, 1998

General Estuarine Transport Model

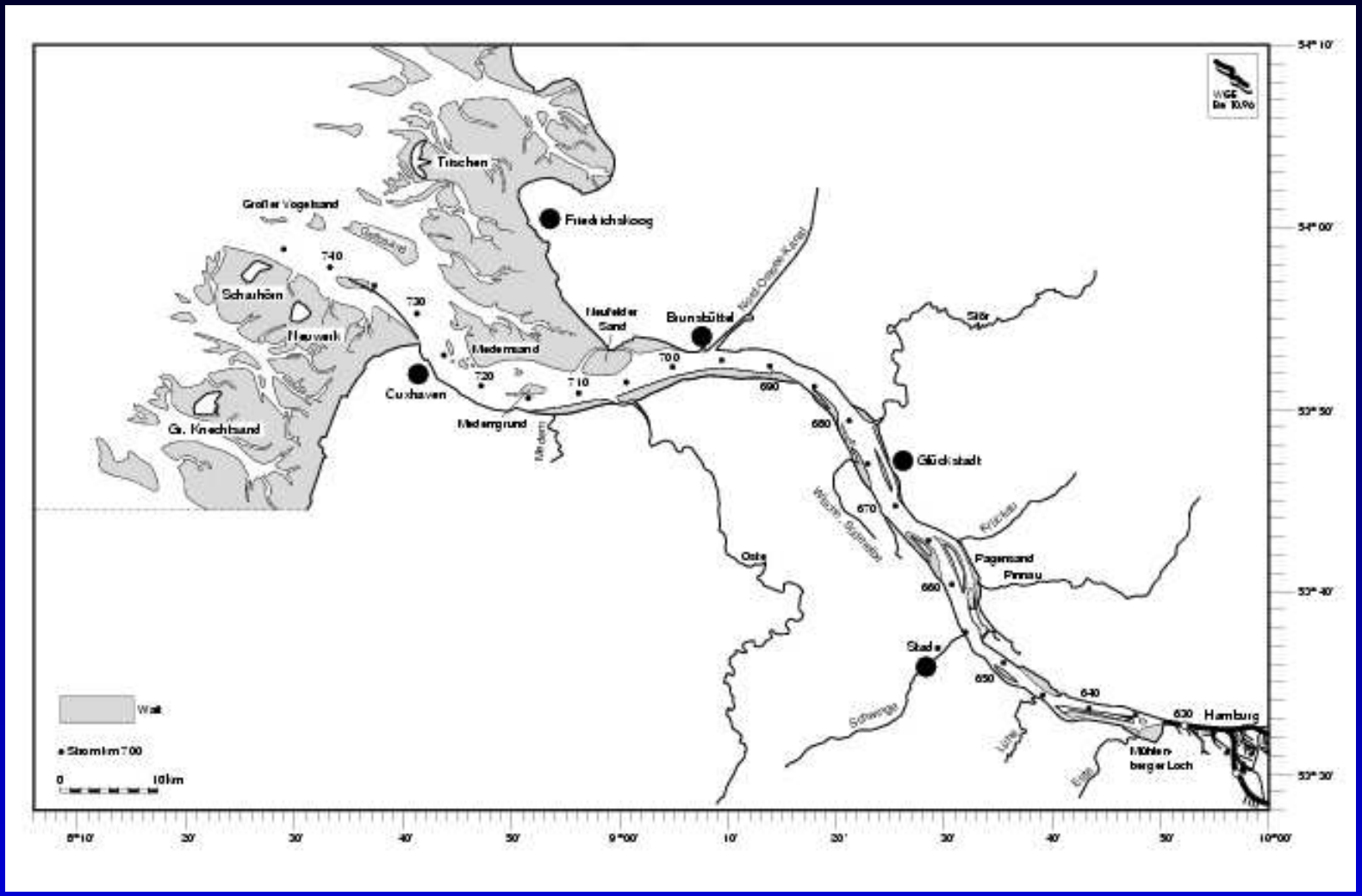
- Three dimensional, hydrostatic, free surface, baroclinic
- Mode-splitting, Arakawa-C grid
- Horizontal coord.: Cartesian, spherical or orthogonal
- Vertical coord.: Sigma, z-levels or generalised
- Turbulence closures from GOTM (`http://www.gotm.net`)
- Various advection schemes for momentum and tracers
- Stable drying and flooding algorithm
- Fully parallelised (domain decomposition)
- Public Domain (`http://www.bolding-burchard.com/getm`)

2D Experiments

- Salinity and and SPM (click for animation), no advection of turbulence
- Salinity and eddy diffusivity (click for animation), no advection of turbulence

Burchard et al. [2004]

Elbe-ETM in 3D: GETM



Animation

Burchard et al. [2004]

Oosterschelde

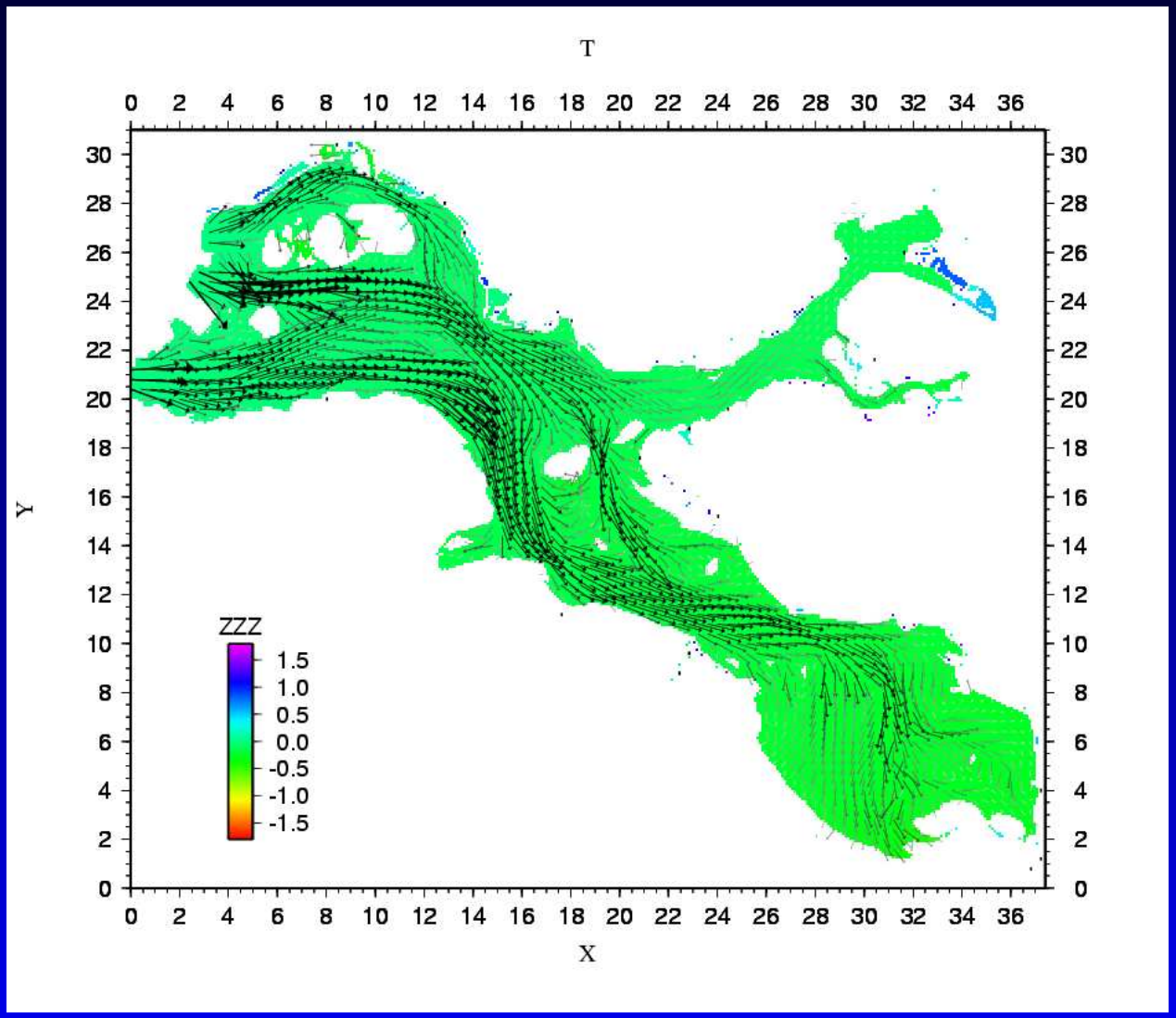
EU-Project MaBenE, Managing Benthic Ecosystems

Photograph by Luis Fernandes, Lisboa, Portugal

Baltic Sea Research Institute Warnemünde

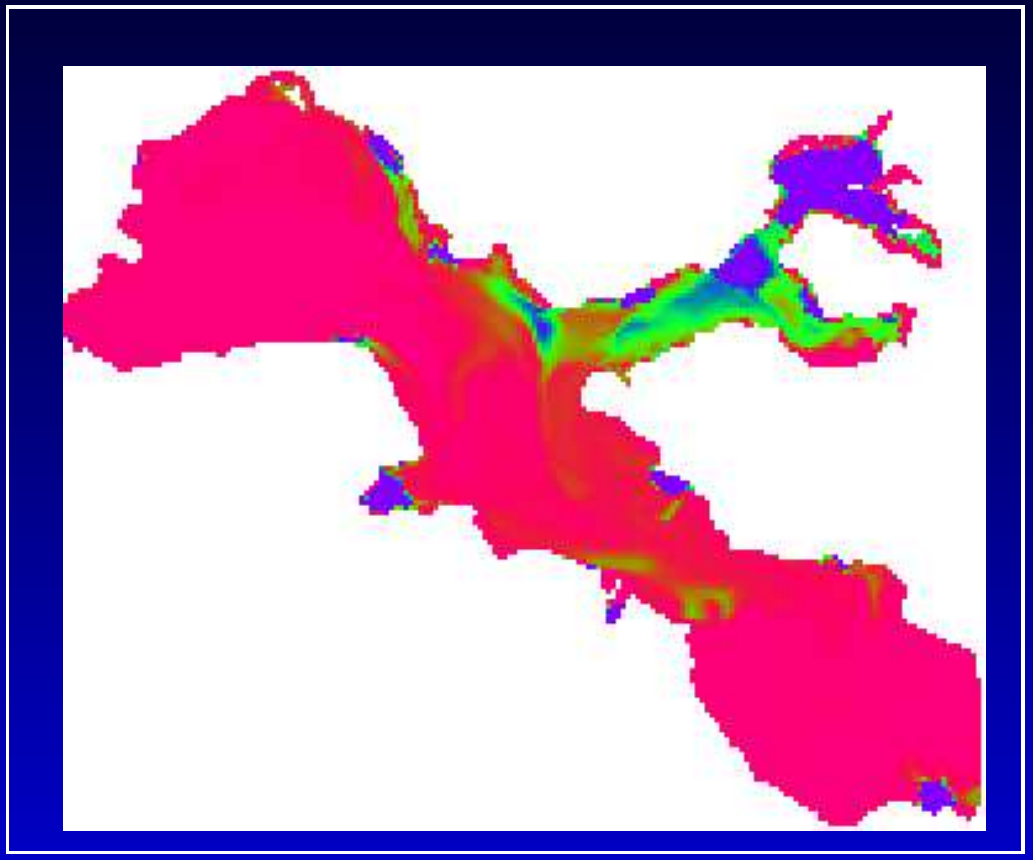
Oosterschelde

Full Flood



Oosterschelde

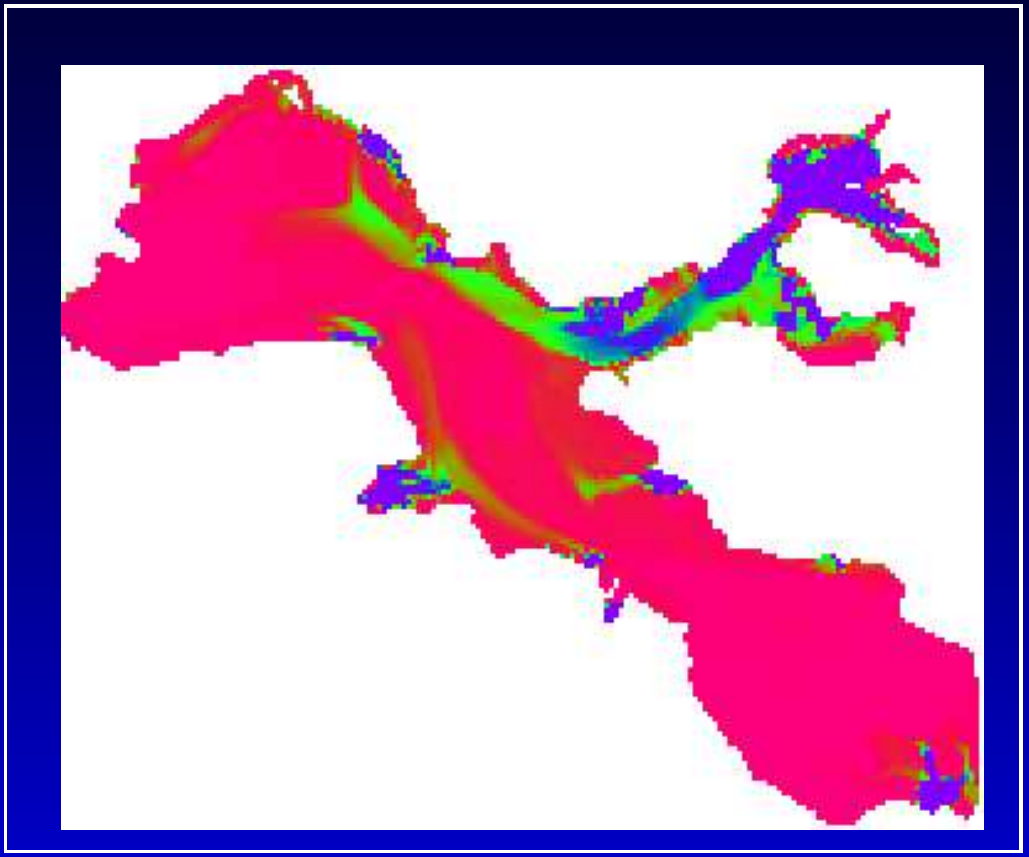
Surface salinity, Full Flood, Range 27 - 29 psu



Will freshwater release into the Wadden Sea lead to accumulation of fine sediments ?

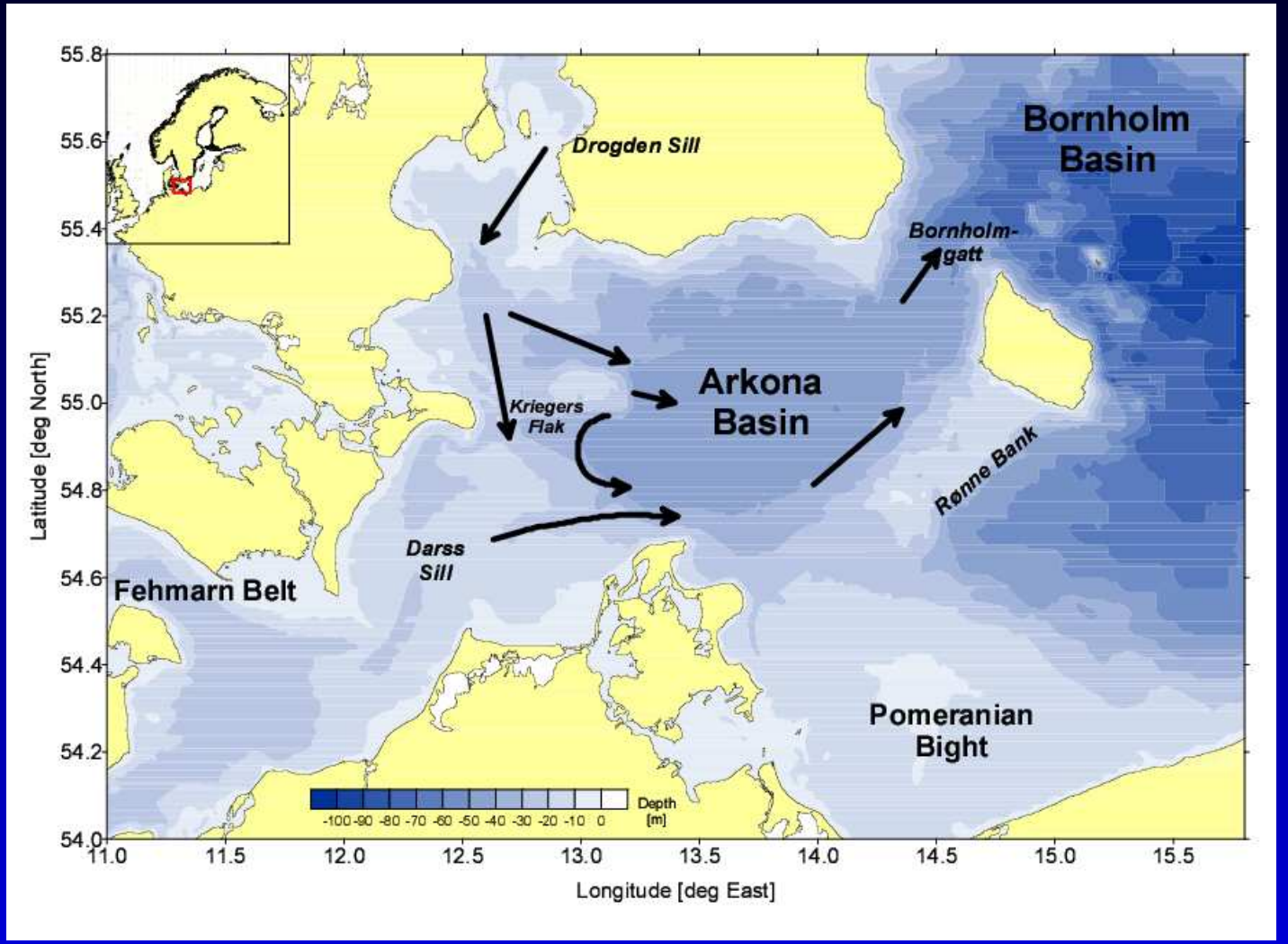
Oosterschelde

Surface salinity, Full Ebb, Range 27 - 29 psu



Will freshwater release into the Wadden Sea lead to accumulation of fine sediments ?

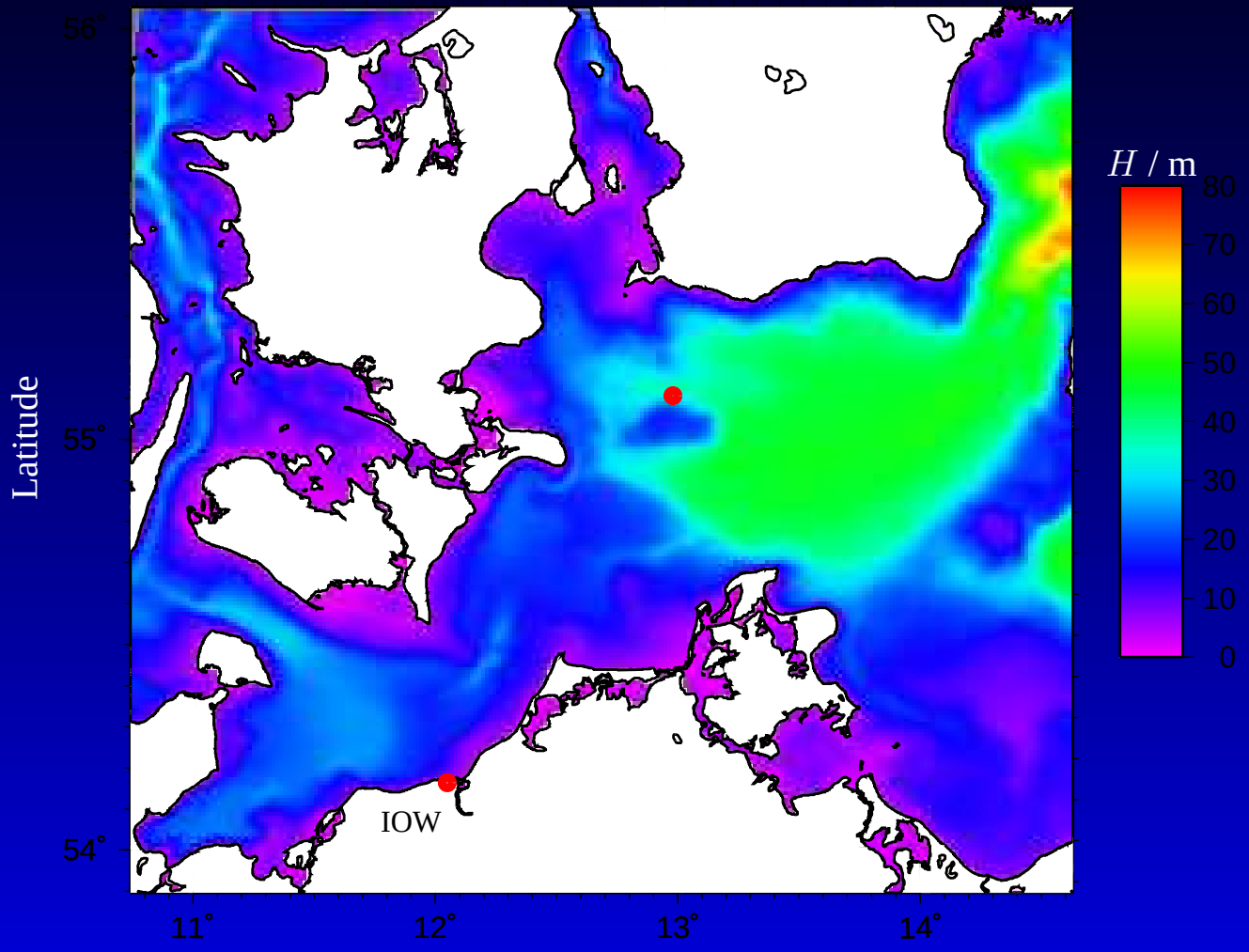
Arkona Sea



Graphics by Volker Mohrholz, IOW

Arkona Sea

Model bathymetry



●: QuantAS station

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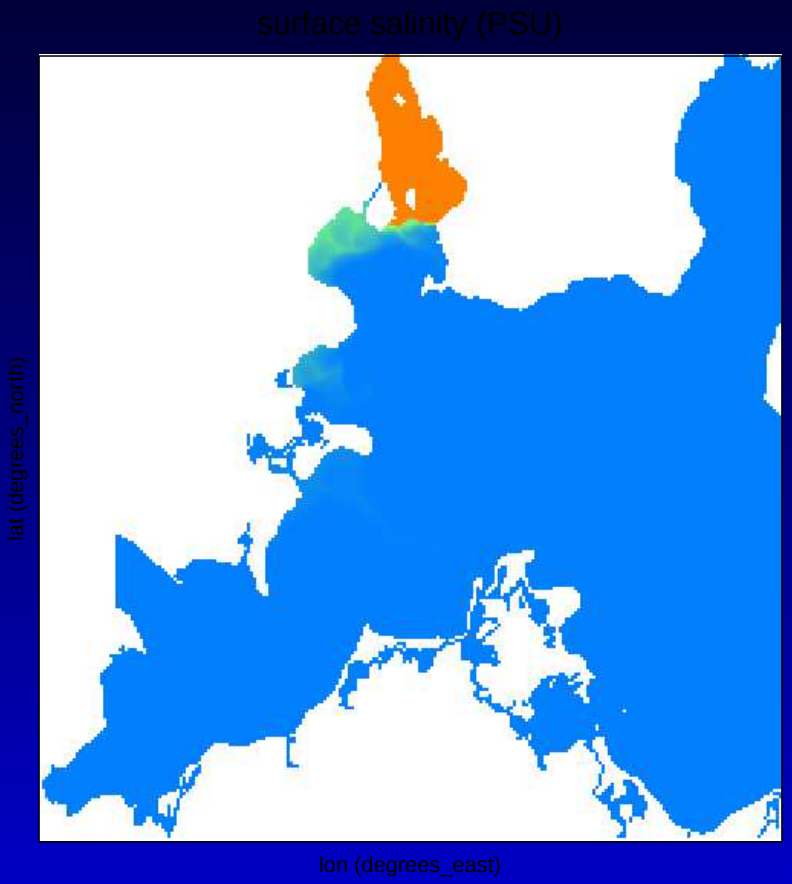
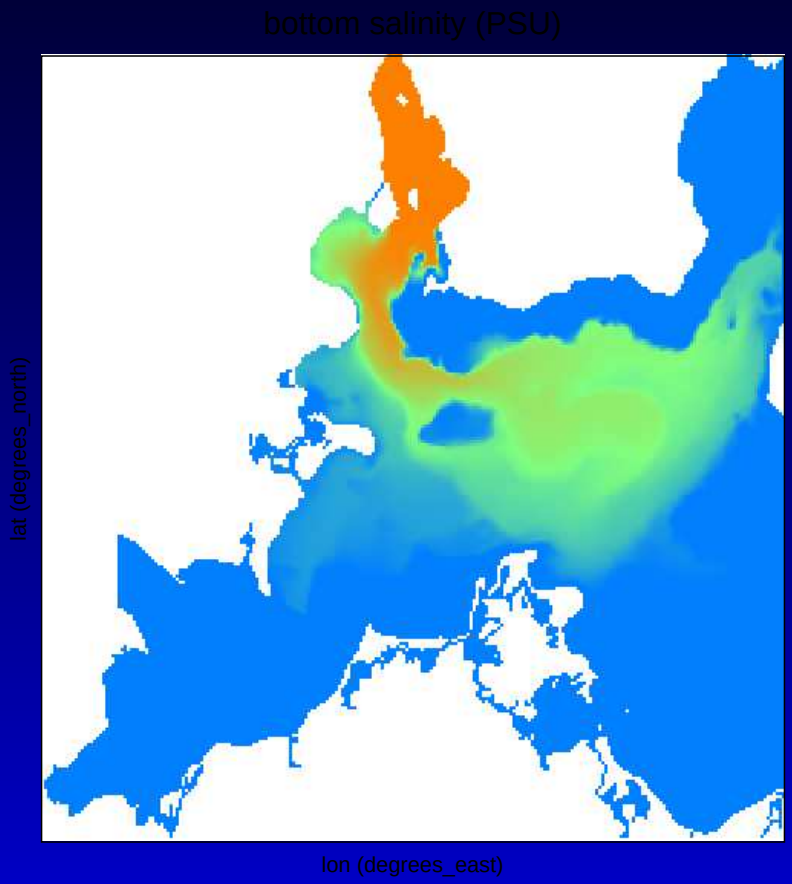
Arkona Sea

Surface salinity (8-25 psu)



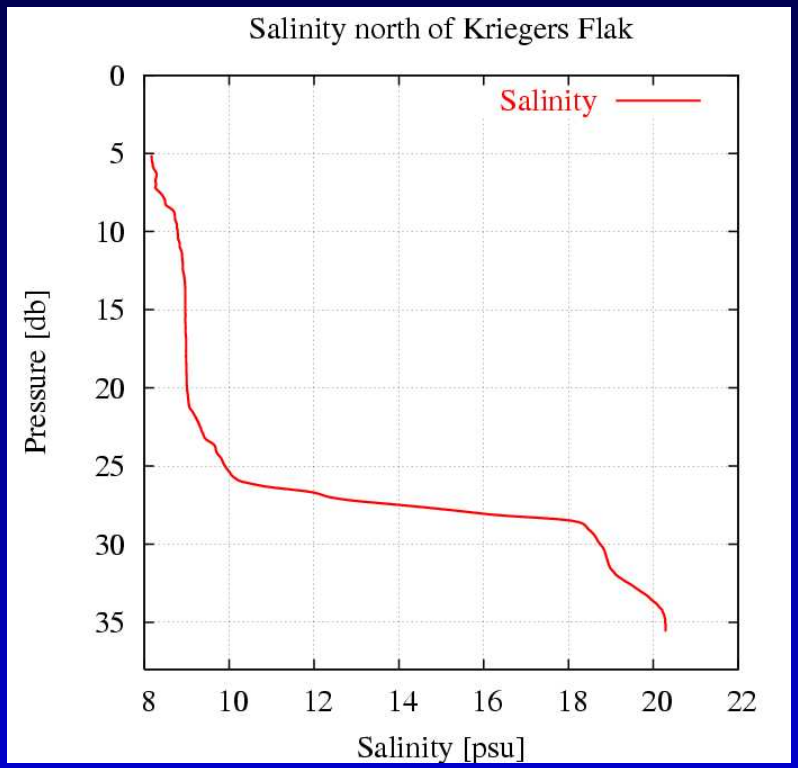
Bottom salinity (8-25 psu)

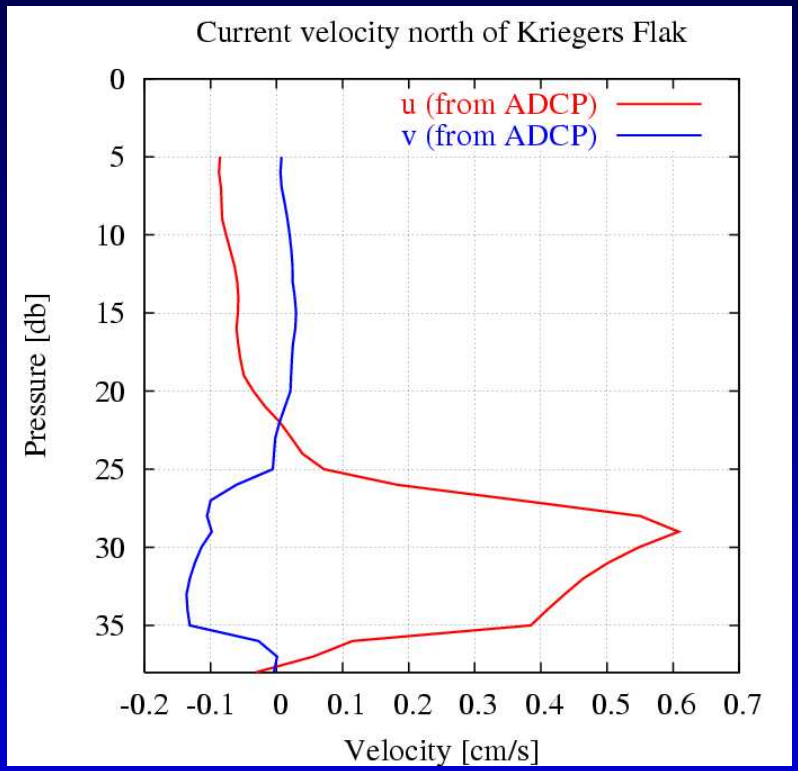


Simulation with GETM

Arkona Sea

Observations from moored ship (MzB Helmsand)

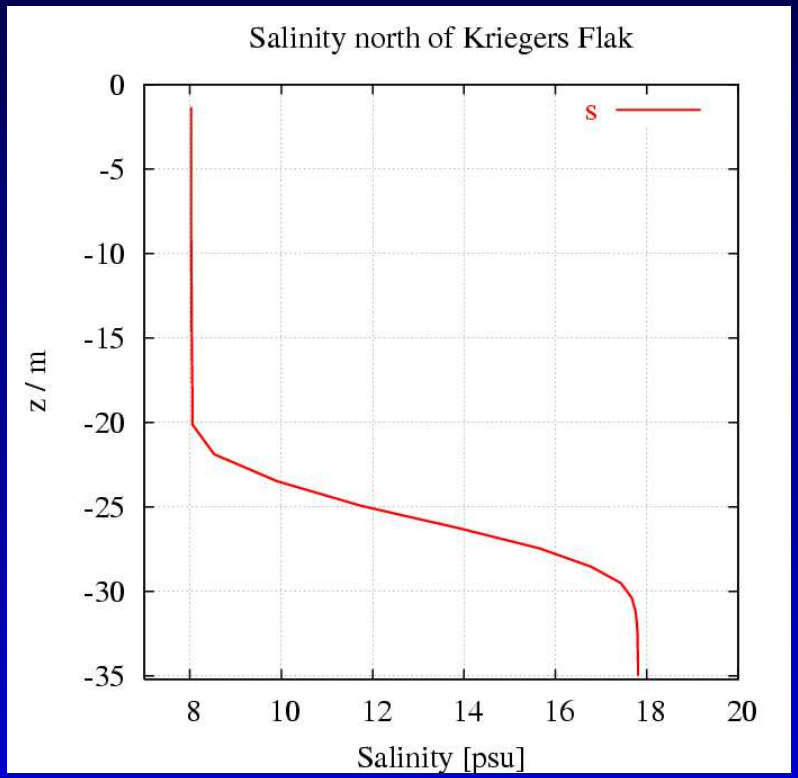


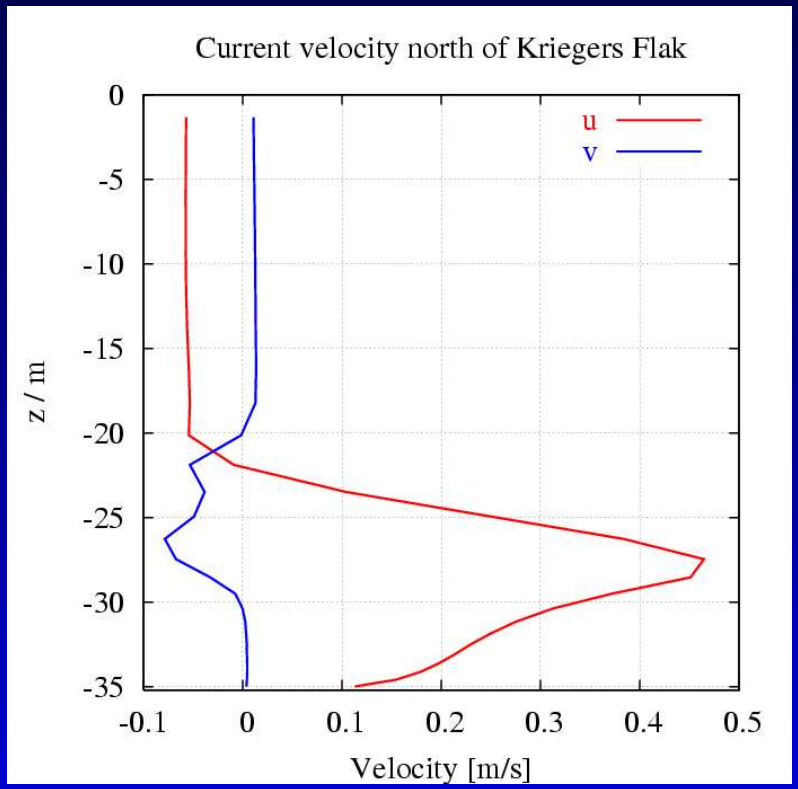


Data by Jürgen Sellschopp, Volker Fiekas, FWG Kiel

Arkona Sea

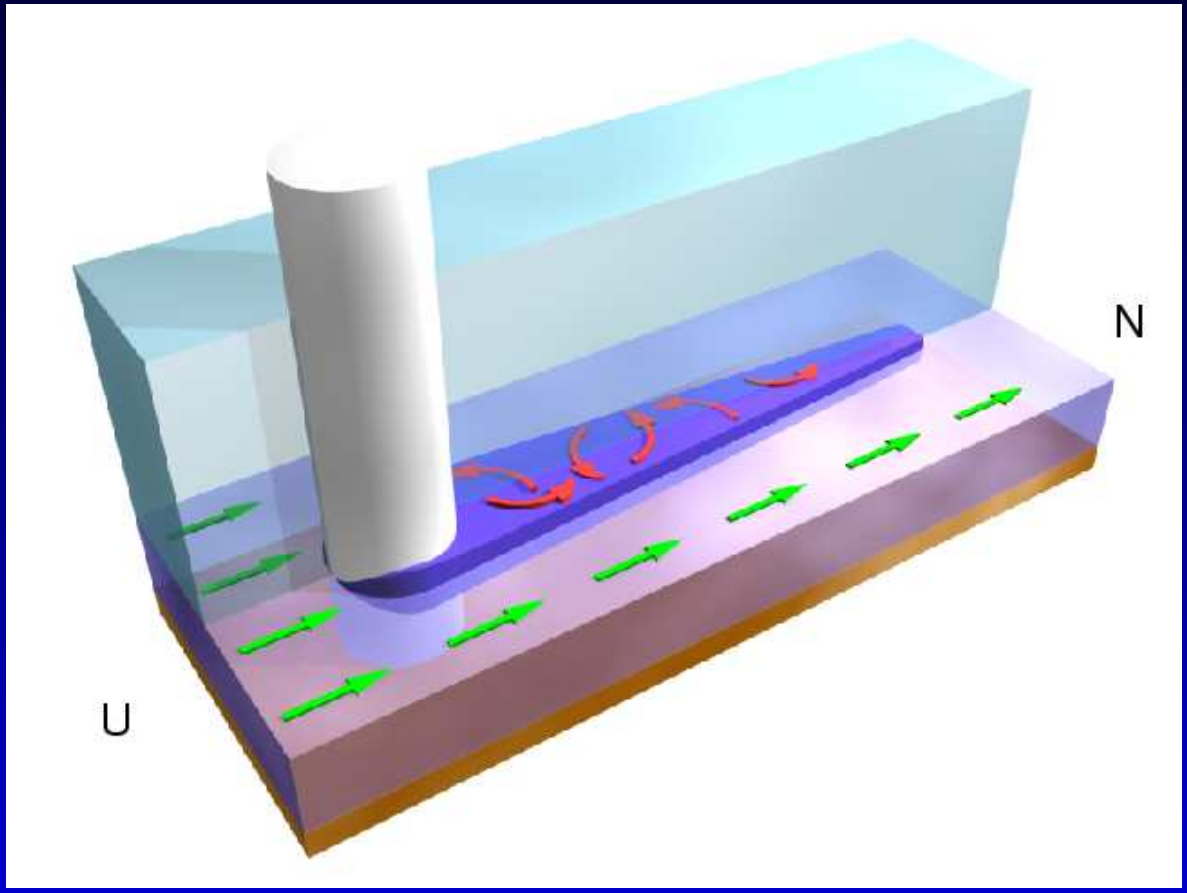
Idealised simulations (with GETM)





Offshore Constructions

Additional mixing by Offshore Wind Farms ?



Graphics by Jan Donath (IOW)

Conclusions

Quantitative numerical simulations of buoyancy effects in the coastal zone require models with certain properties such as

- Higher turbulence closures
- Surface and bottom following coordinates
- Positive definite and monotone advection schemes

Advantageous are highly flexible vertical and horizontal coordinates.