

# The dynamics of turbidity zones in tidal estuaries

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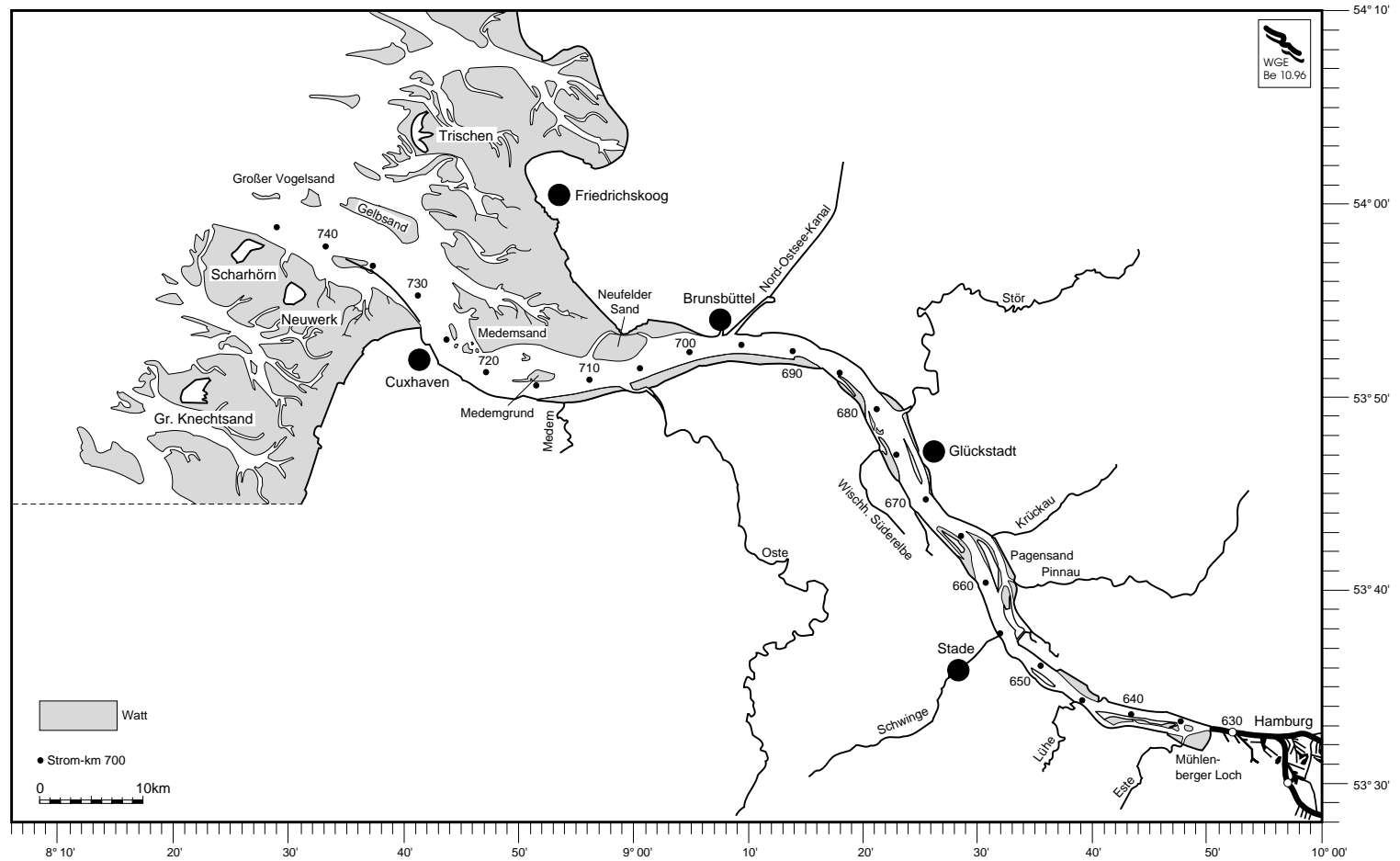
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# Program of the talk

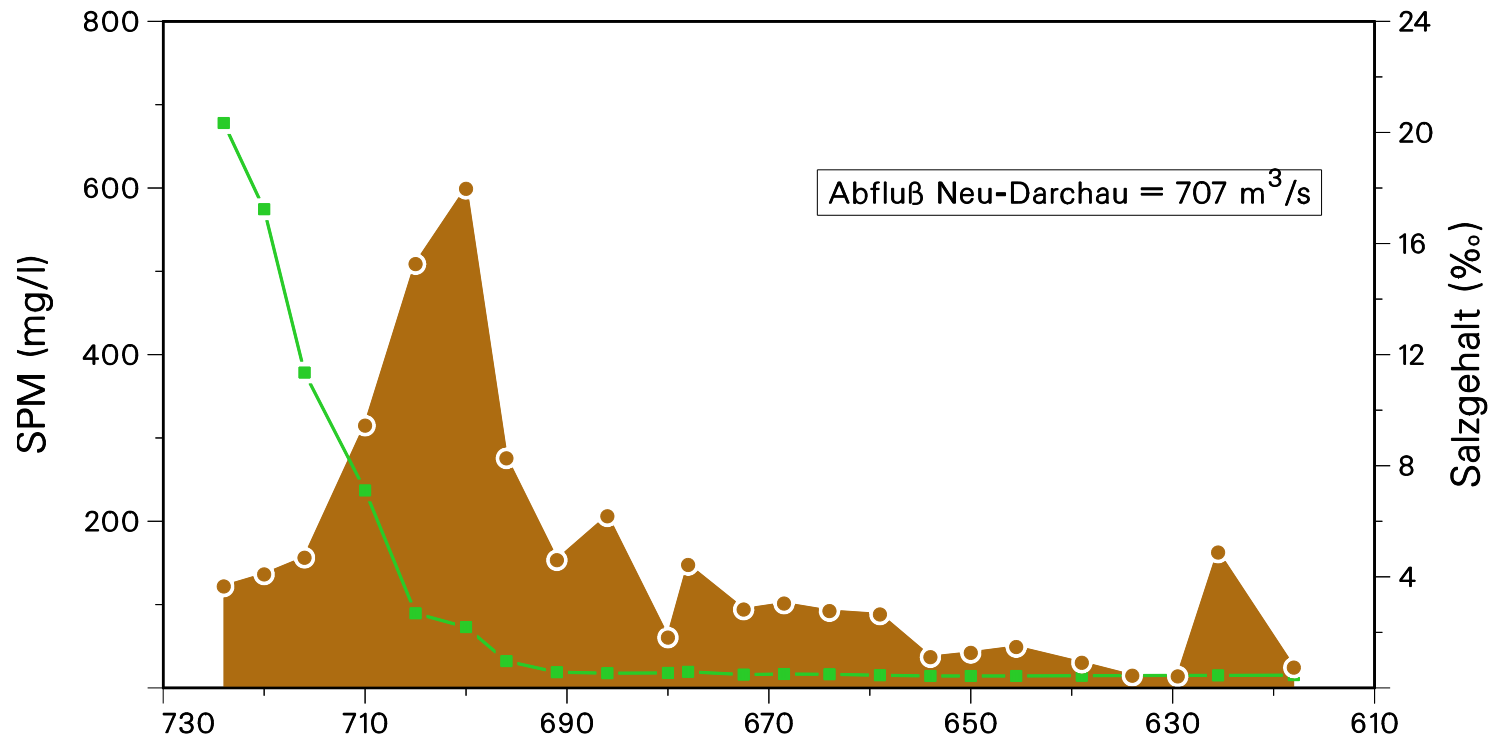
- Phenomenology
- Conceptual models
- Numerical simulations (historical)
- Numerical simulations (recent)
- Conclusions

# Map of the tidal Elbe



# Phenomenology

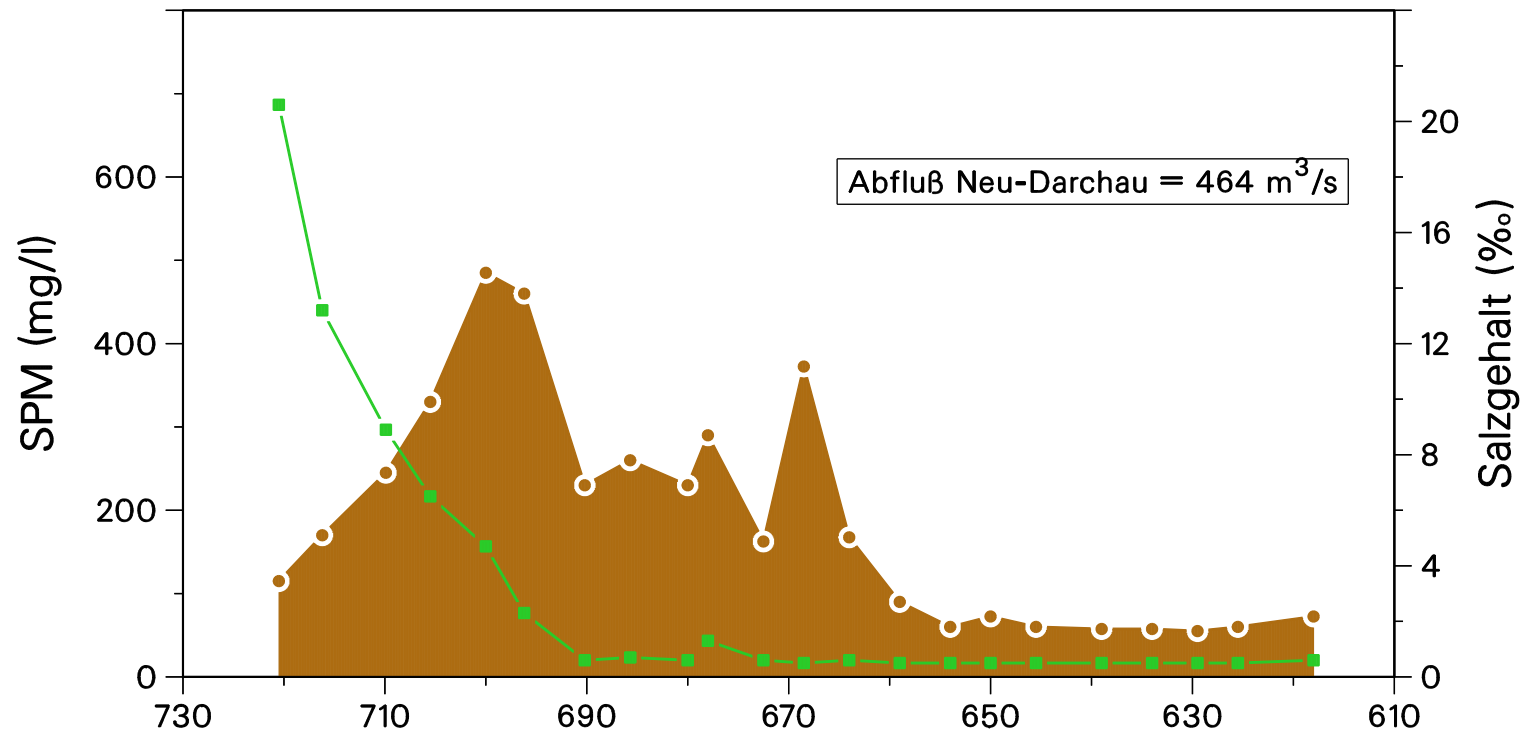
## SPM observations in the tidal Elbe



Pers. comm. Jens Kappenberg

# Phenomenology

## SPM observations in the tidal Elbe

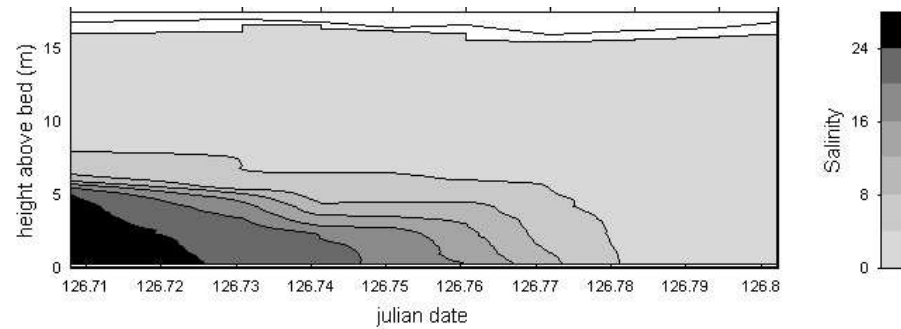


Pers. comm. Jens Kappenberg

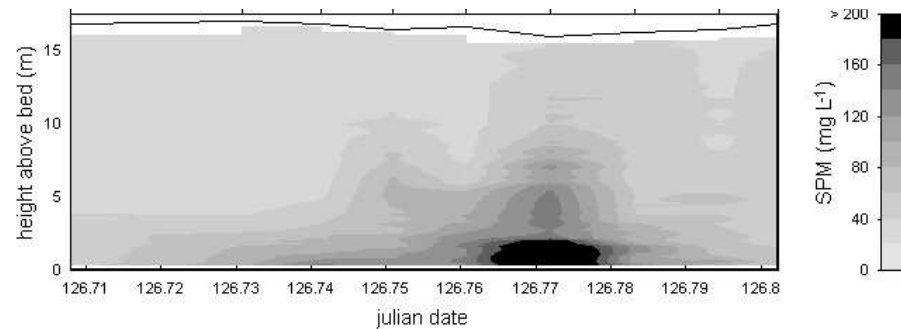
# Phenomenology

## SPM observations in Columbia River

Salinity



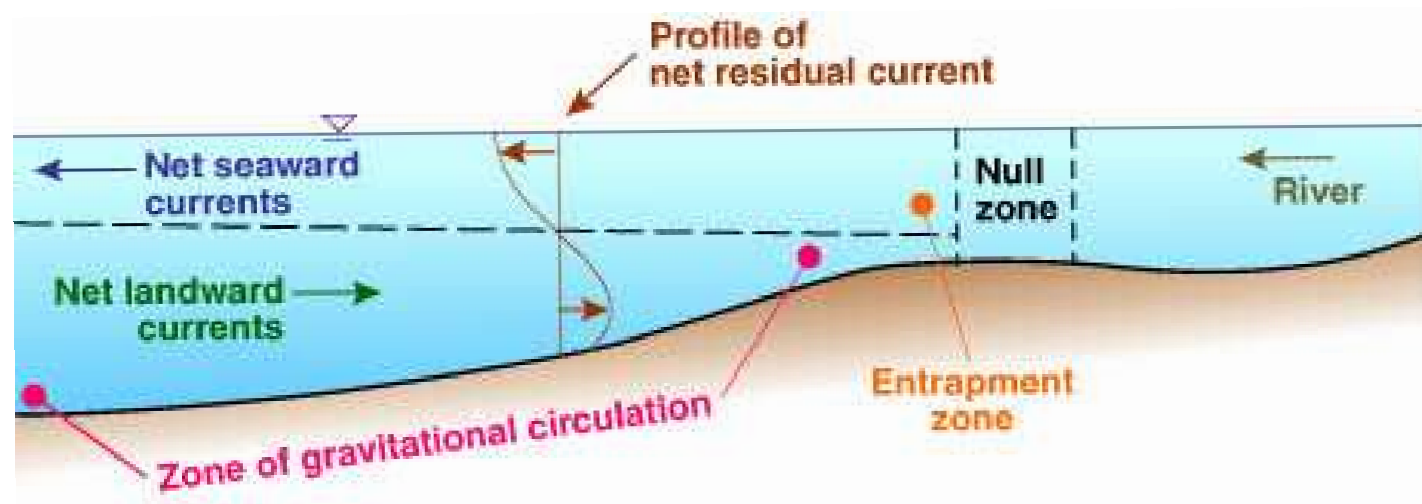
SPM



Pers. comm. David Jay, Phillip Orton

# Classical conceptual models

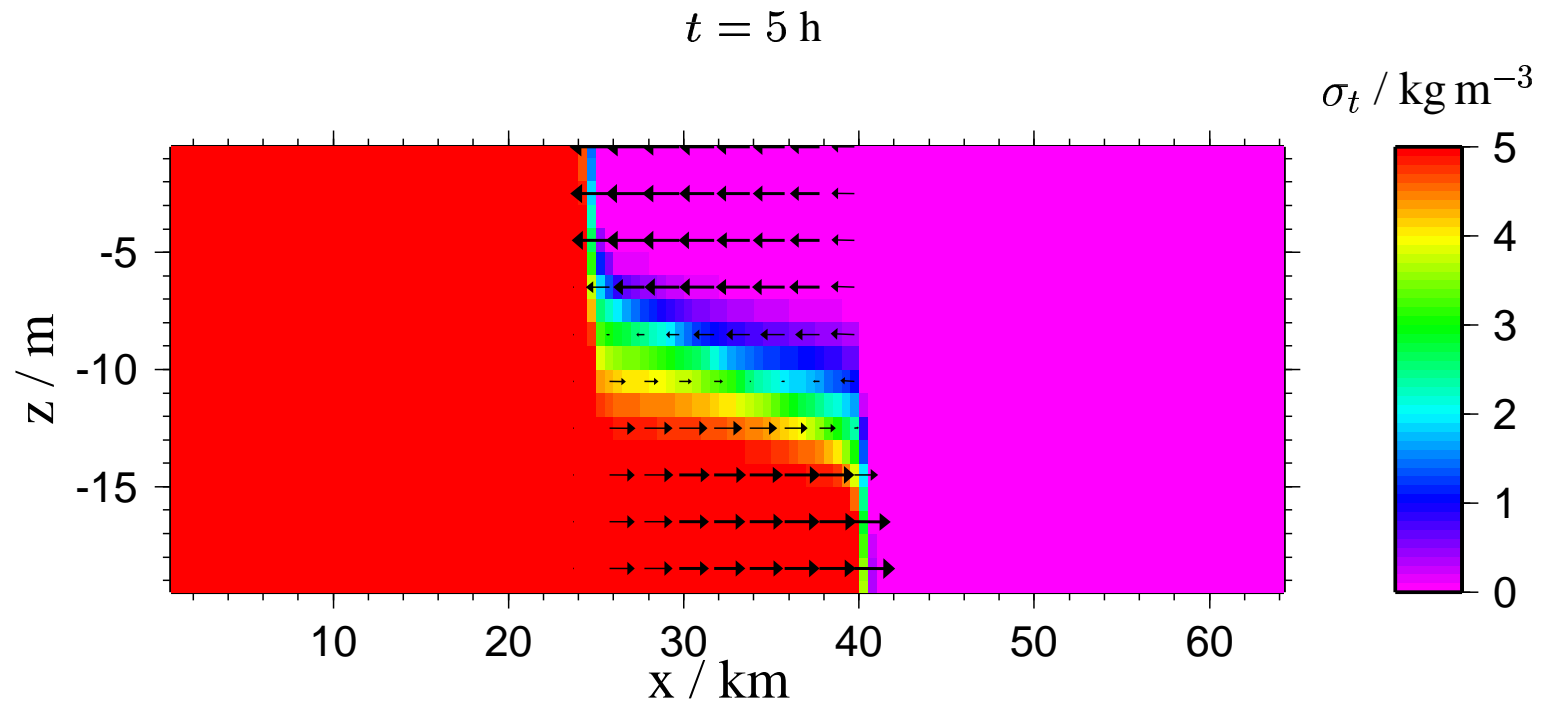
- Flocculation of riverine colloids due to the ion content of the saline sea water (*Lucht* [1953]).
- "The peculiar process of mixing between riverine and marine water in the tidal zone works as a SPM trap." (*Postma und Kalle* [1955]).



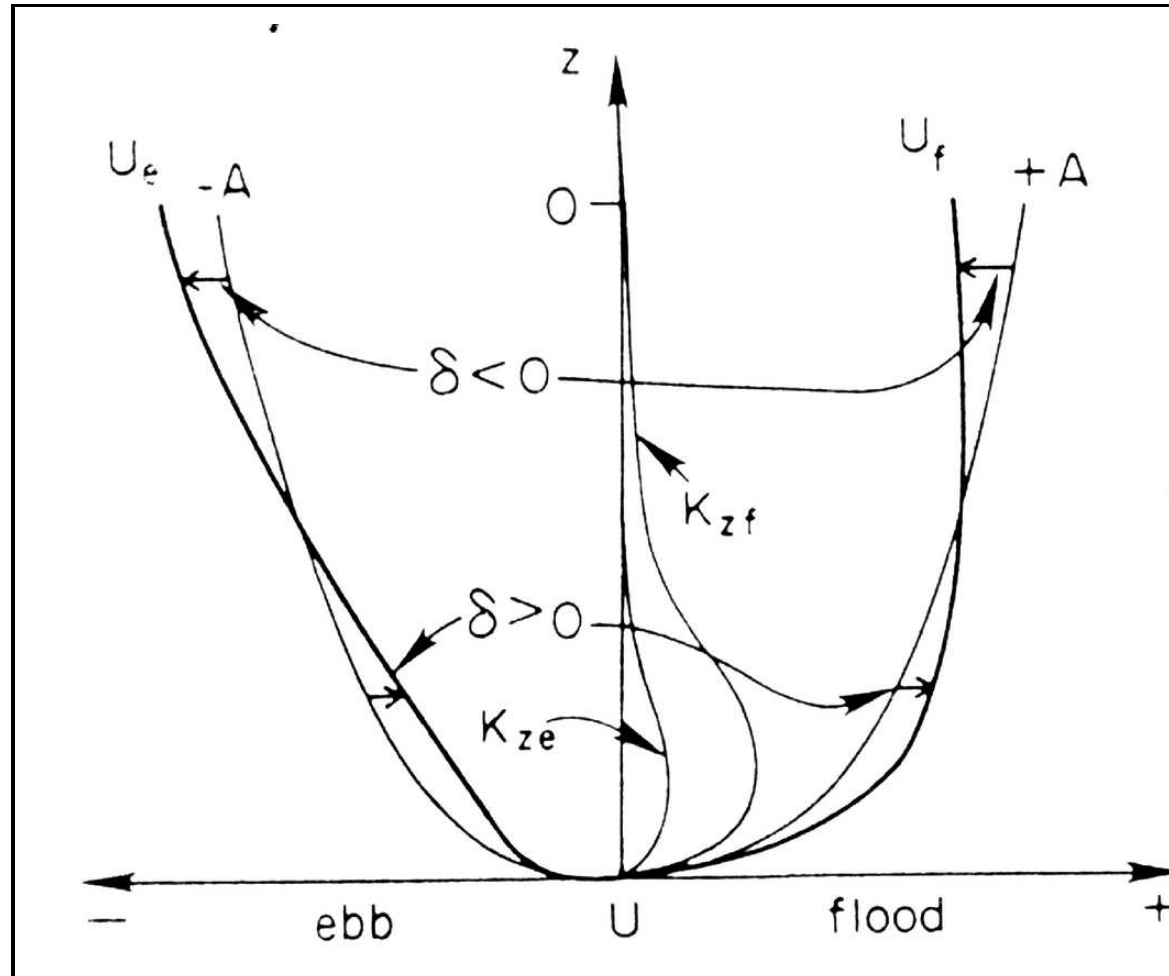
Schoellhamer & Burau, 1998

# Classical conceptual models

## Density currents from numerical lock exchange

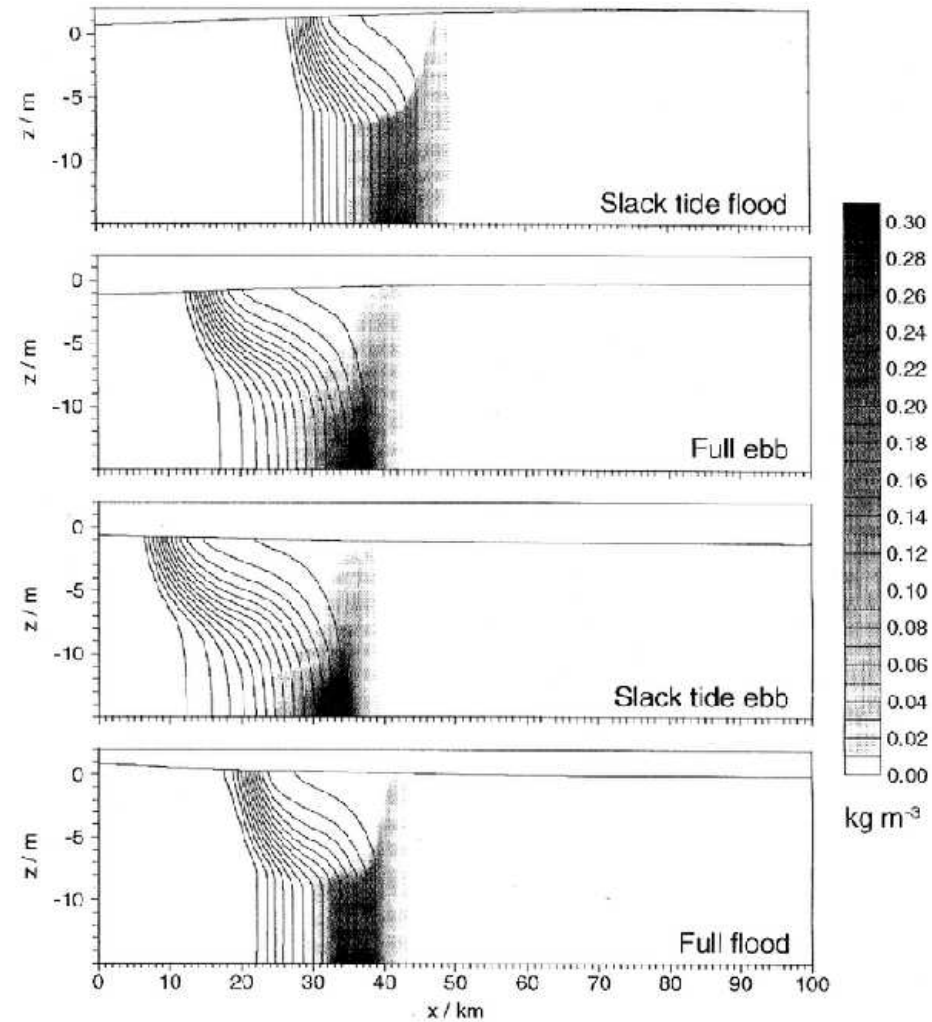


# Conceptual model



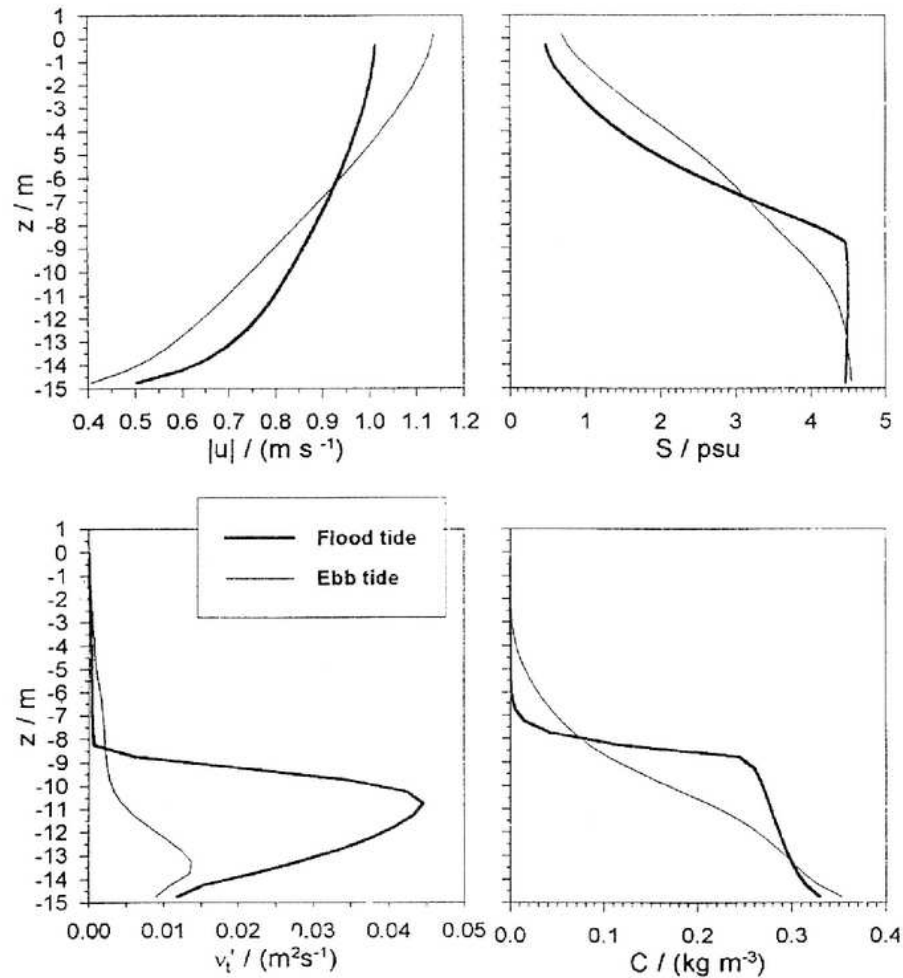
Jay & Musiak, 1994

# Computer simulations



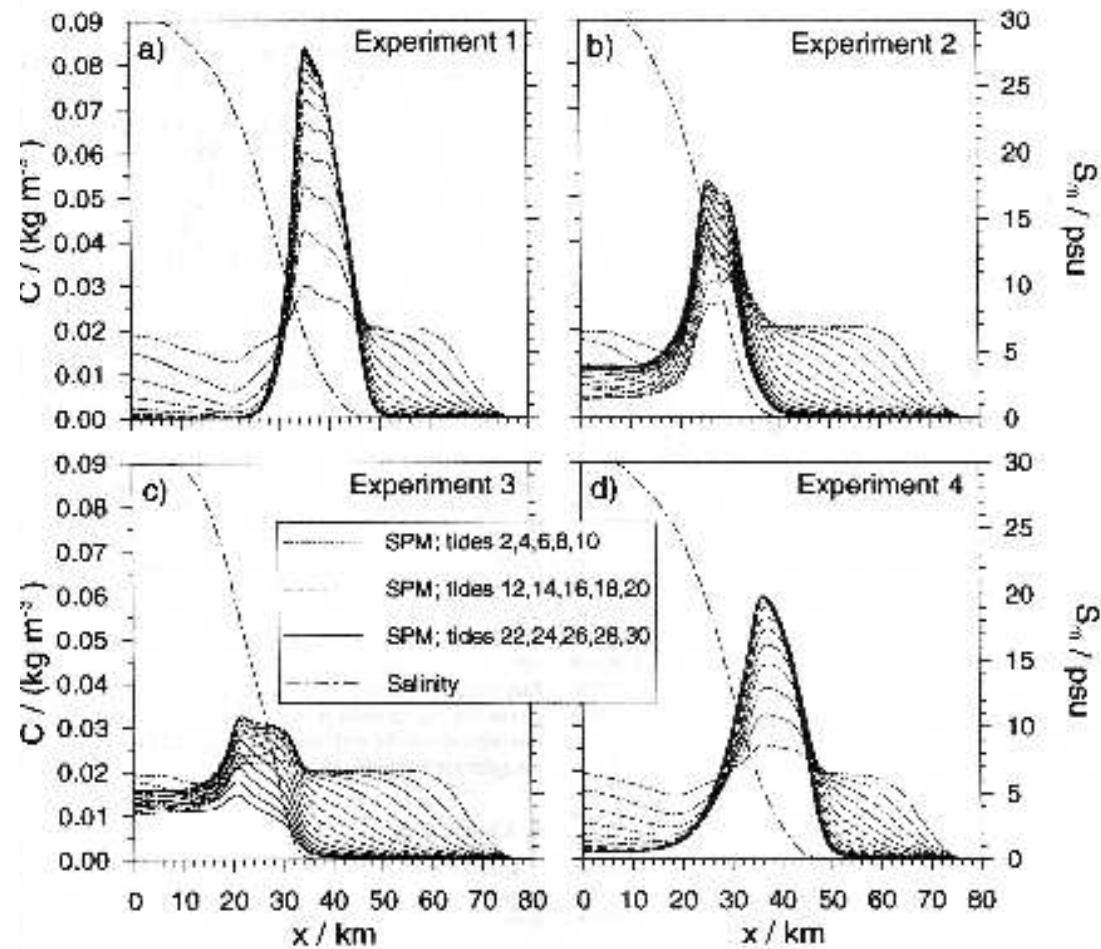
Burchard & Baumert, 1998

# 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:

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

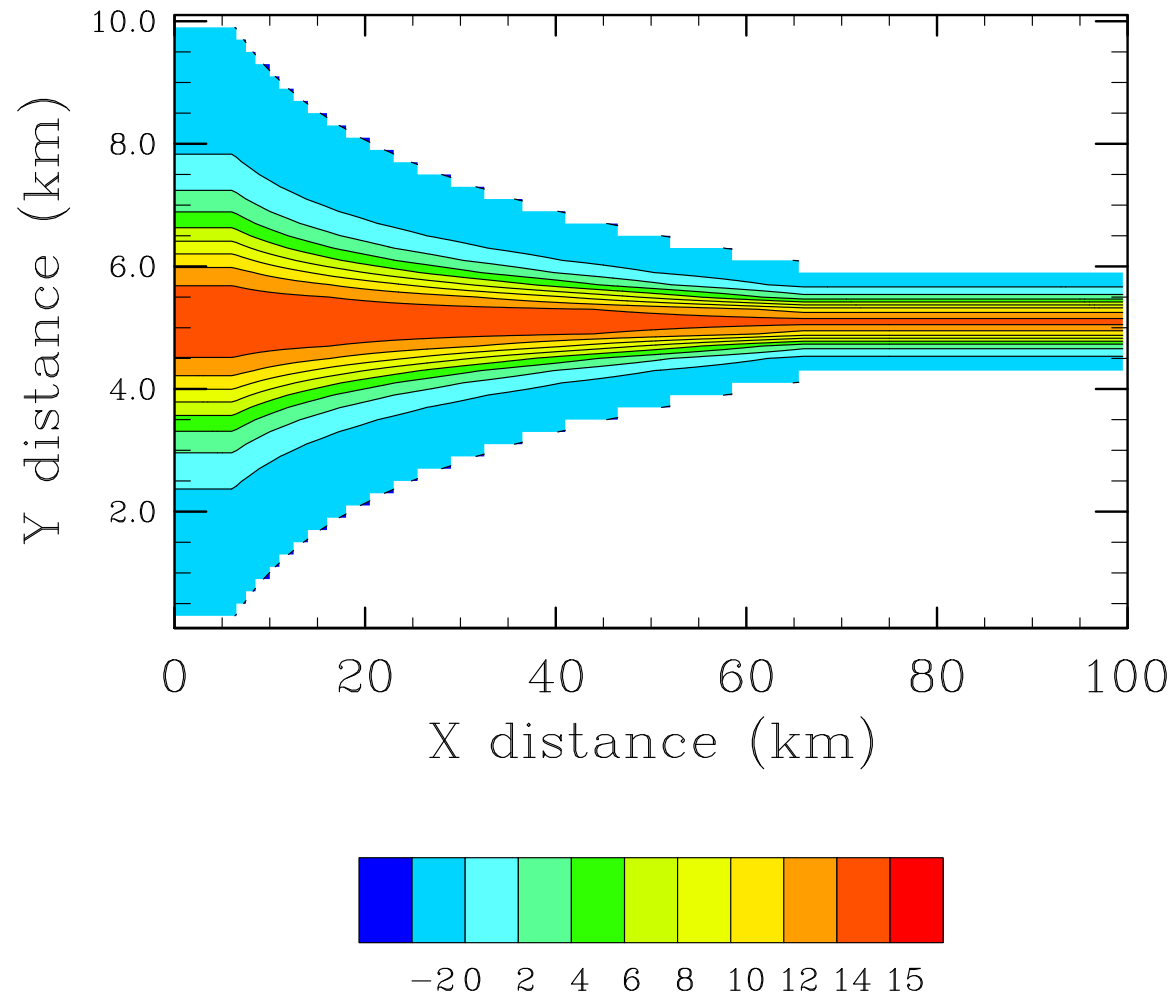
Bottom SPM pool:

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

# 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.