

The dynamics of turbidity zones in tidal estuaries

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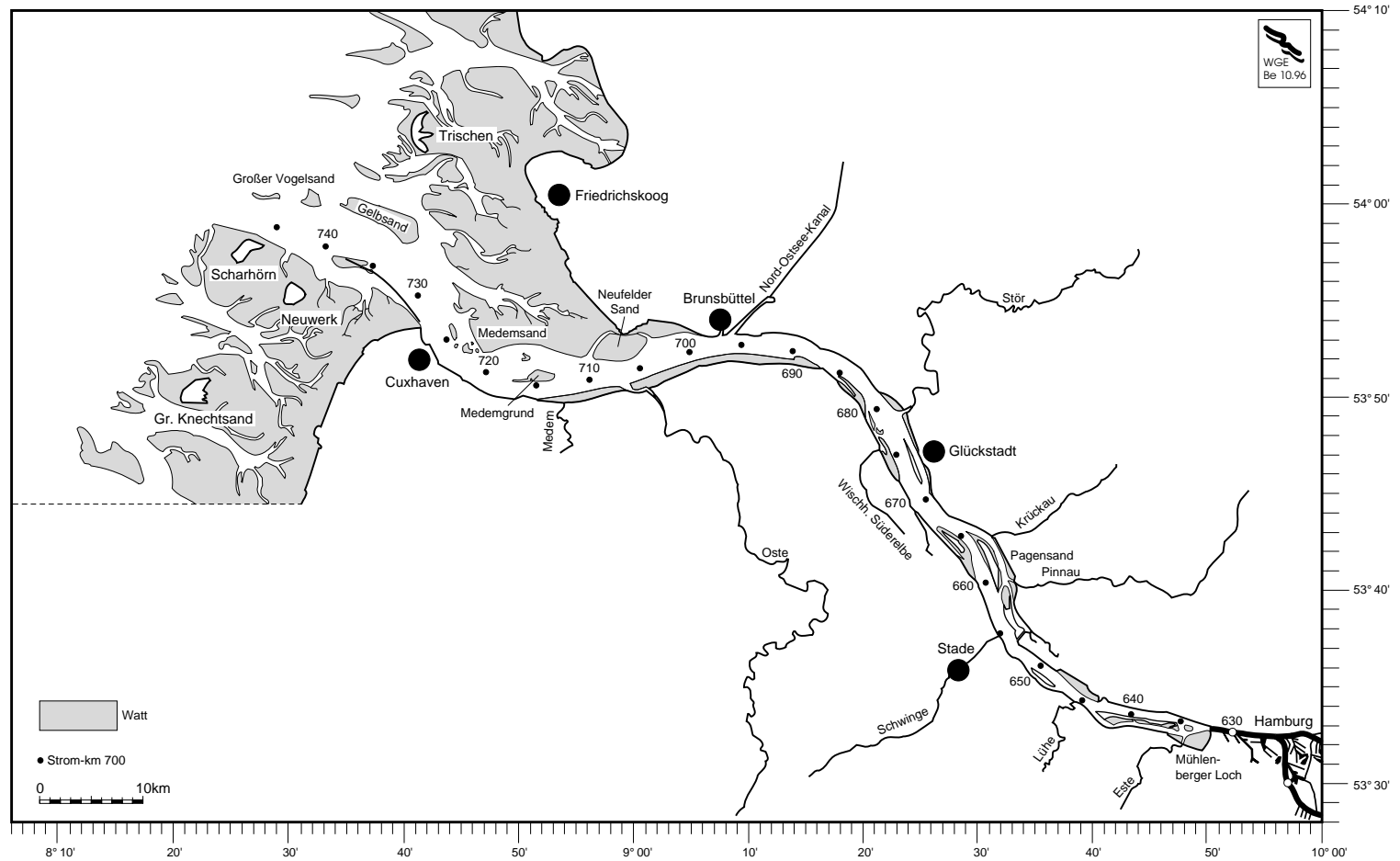
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Program of the talk

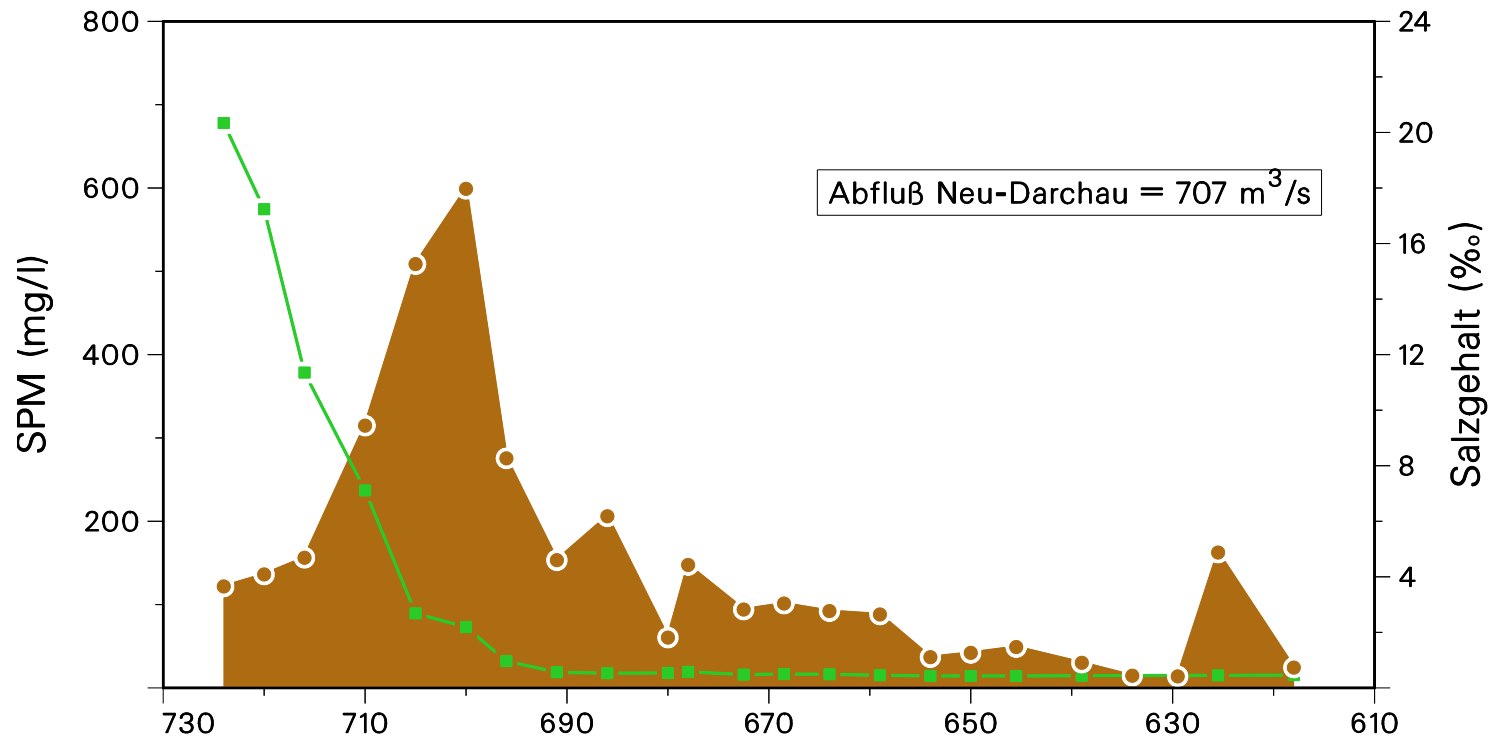
- Phenomenology
- Conceptual models
- Numerical simulations (historical)
- Numerical simulations (recent)
- Conclusions

Map of the tidal Elbe



Phenomenology

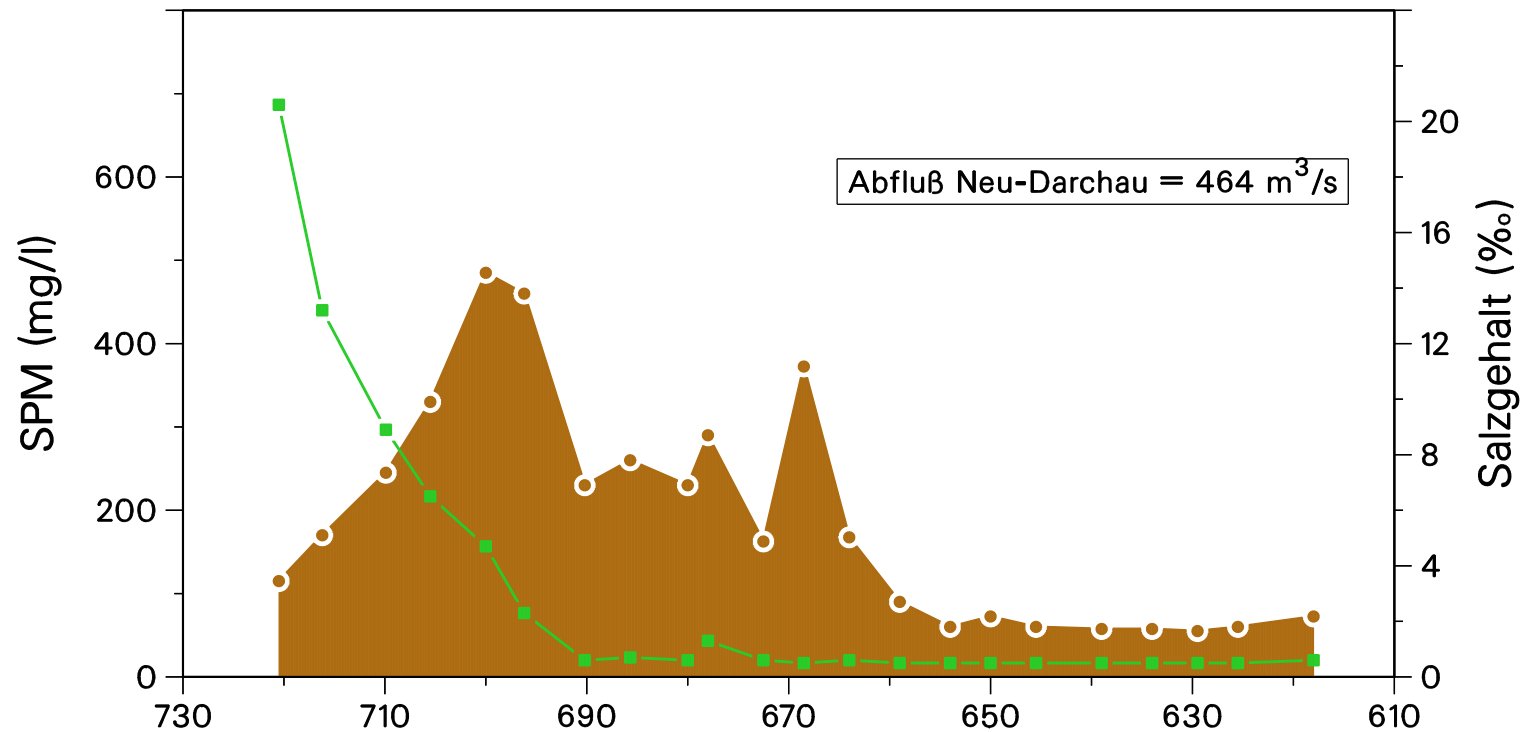
SPM observations in the tidal Elbe



Pers. comm. Jens Kappenberg

Phenomenology

SPM observations in the tidal Elbe

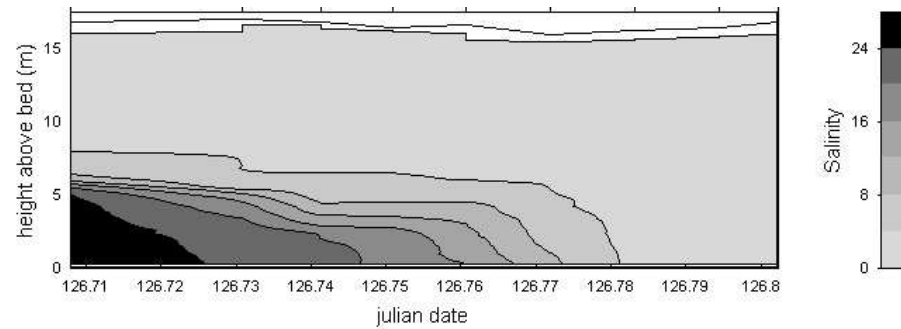


Pers. comm. Jens Kappenberg

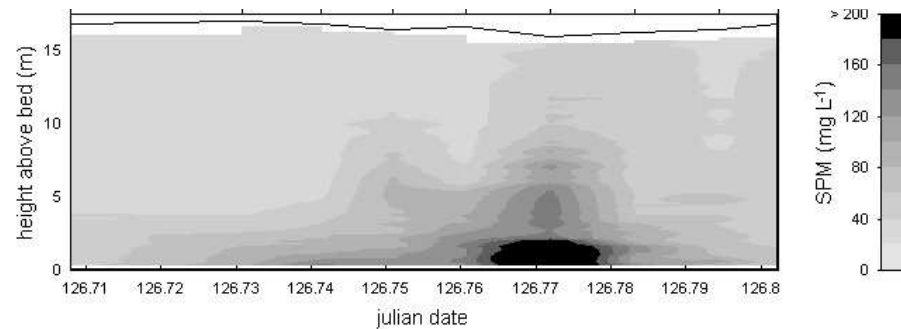
Phenomenology

SPM observations in Columbia River

Salinity



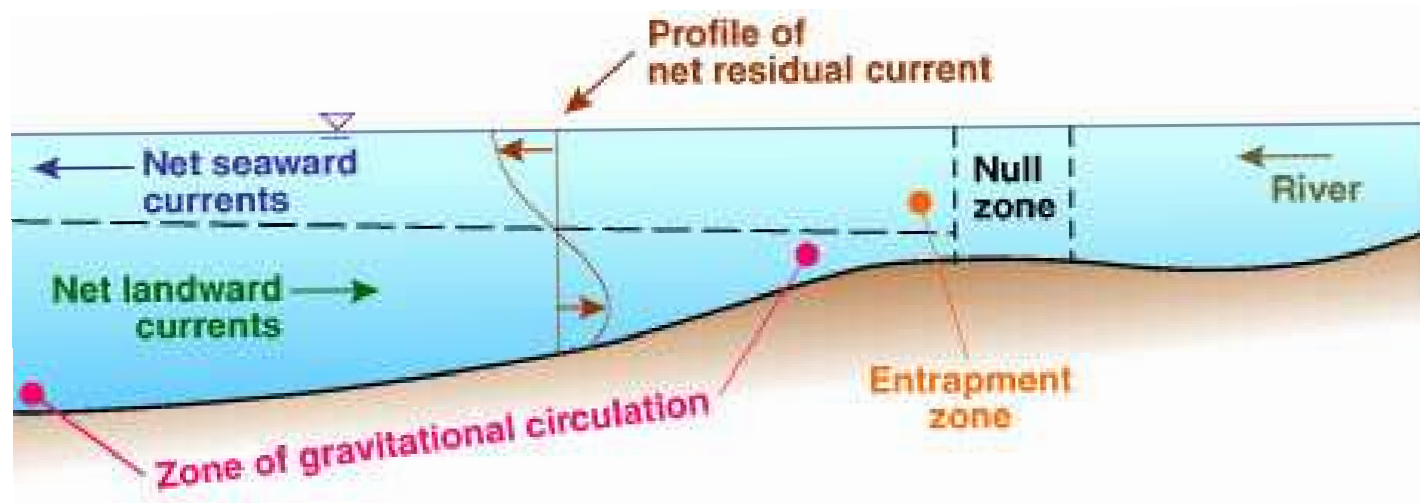
SPM



Pers. comm. David Jay, Phillip Orton

Classical conceptual models

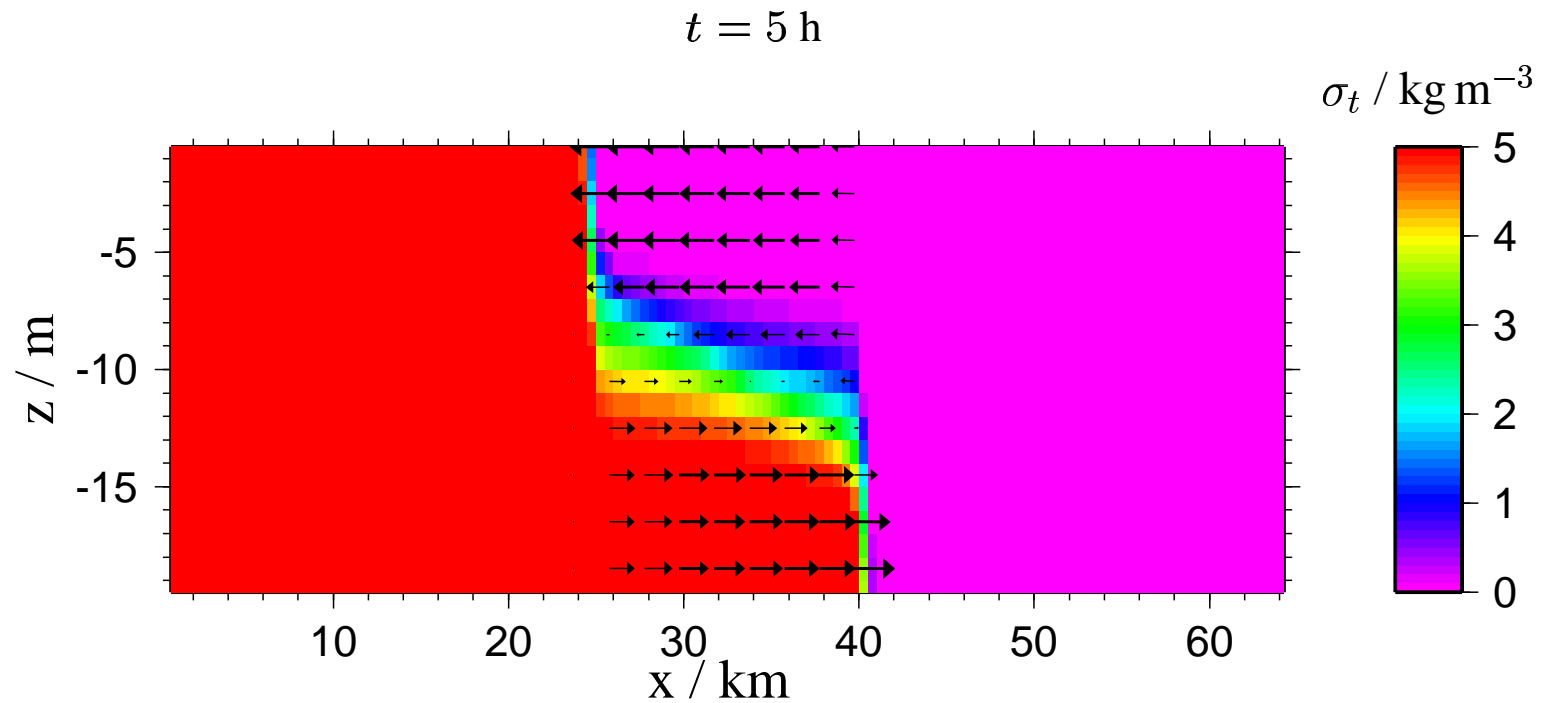
- Flocculation of riverine colloids due to the ion content of the saline sea water (*Lucht* [1953]).
- "The peculiar process of mixing between riverine and marine water in the tidal zone works as a SPM trap." (*Postma und Kalle* [1955]).



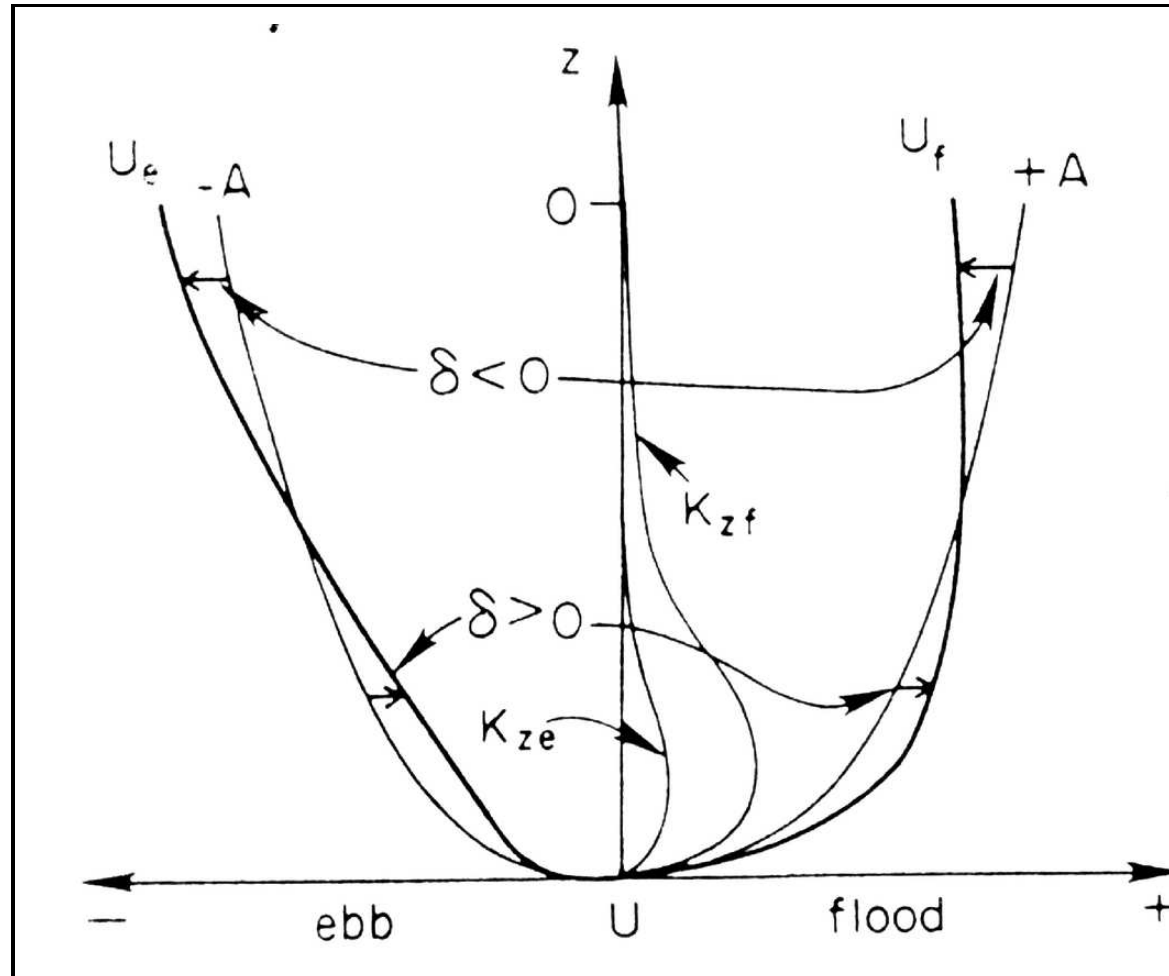
Schoellhamer & Burau, 1998

Classical conceptual models

Density currents from numerical lock exchange

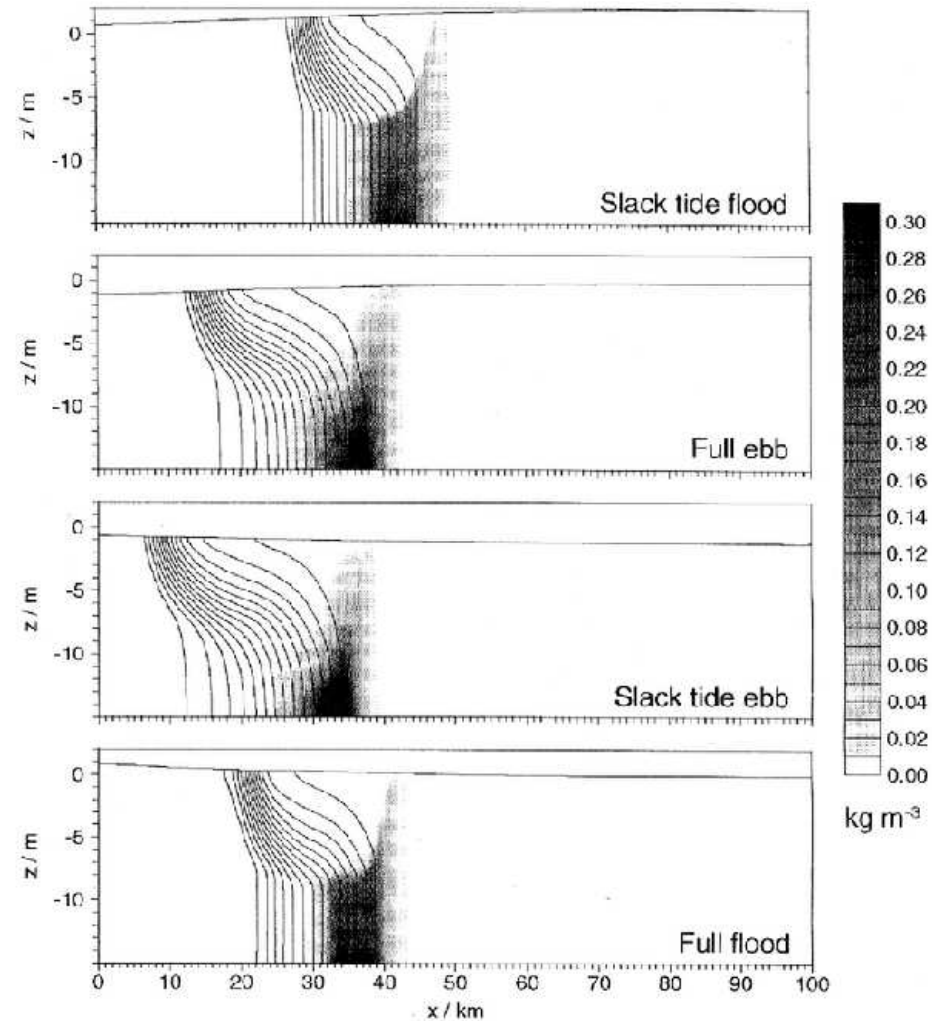


Conceptual model



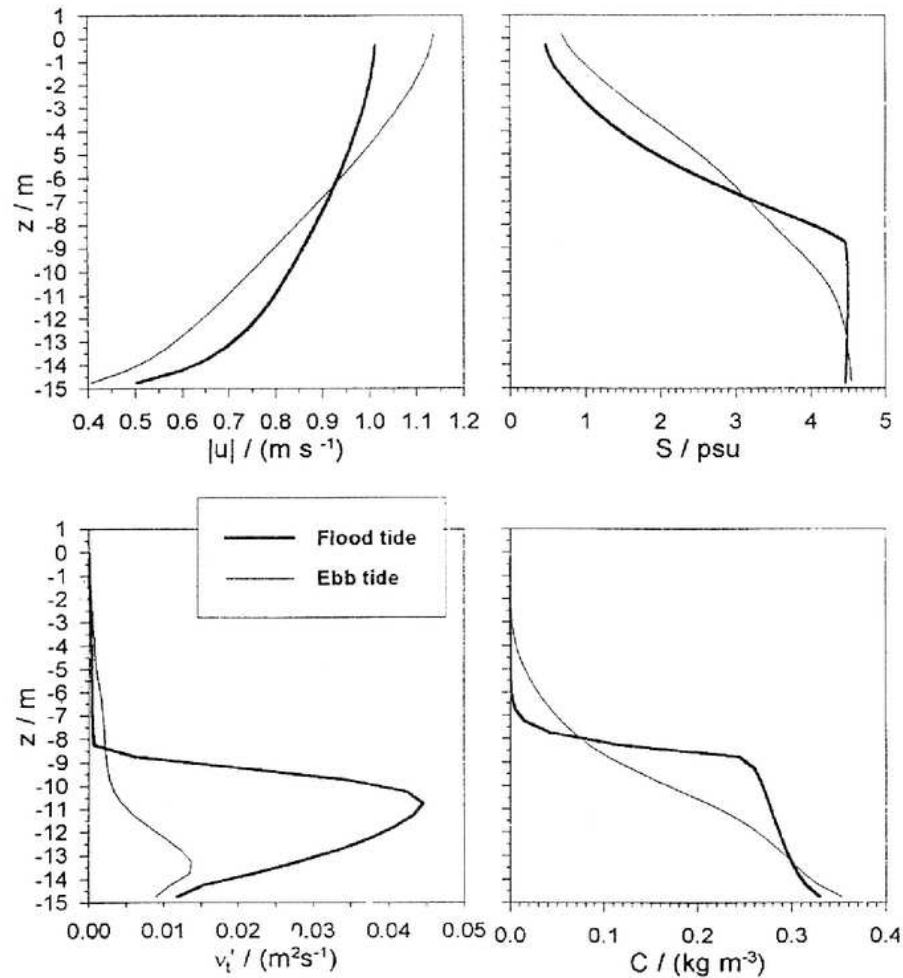
Jay & Musiak, 1994

Computer simulations



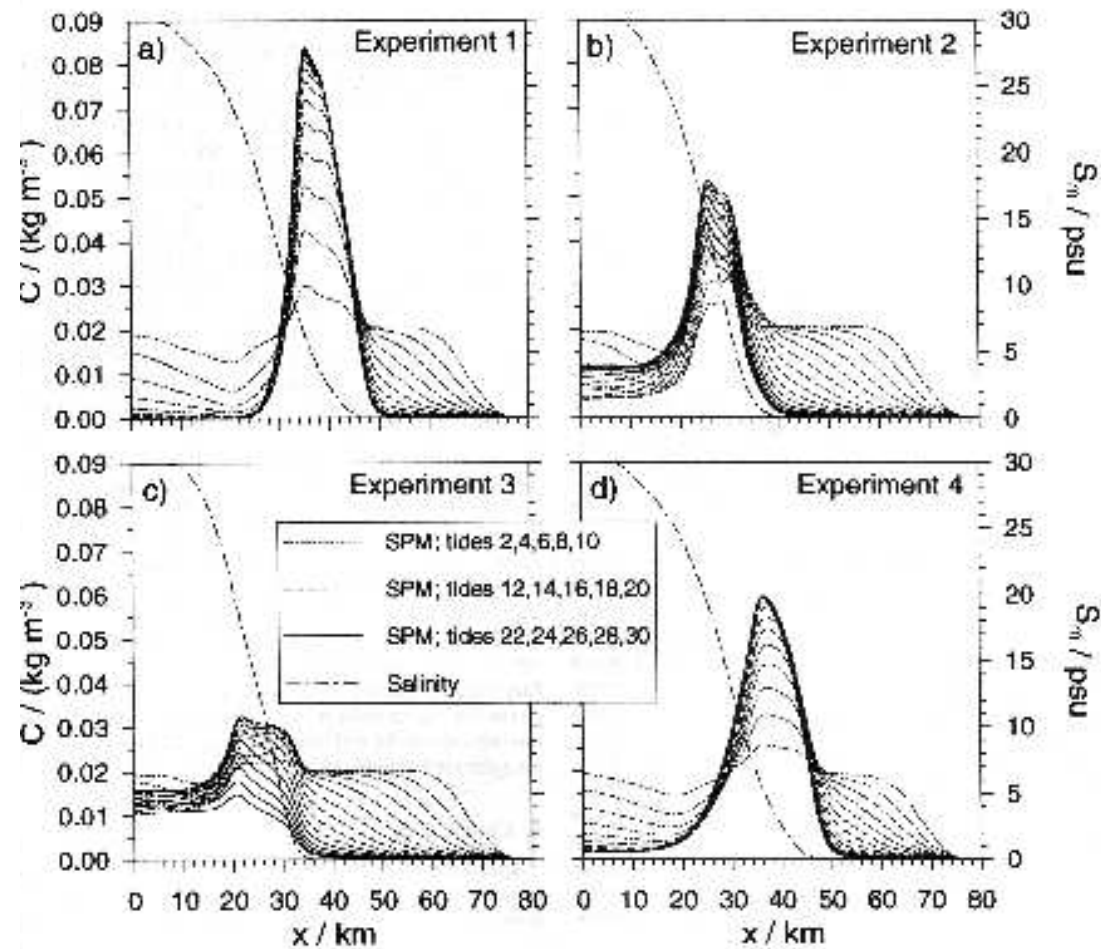
Burchard & Baumert, 1998

Computer simulations



Burchard & Baumert, 1998

Computer simulations



Burchard & Baumert, 1998

GETM

- Three dimensional, hydrostatic, free surface, baroclinic
- Mode-splitting, Arakawa-C grid
- Horizontal coord.: Cartesian, spherical or orthogonal
- Vertical coord.: Sigma, z-levels or generalized
- Turbulence closures from GOTM (<http://www.gotm.net>)
- Various advection schemes for momentum and tracers
- Stable drying and flooding algorithm

Burchard & Bolding, 2002

Suspended matter module

Transport equation:

$$\partial_t C + \partial_x(uC) + \partial_y(vC) + \partial_z((w - w_s)C) - \partial_z(\nu'_t \partial_z C) = 0 \quad (1)$$

Bottom boundary condition:

$$-w_s C - \nu'_t \partial_z C = F_e - F_s \quad (2)$$

Erosion & sedimentation flux:

$$F_e = \frac{C_e}{\rho_0} (|\tau_b| - \tau_{ce})^+; \quad F_s = \frac{w_s C_b}{\tau_{cs}} (|\tau_b| - \tau_{cs})^- \quad (3)$$

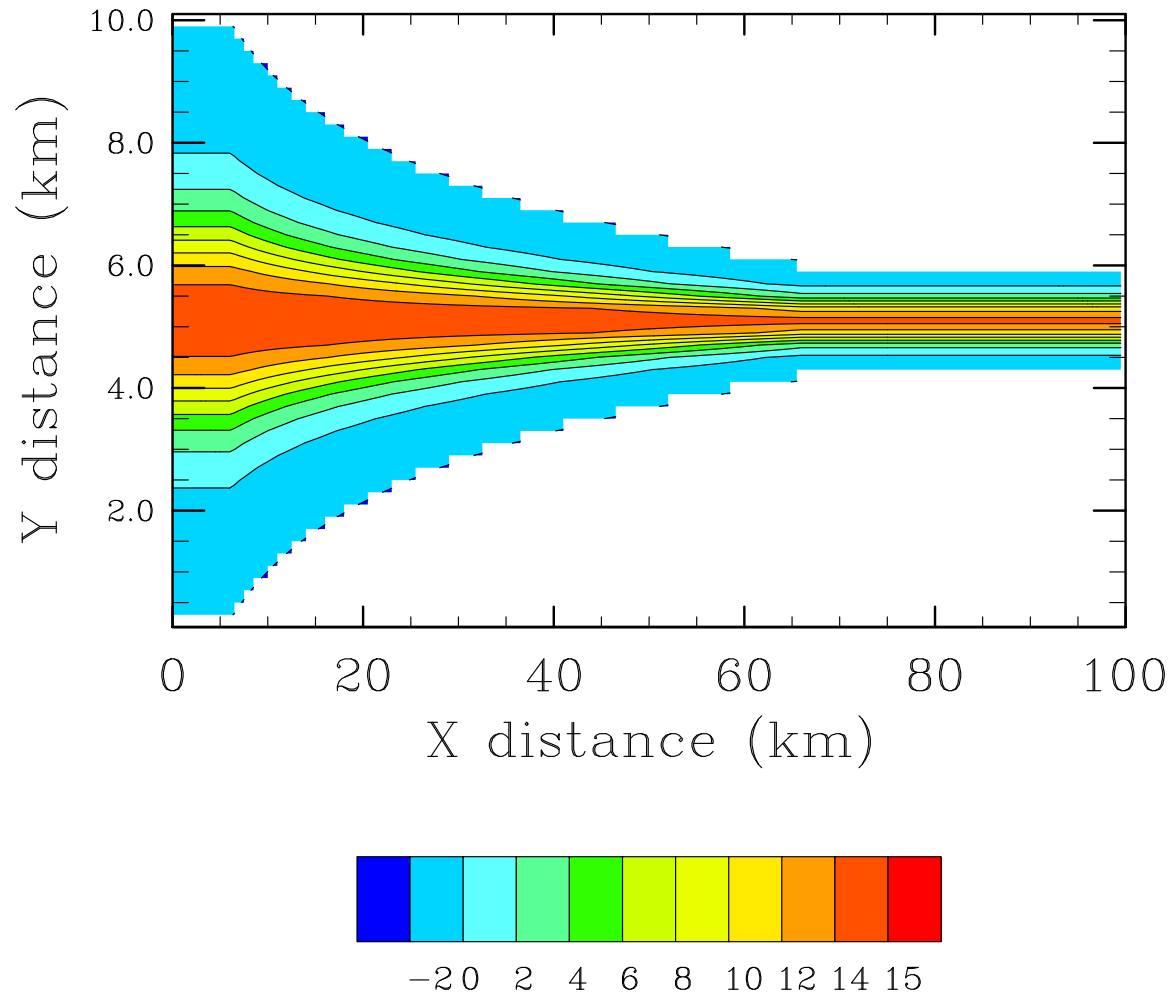
Bottom SPM pool:

$$\partial_t(B) = F_s - F_e \quad (4)$$

Two-dimensional experiments

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

Idealised bathymetry



Three-dimensional experiment

- Salinity and SPM, longitudinal section (click for animation)
- Salinity, SPM and velocity, surface view (click for animation)
- Salinity and velocity, cross-sectional view (click for animation)

Conclusions

- In many estuaries, turbidity maxima (ETMs) are observed at the tip of the salt intrusion.
- These types of ETMs have been numerically simulated with different 2D- and 3D-models.
- Two major ETM generation mechanisms have been pinpointed, residual gravitational circulation and tidal velocity asymmetry.
- Even in idealised 3D cases, complex secondary flows occur and strongly influence the ETM dynamics.

Future work

- Detailed numerical analysis of ETM dynamics in three dimensions.
- Numerical analysis of turbulence advection.
- Application of the model to process studies in the tidal Elbe by using a curvi-linear orthogonal grid.