

A 3D unstructured numerical model of
Ems-Dollart estuary
Observations and 3-D modeling

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in the framework of *Future-Ems* project.



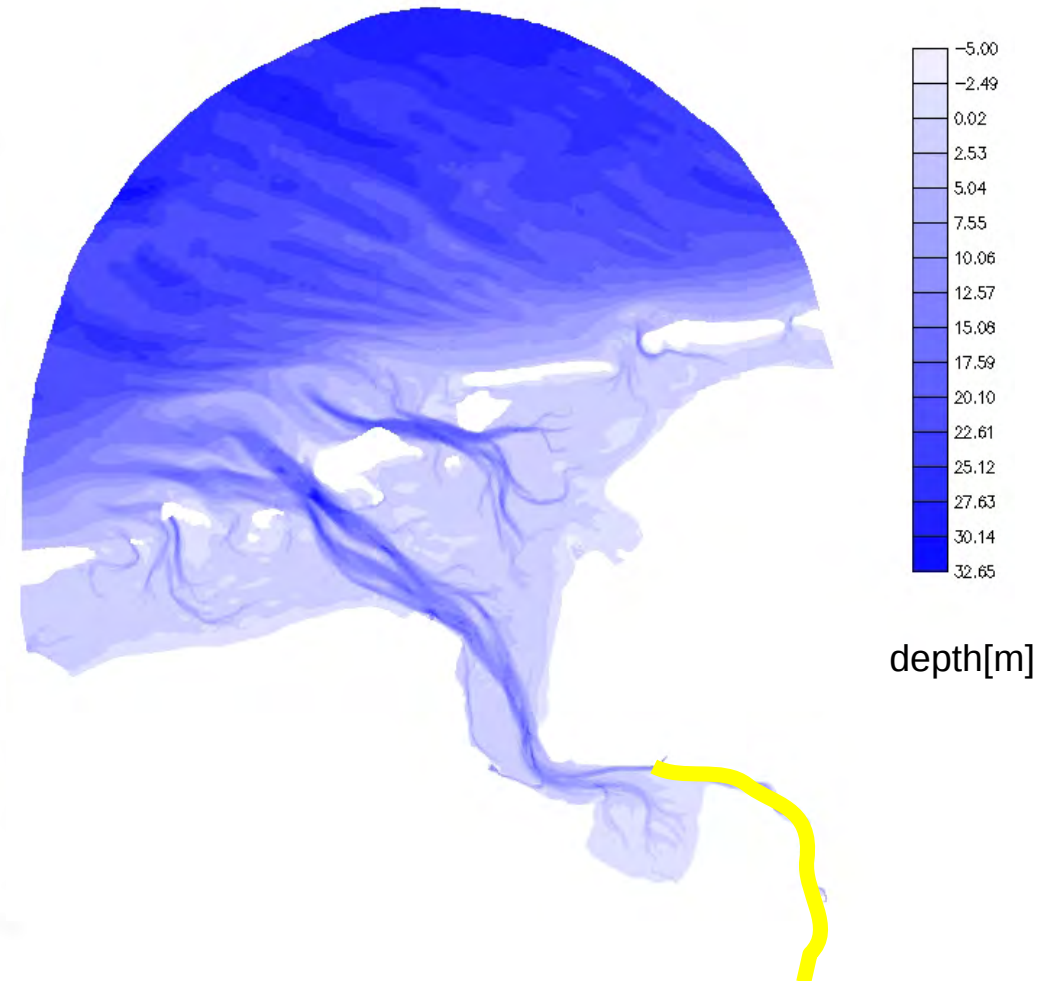
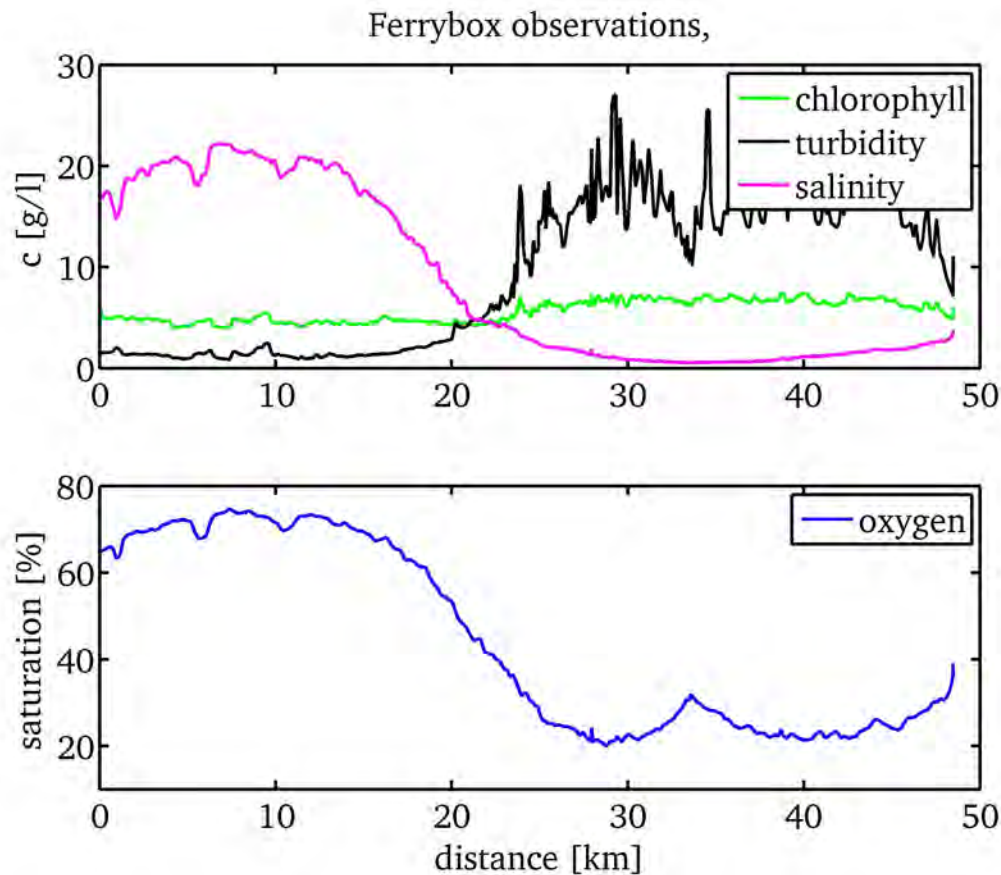
Netherlands Organisation for Scientific Research



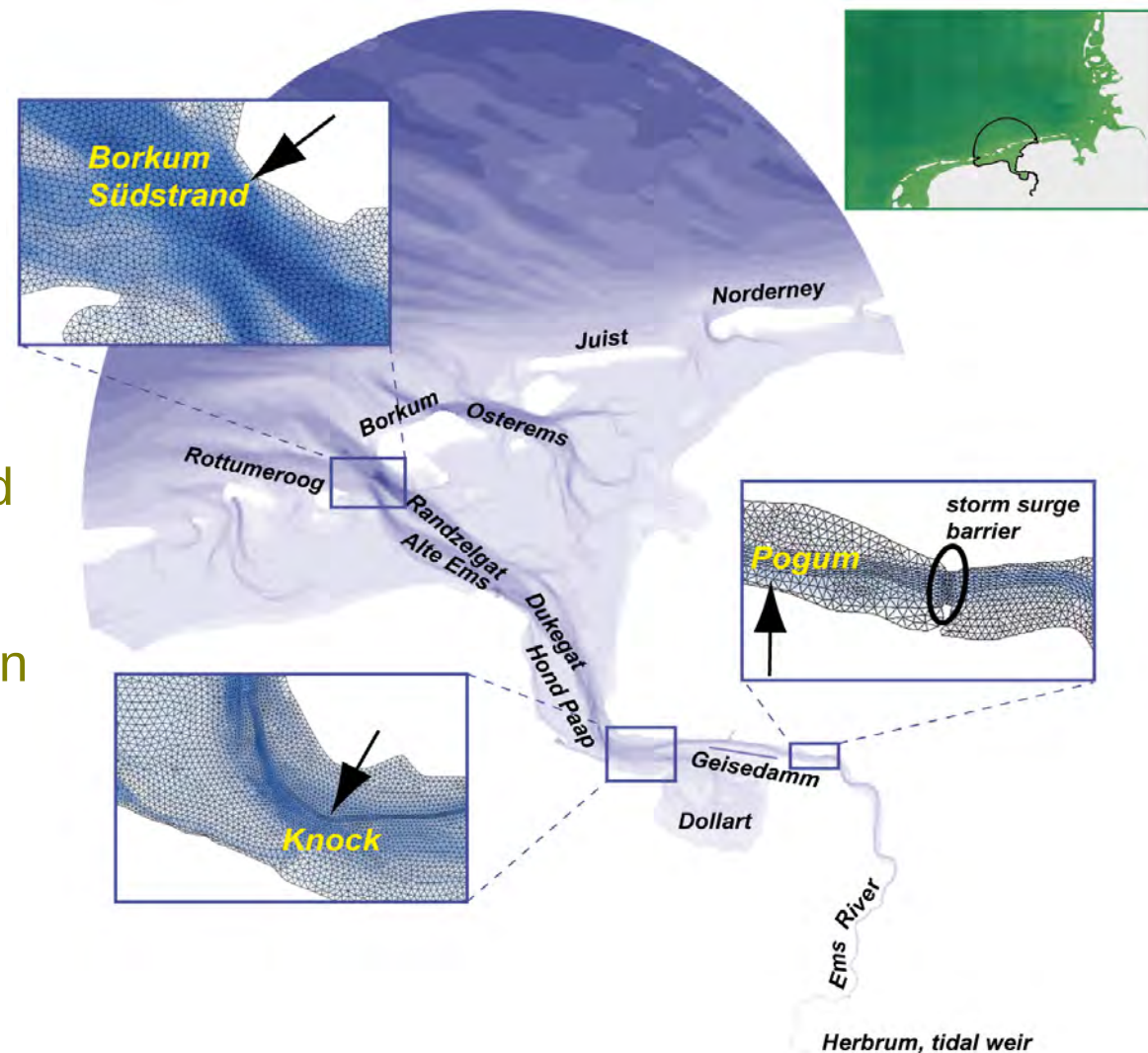
Bundesministerium
für Bildung
und Forschung

Model area & general research issues

- Ems river suffers from very high turbidity and seasonal oxygen depletion
- Ems system morphology: barrier islands, tidal channels and flats & river

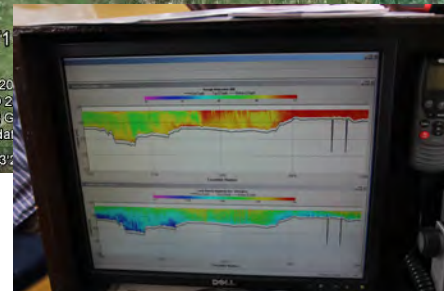
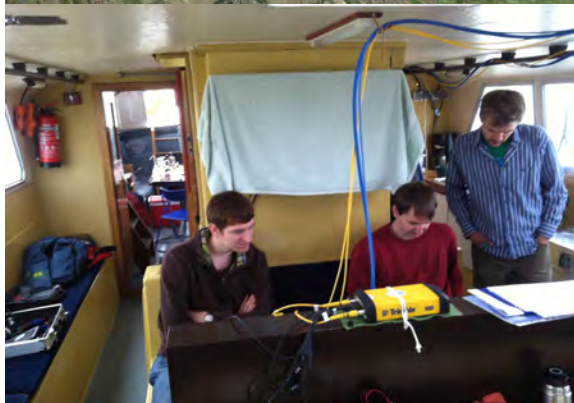
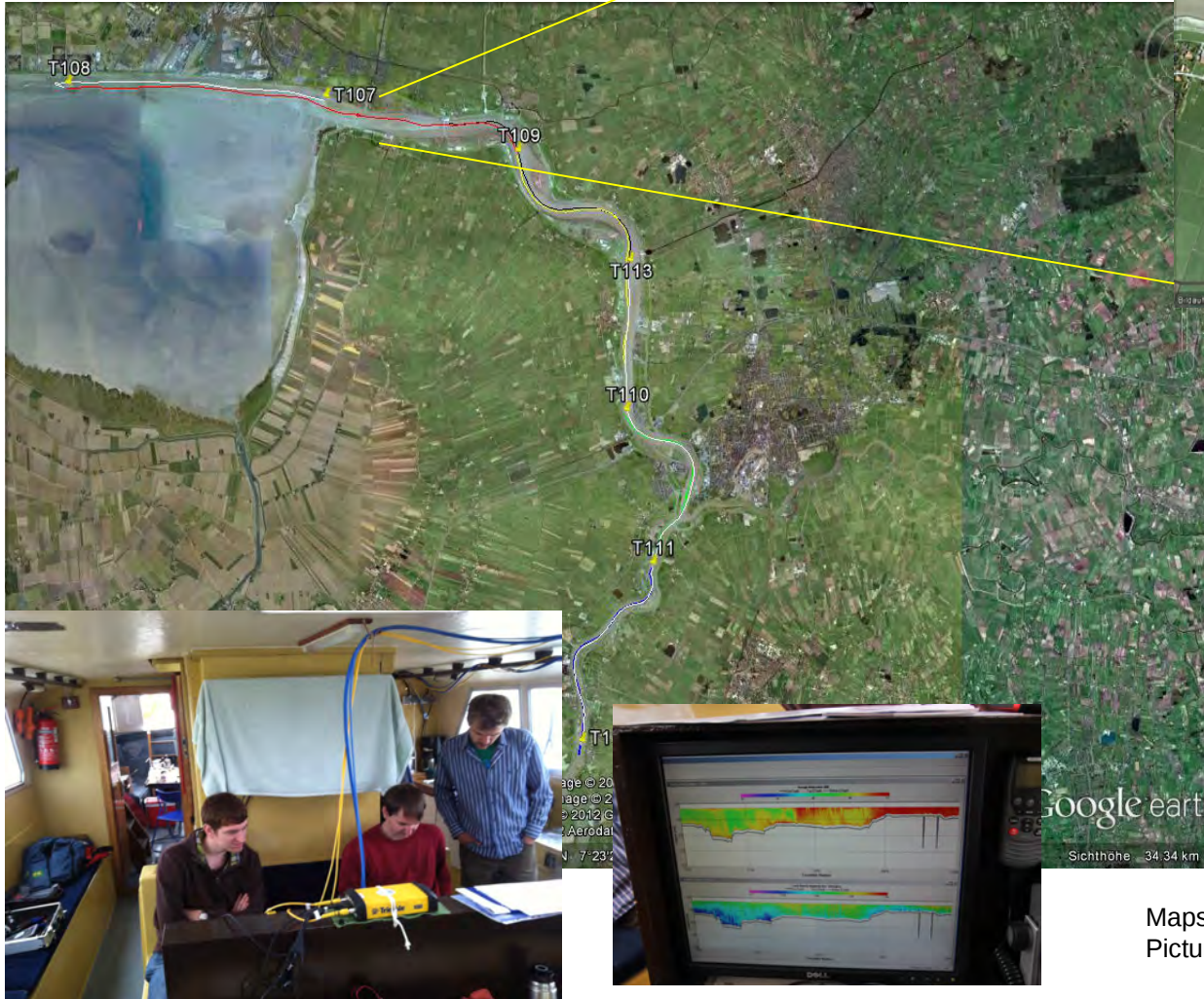


- Unstructured numerical model SELFE
- 70-90k nodes, 25 sigma layers, time step 80-100s
- Boundary conditions: vertical and horizontal tides, salinity and temperature from an operational forecast model (myocean based on NEMO)
- Atmospheric forcing (DWD data), river inflow at the tidal weir at Herbrum



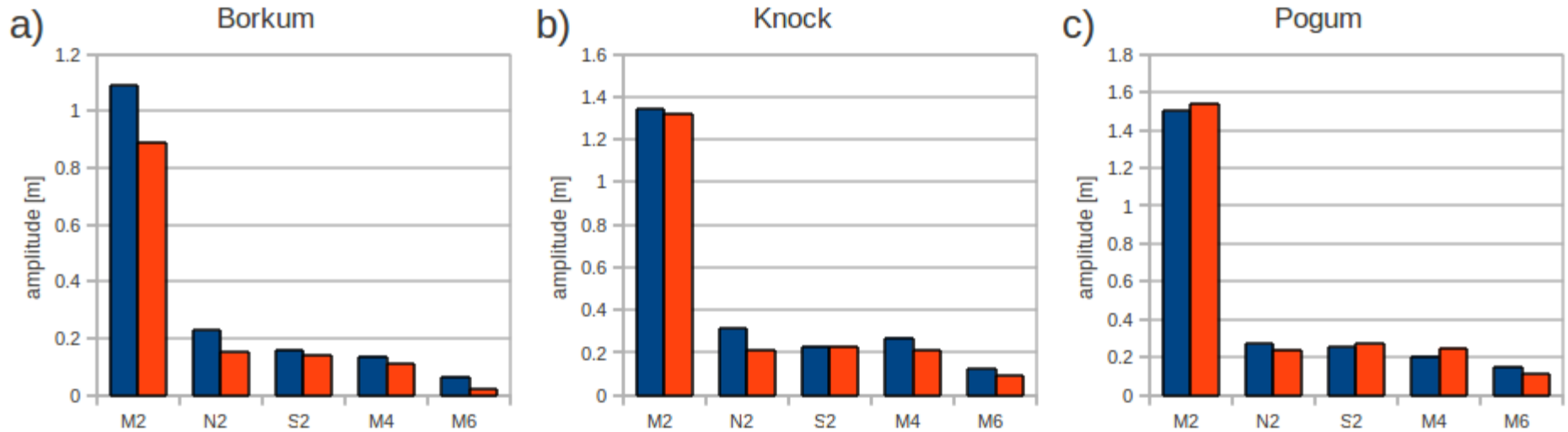
Measuring campaigns in Ems river with research boat *Otzum*

Sampling of ADCP, CTD, Ferrybox
data, collecting samples of SPM...

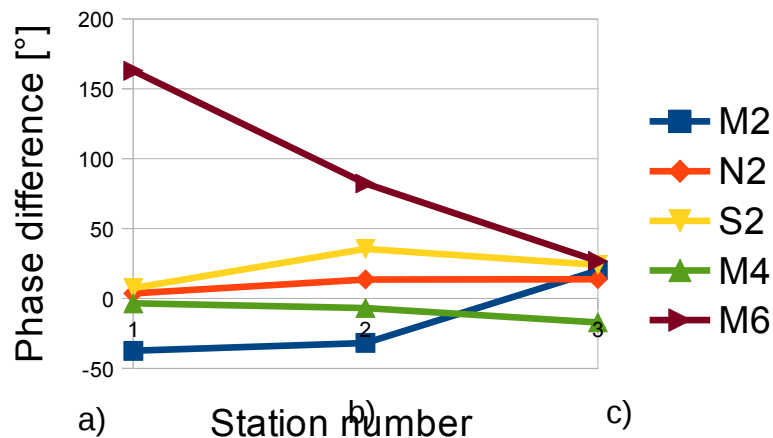


Maps: Transect Emden-Papenburg, cross transect near Pogum (Google).
Pictures: on board, backscatter monitor, *Otzum*

Harmonical analysis of vertical tides



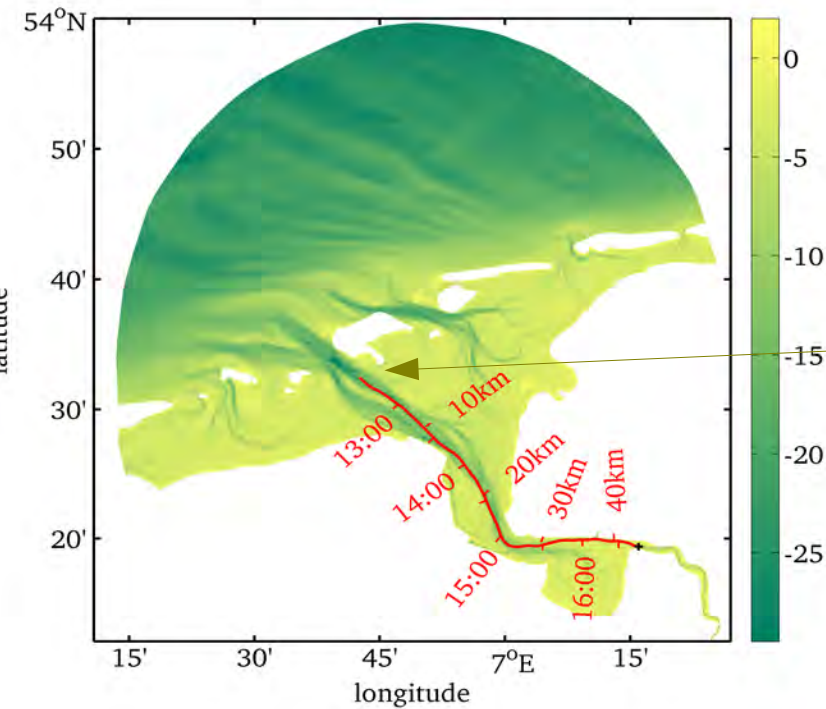
Data from www.pegelonline.wsv.de



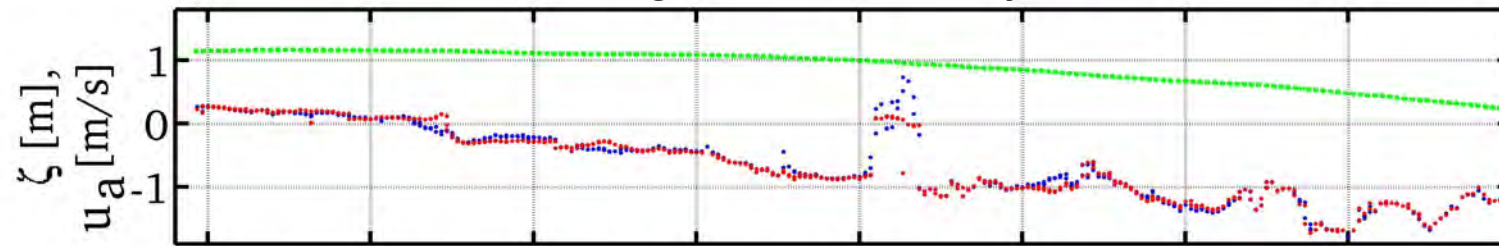
- M2, N2, S2 dominant tidal components
- increase of tidal range
- simulation improves towards the head of the estuary

Validation of horizontal surface velocity ADCP observations *MS Otzum* June 2012

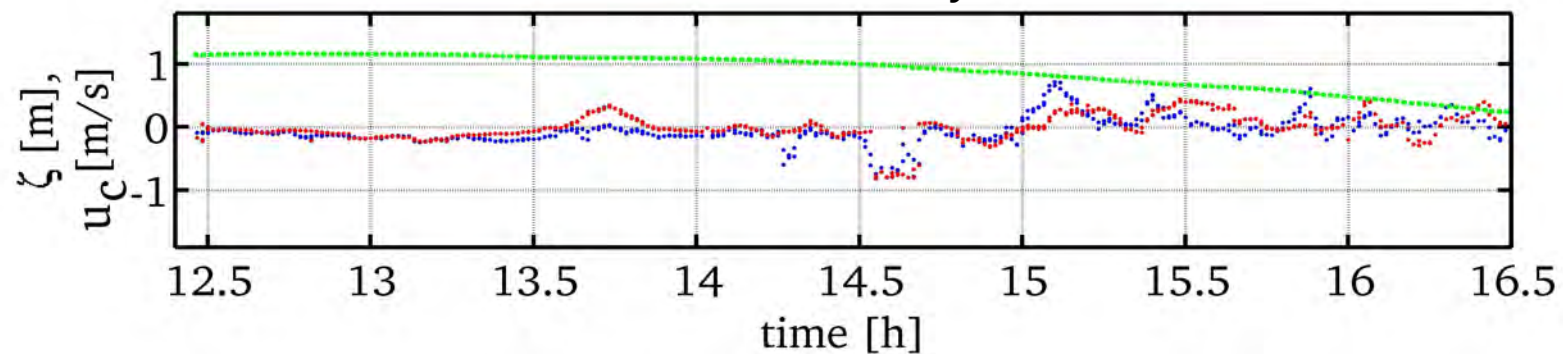
The survey started at Borkum, the ship heading towards the falling tide.

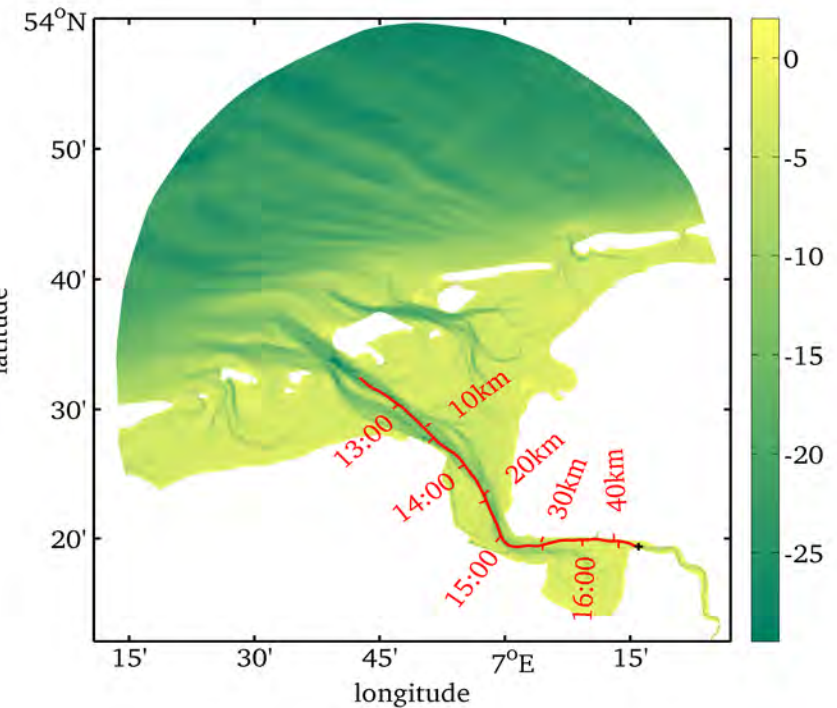


Along-channel velocity

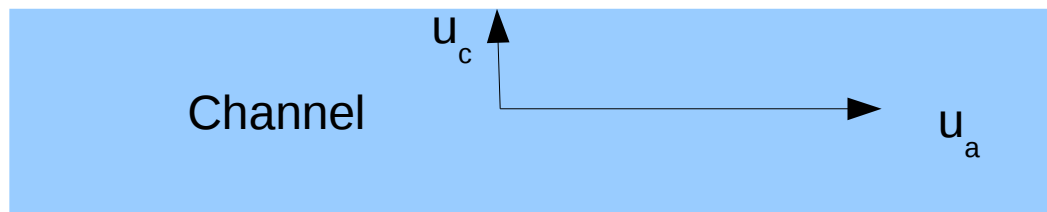


Lateral velocity

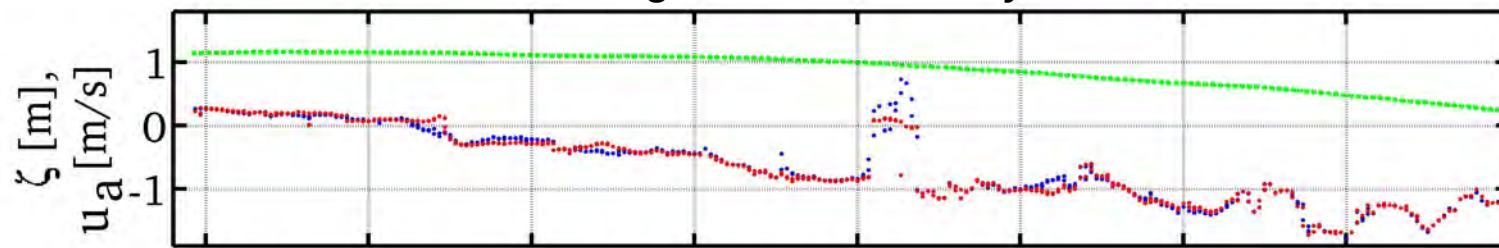




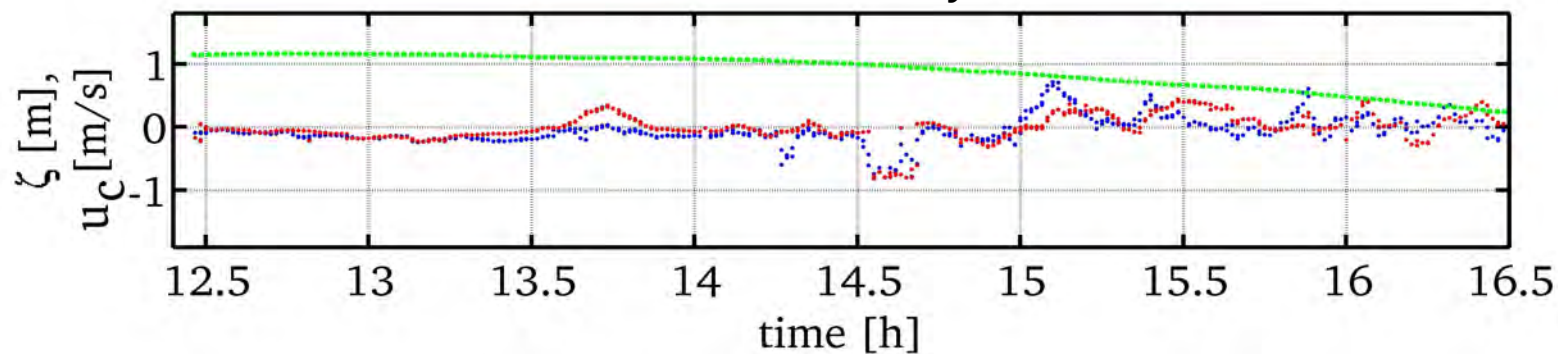
Validation of horizontal surface velocity ADCP observations *MS Otzum* June 2012



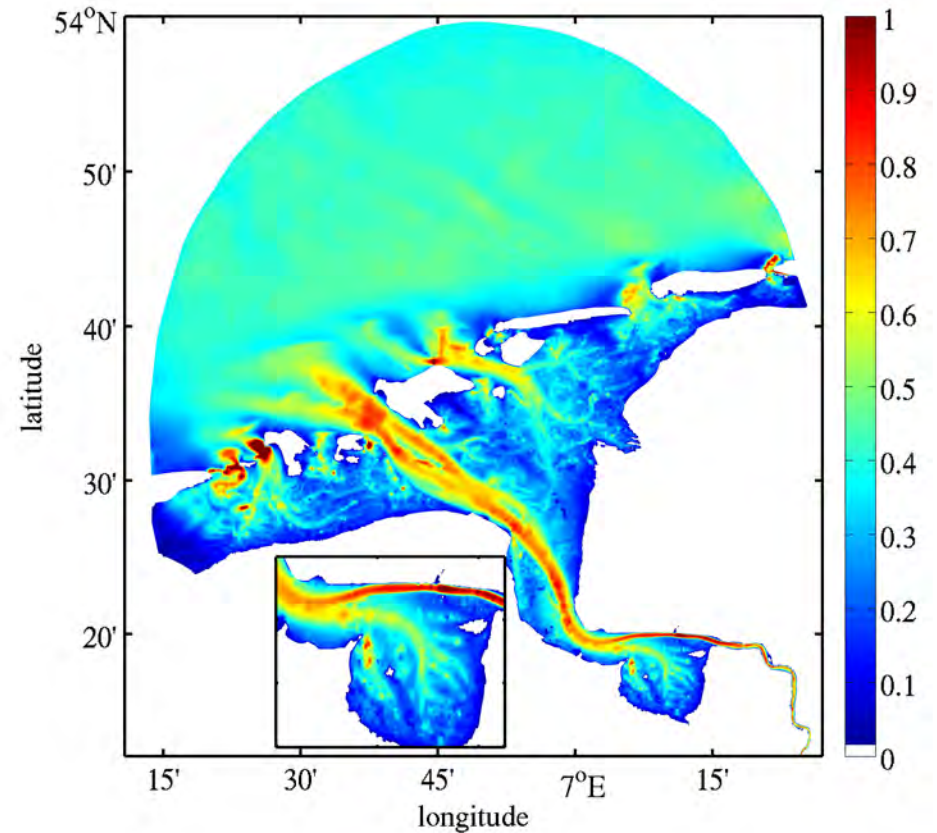
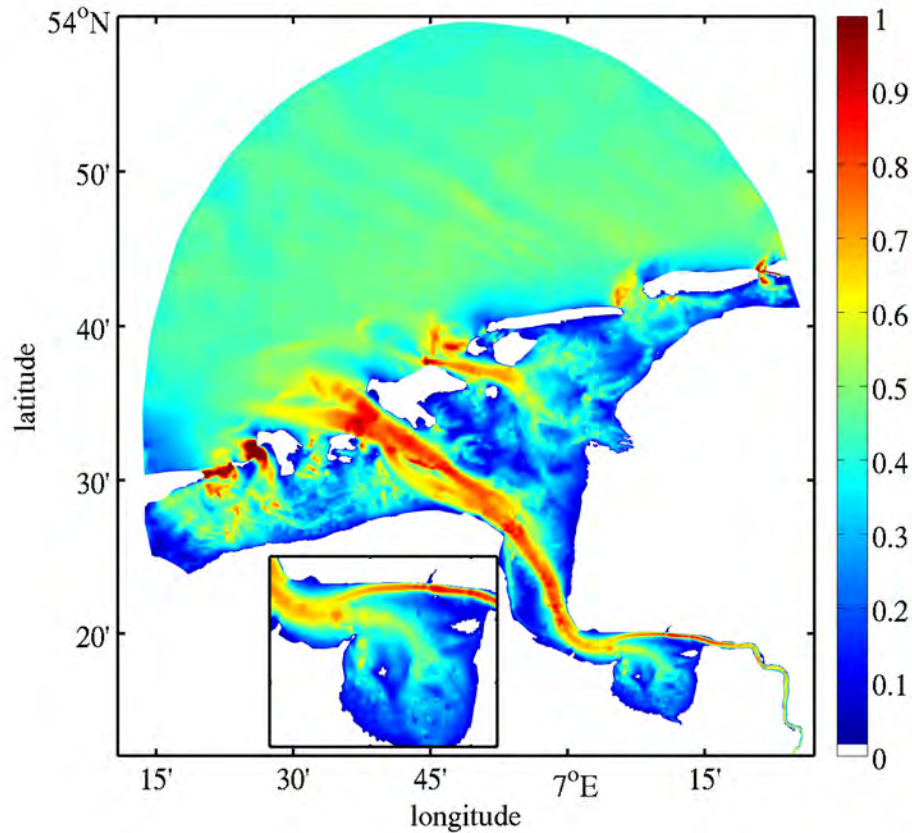
Along-channel velocity



Lateral velocity



Average flood and ebb velocity magnitude [m/s]

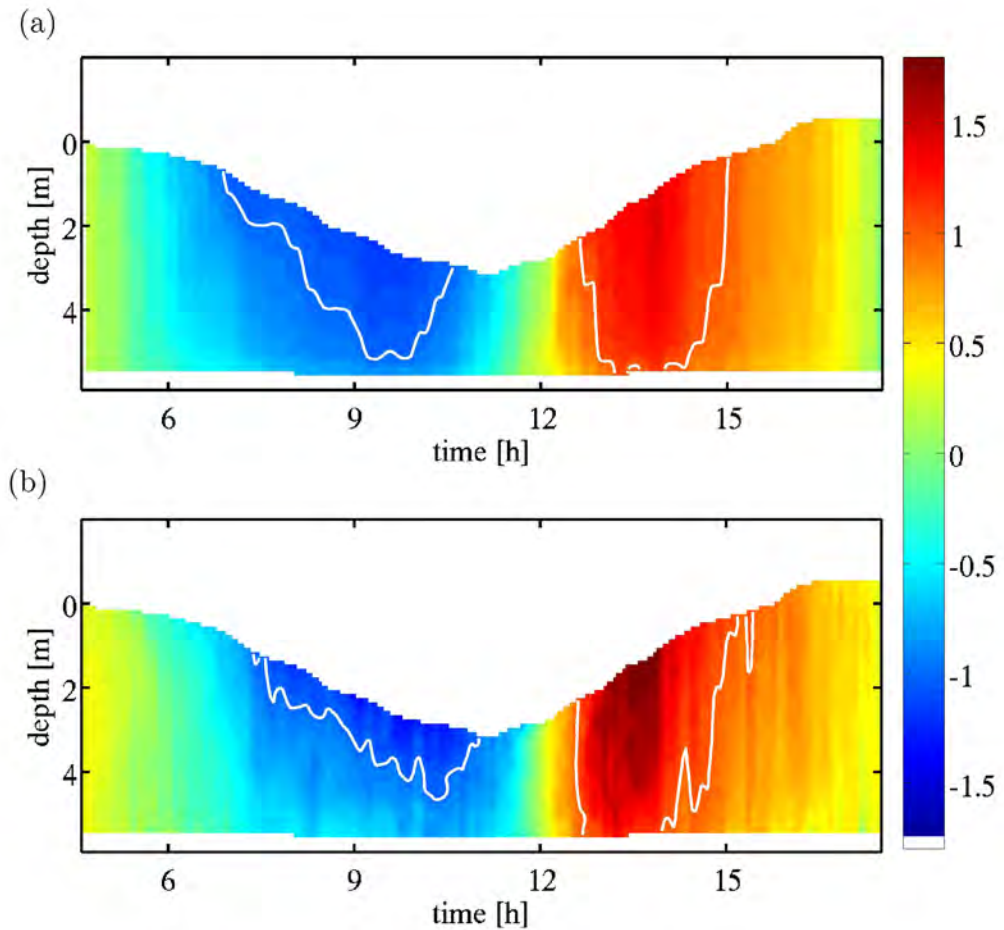


Vertical structure of along-channel flow

- 12 h of transect ADCP data
- data sampled in the middle of the channel
- **Flood**: strong mixing
- **Ebb**: Increased shear, surface intensified Jet



u [m/s]: Model, observations



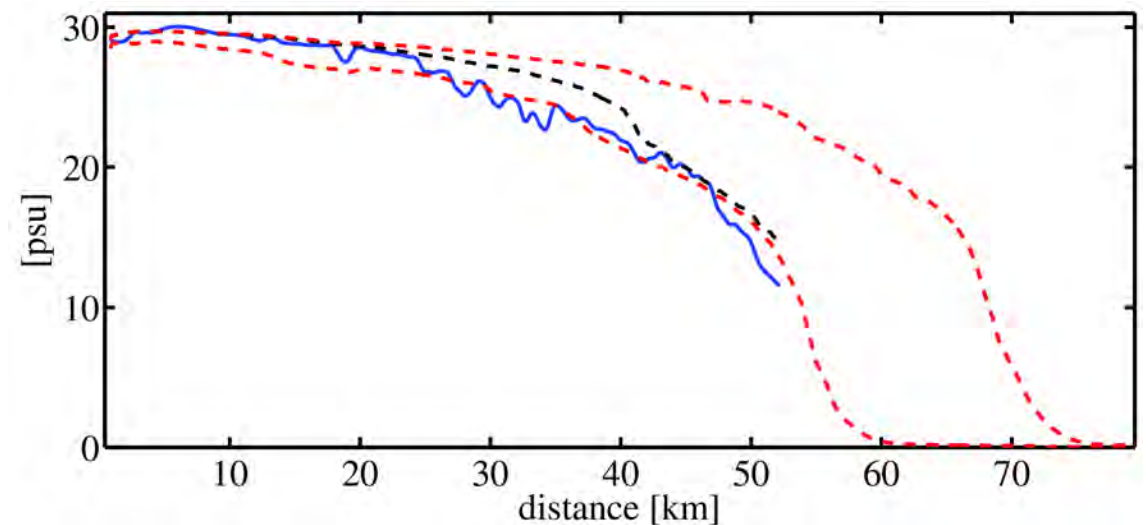
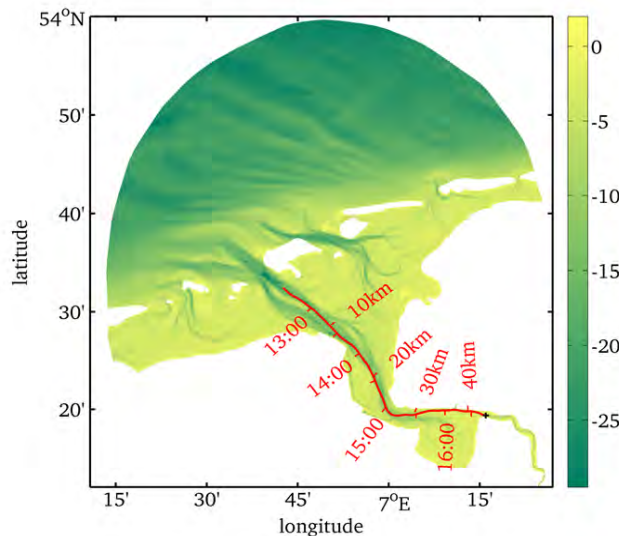
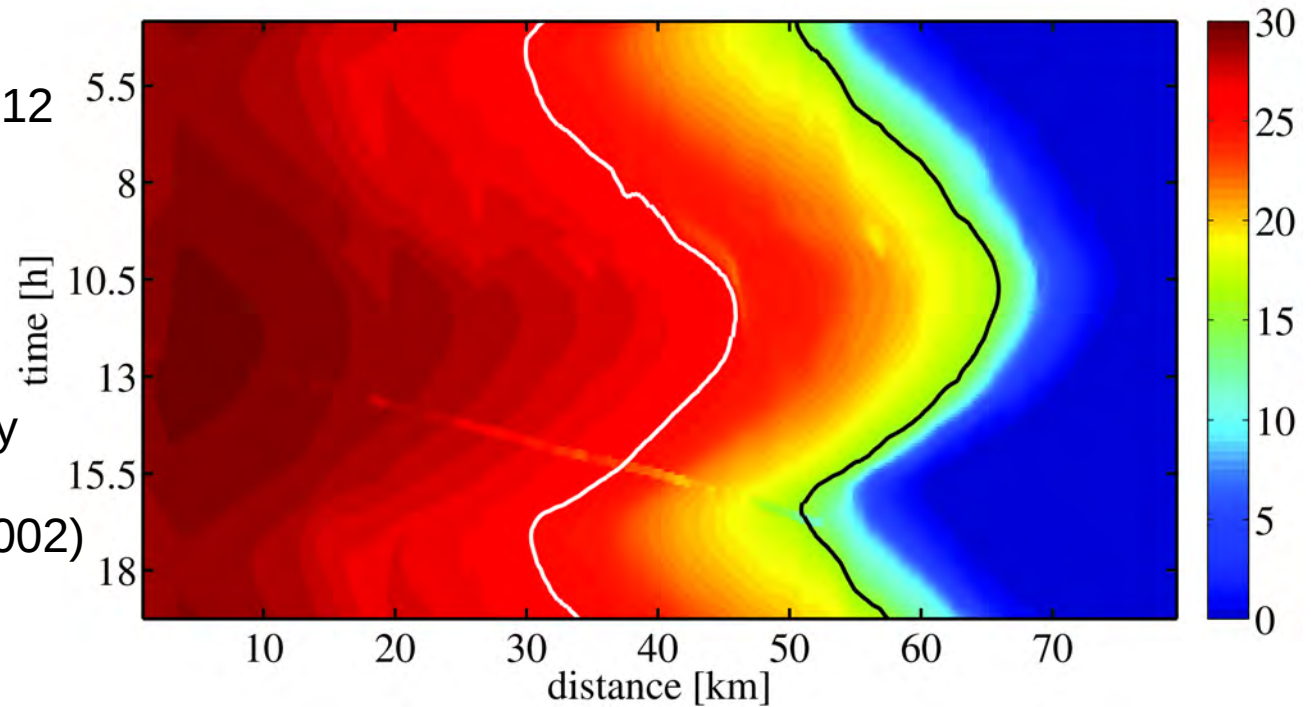
CTD observations and the salinity front

- observations of sea surface salinity (SSS), *MS Otzum*, June 2012

- salinity transect projected onto the plane spanned by along-channel distance and time

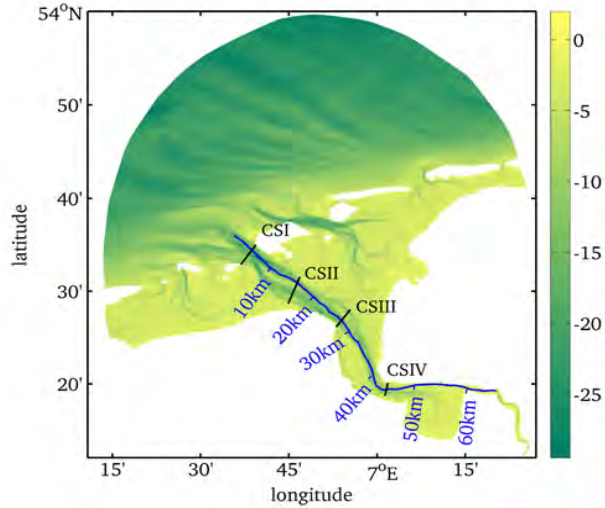
- proper simulation of SSS critically depends on correct presentation of stratification (Monismith et al. 2002)

- frontal region in Ems Estuary between km 30 and 55; tidal excursion ~ 15 km.

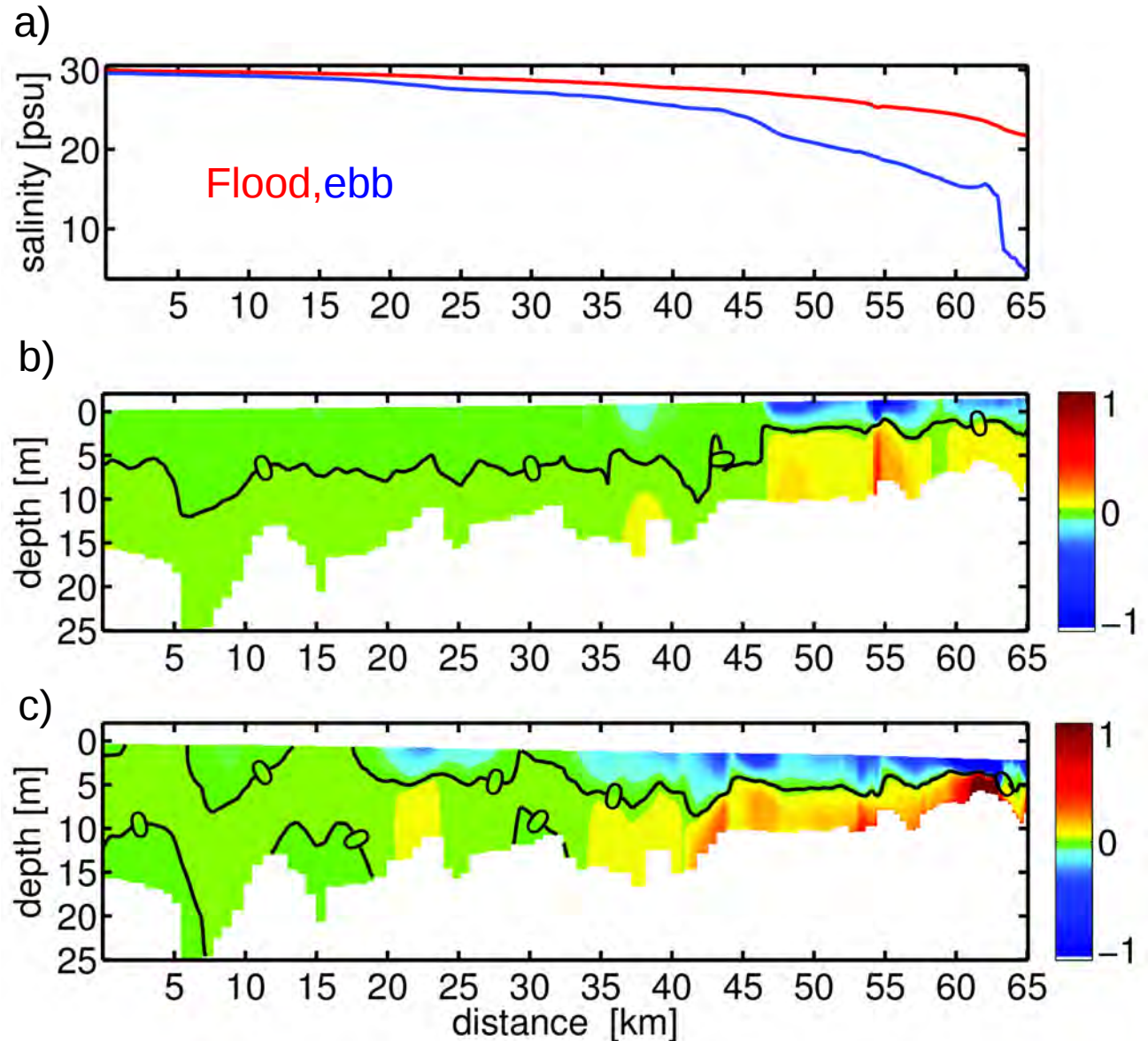


Salinity: Longitudinal and vertical gradients

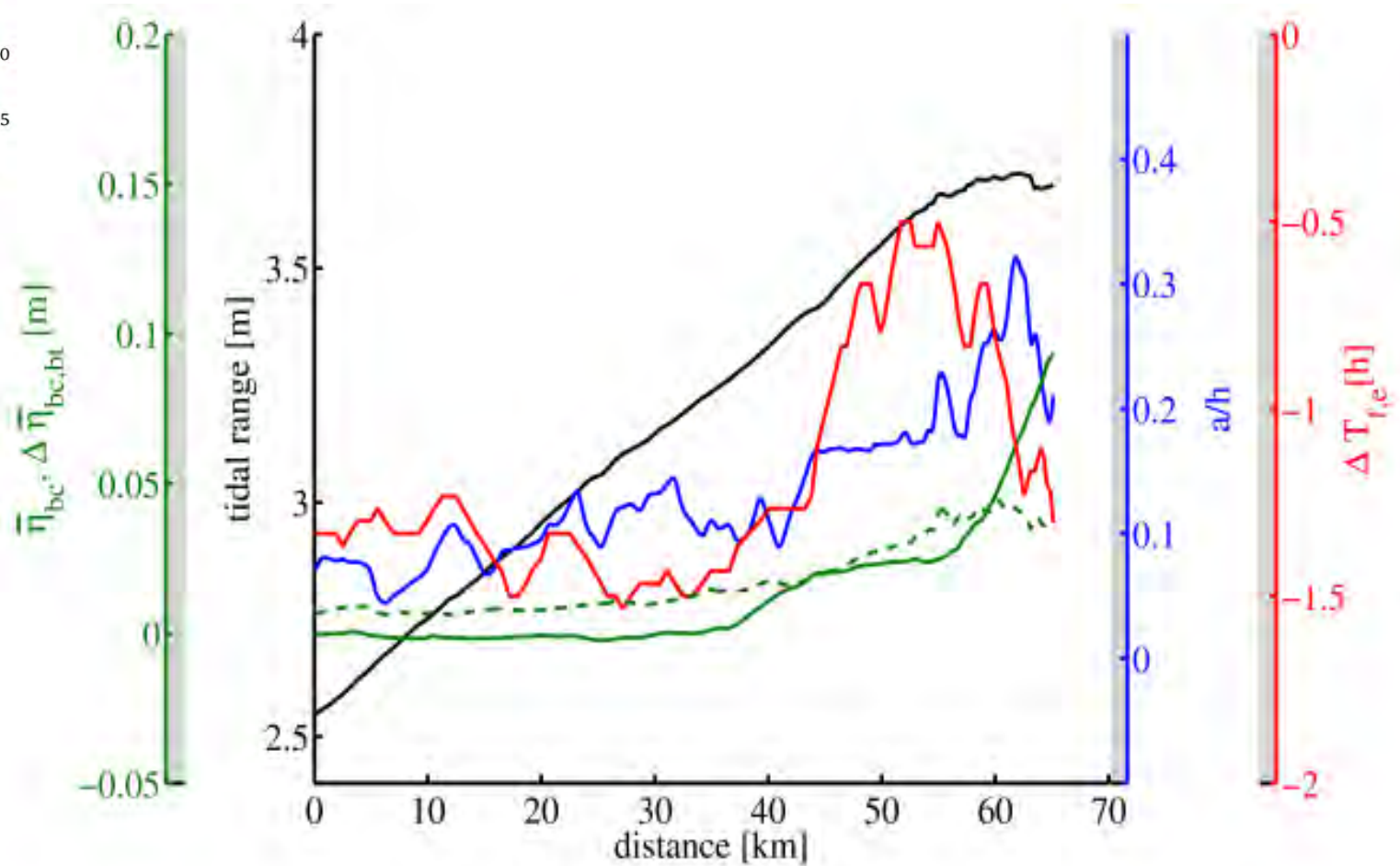
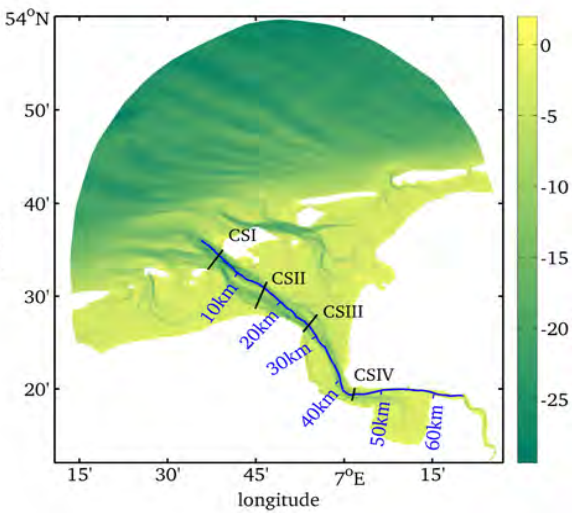
Simulated vertically averaged salinity (a) along main-channel transect. Anomalies from the vertical mean [psu] are given for (b) **flood** and (c) **ebb**.



Advection of buoyancy induces stratification!

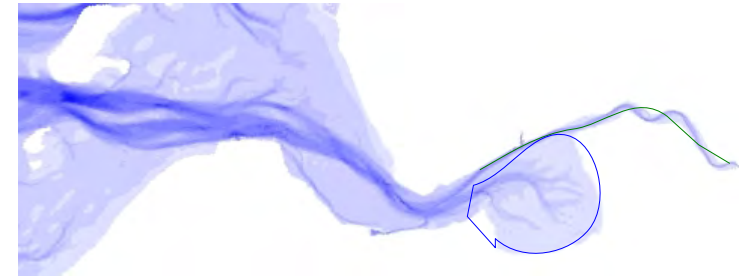
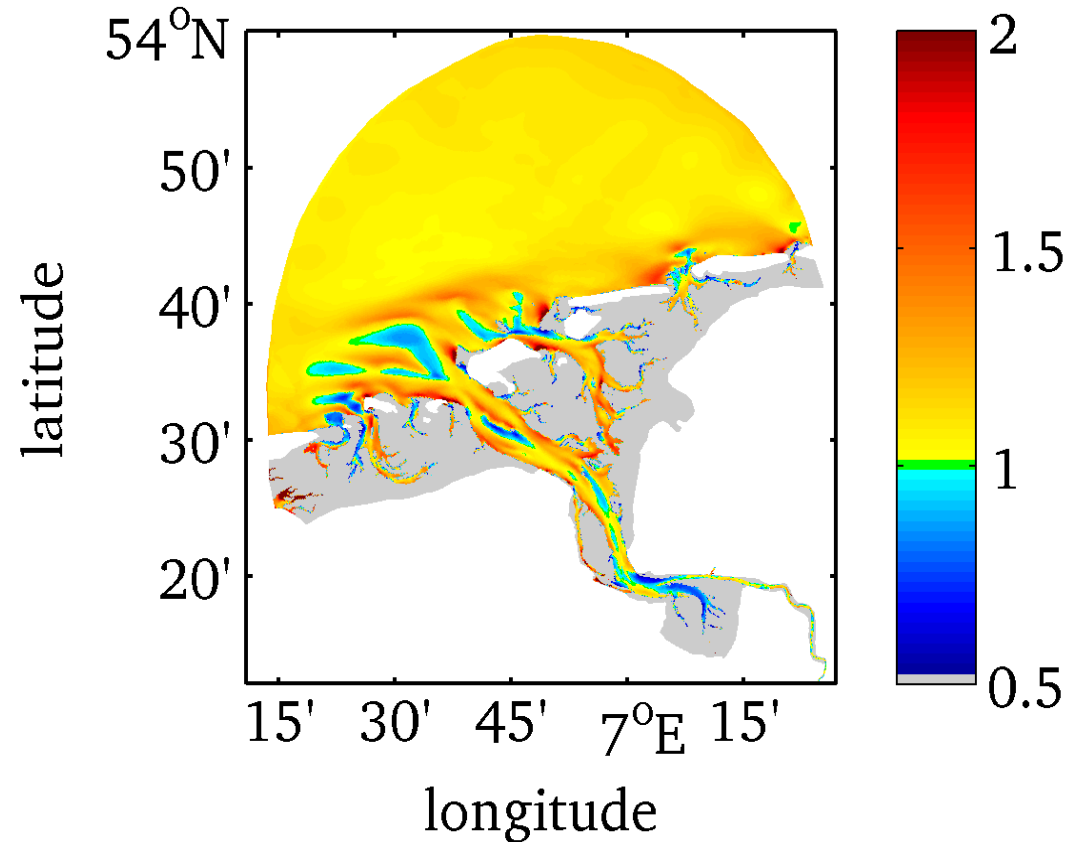


Tidal characteristics along the main channel

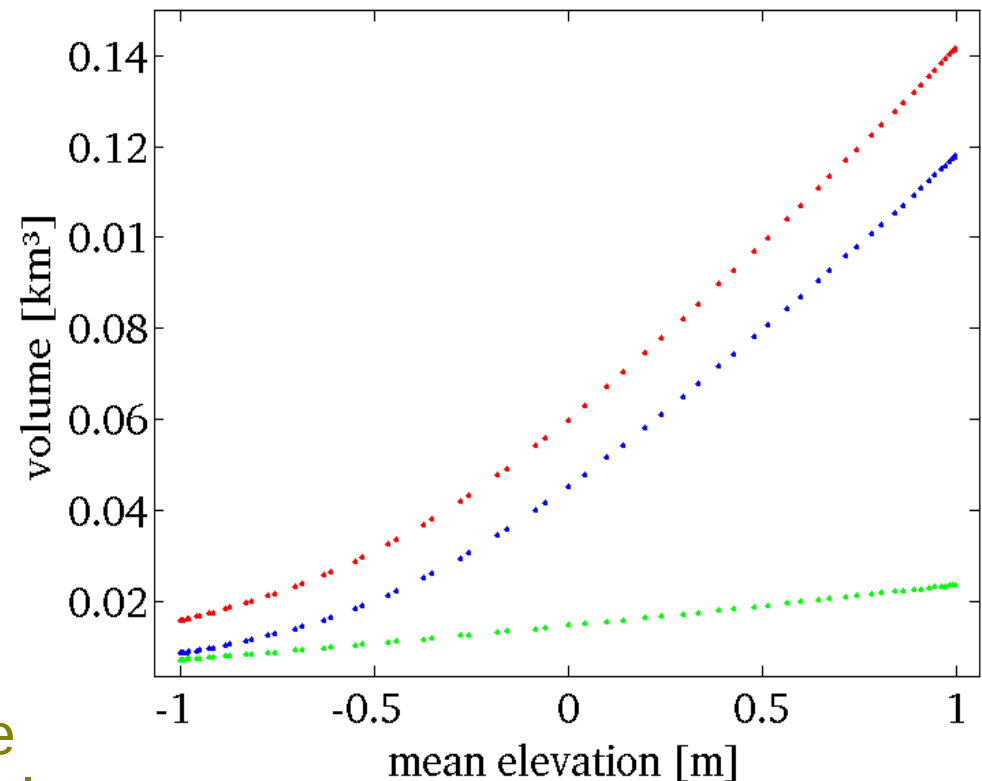


Tidal range [m] increases towards head of estuary.
Baroclinicity contributes to tidally-averaged water level [m].
Tidal duration asymmetry [h] reduces at Dollart Bay.

Tidal current asymmetry and inter-tidal storage area



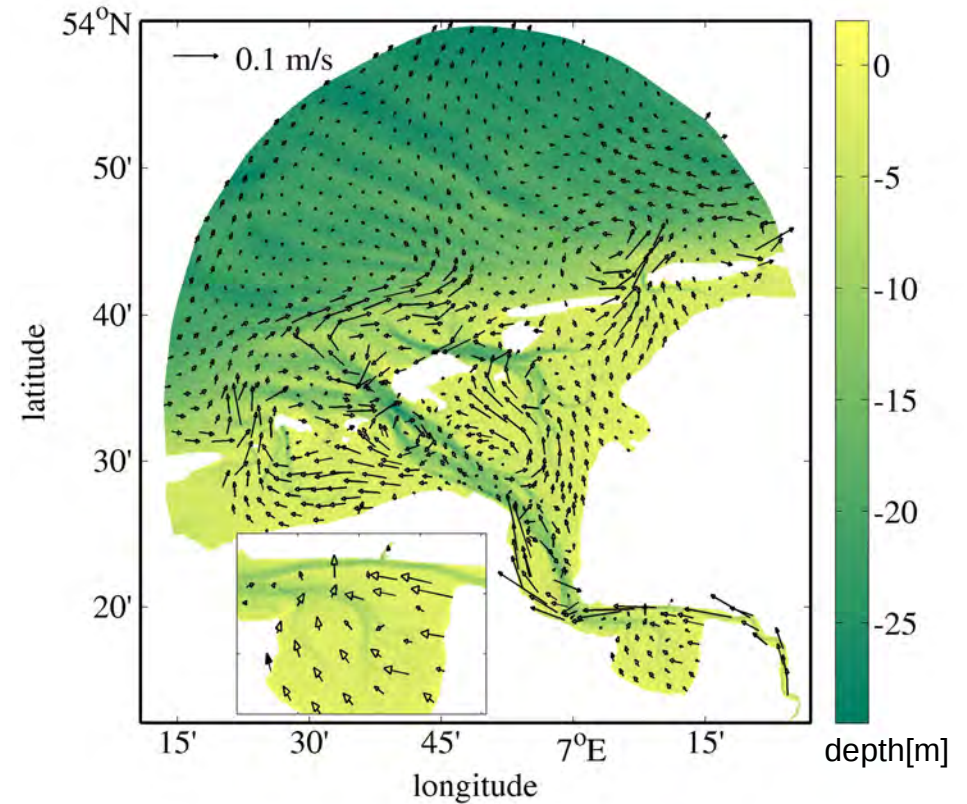
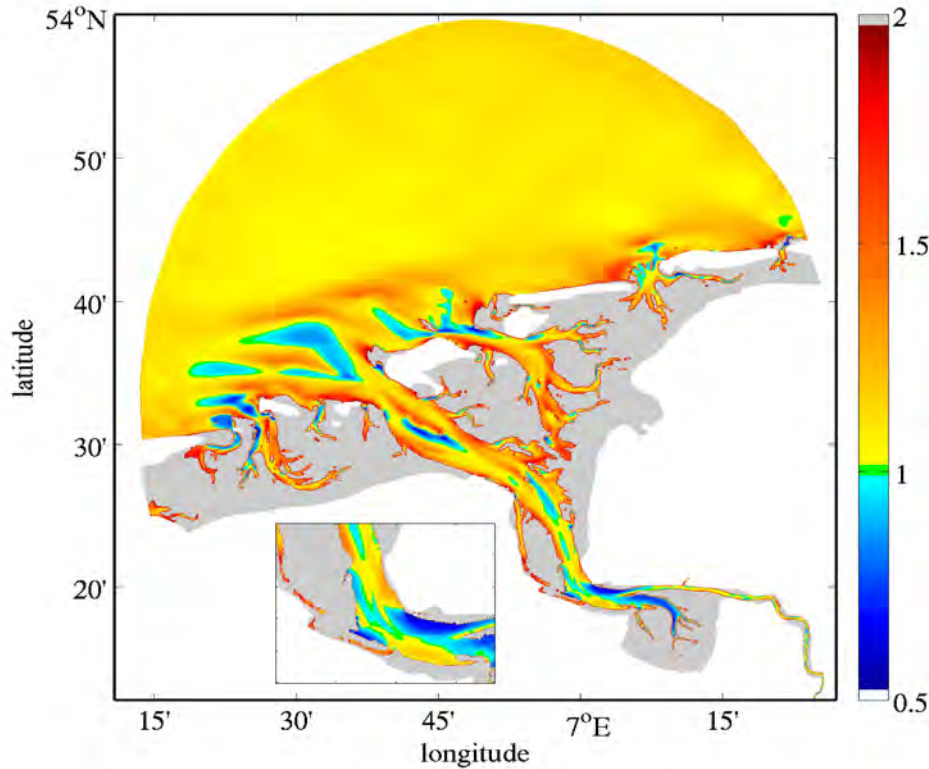
basin volumetrics



The tidal pumping of sediments requires a **flood-dominant tide**.

Ebb-dominant conditions establish if there is sufficient inter-tidal storage area available.

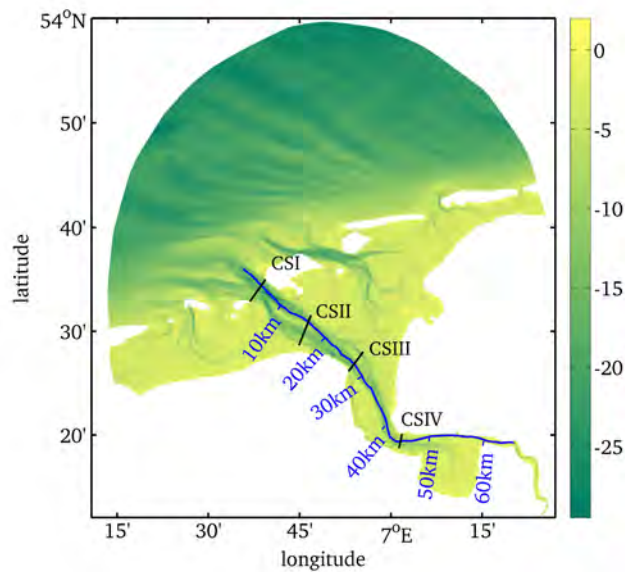
Tidal current asymmetry and residual flow



$$\sqrt{u_{max,f}^2 + v_{max,f}^2} / \sqrt{u_{max,e}^2 + v_{max,e}^2}$$

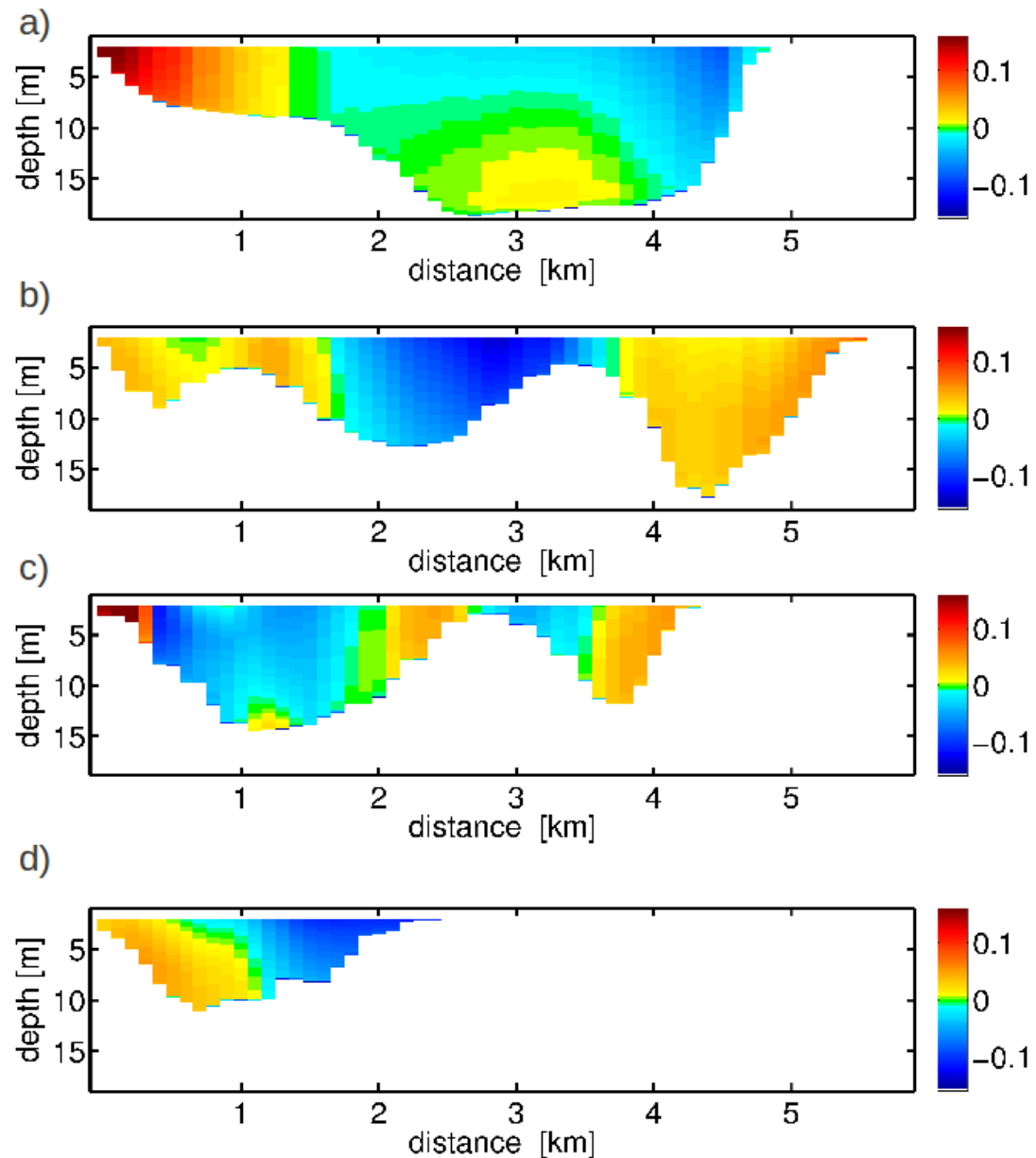
$$\bar{U}(x, y) = \frac{1}{T} \int_{t=0}^{t=T} U(t) dt$$

The 3D model basically reproduces earlier 2D-modeling results (Van de Kreeke & Robaczewska, 1993) as well as observations (de Jonge, 1992).

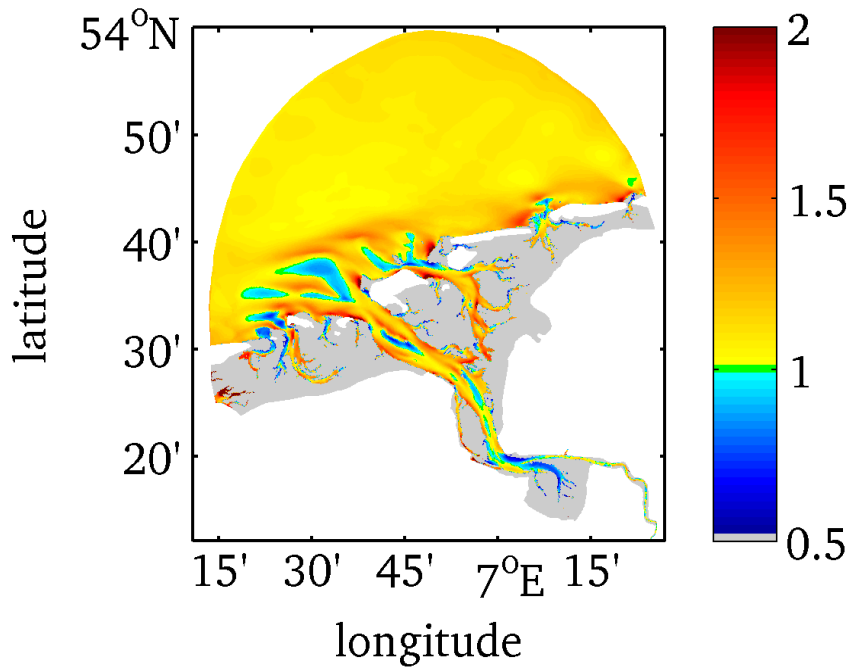


- the cross-sectional pattern of residual flow reveals the dominating physics in the region (cf. Valle-Levinson et al. 2003):
- a laterally sheared pattern emerges if barotropic processes are dominant
- diagonally or vertically structured pattern indicate an influence of density differences (baroclinicity) on the flow regime

Along-channel residual flow

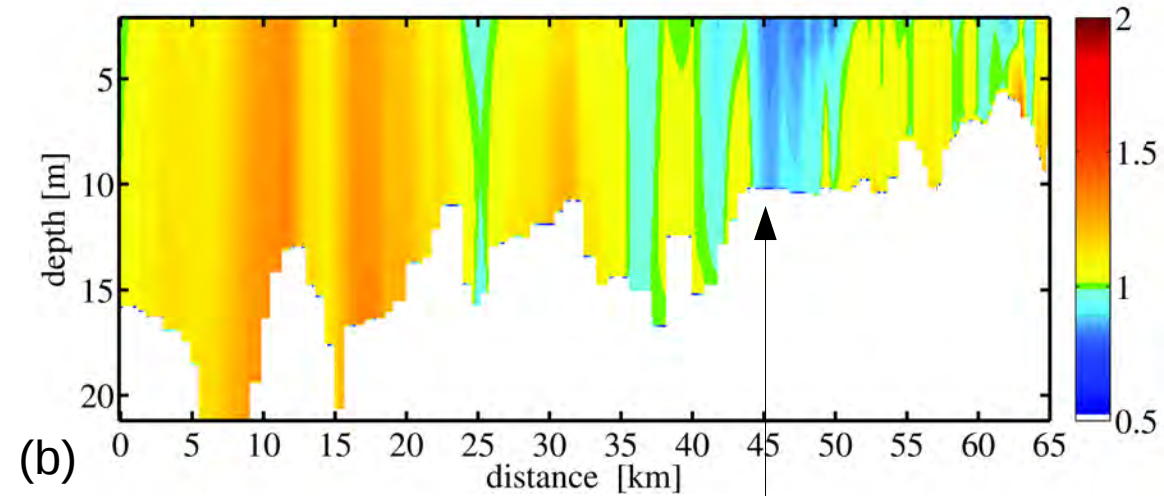
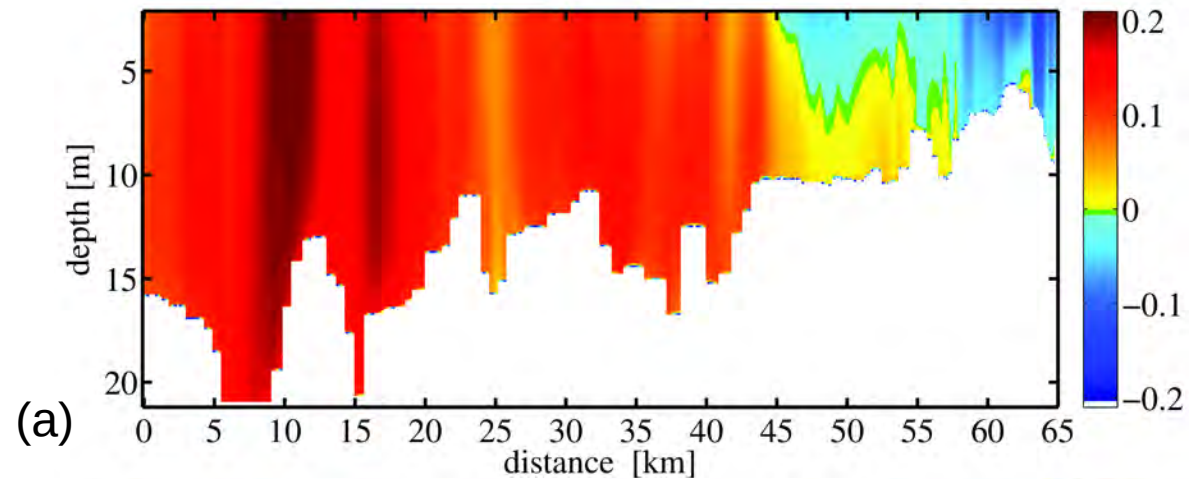


Across-channel profiles of along-channel residual flow [m/s] in CS I-IV (a-d)



In the region of Knock, the typical estuarine circulation emerges, with residual **inflow** at the sea floor, and residual **outflow** at the sea surface.

(a) residual (i.e. tidally-averaged) along-channel flow
(b) tidal current asymmetry

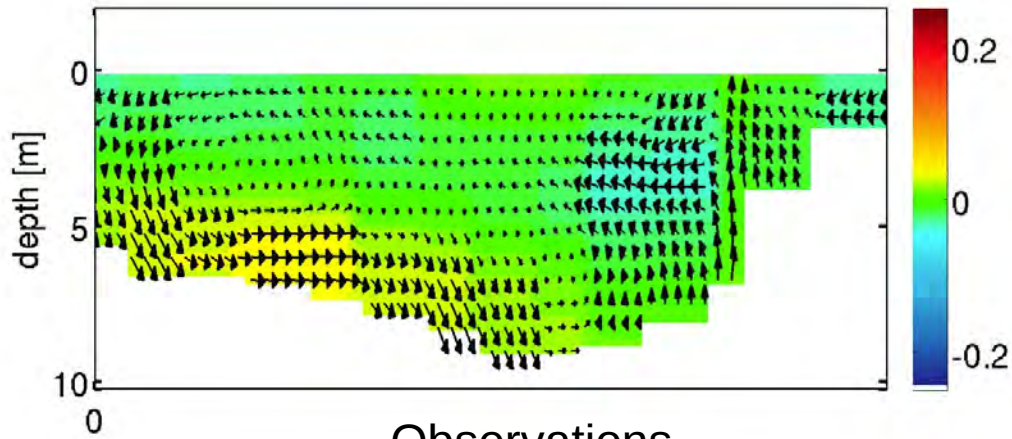


Knock

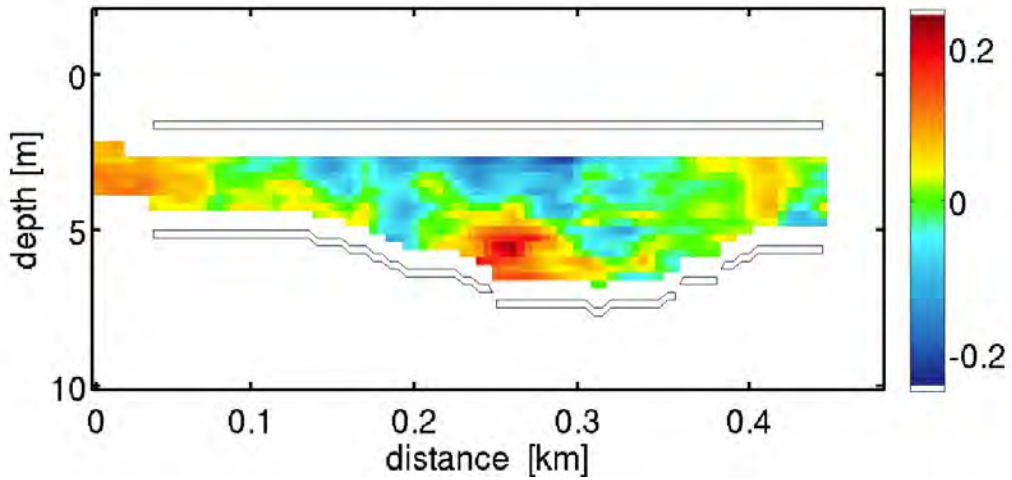
Secondary circulation in the tidal river

ADCP observations of v [m/s] and model results

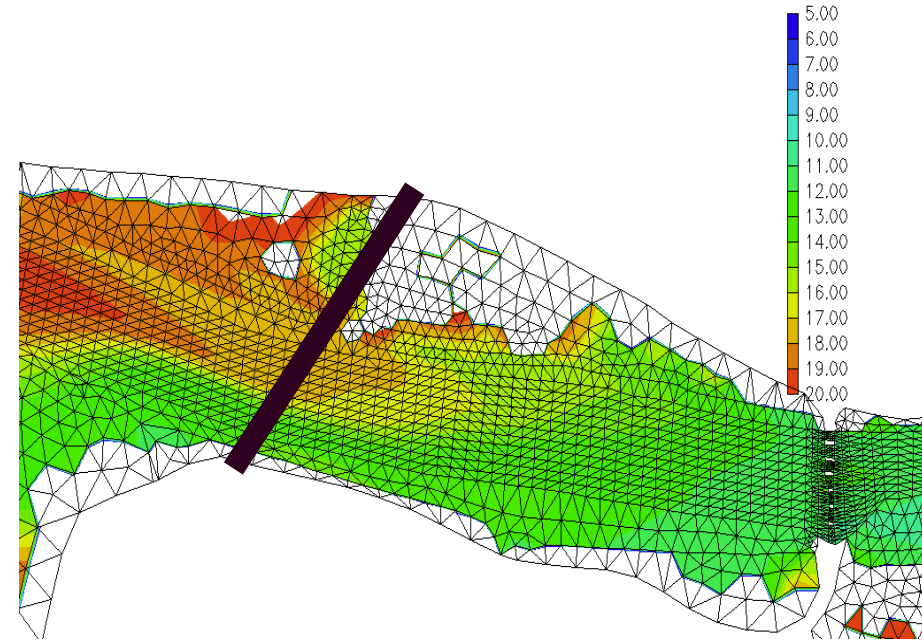
Model results



Observations



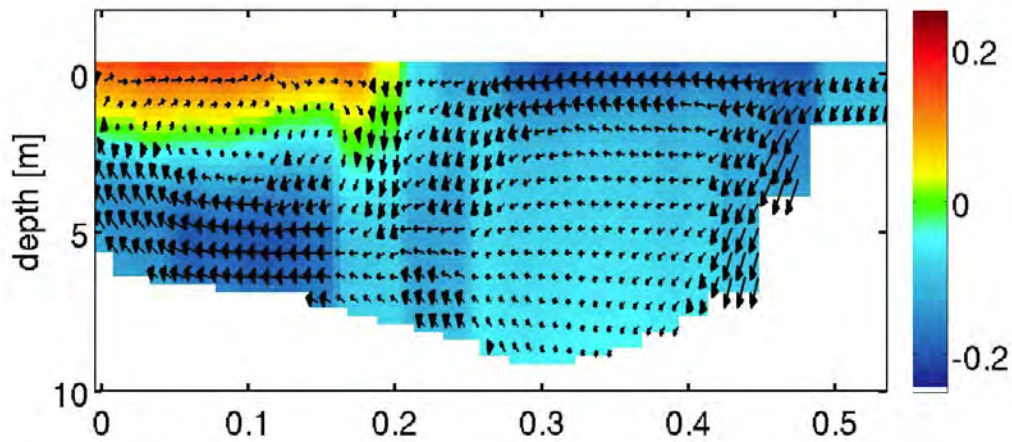
[psu]



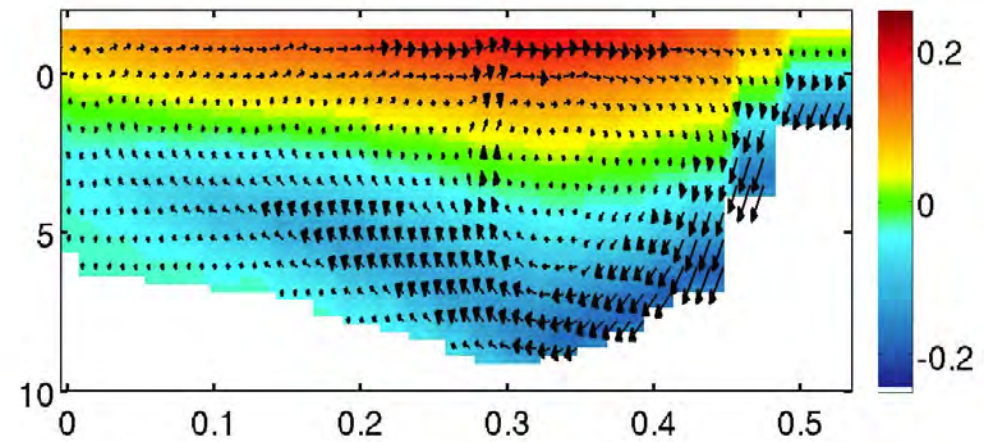
Secondary circulation – lateral velocity field

v [m/s]

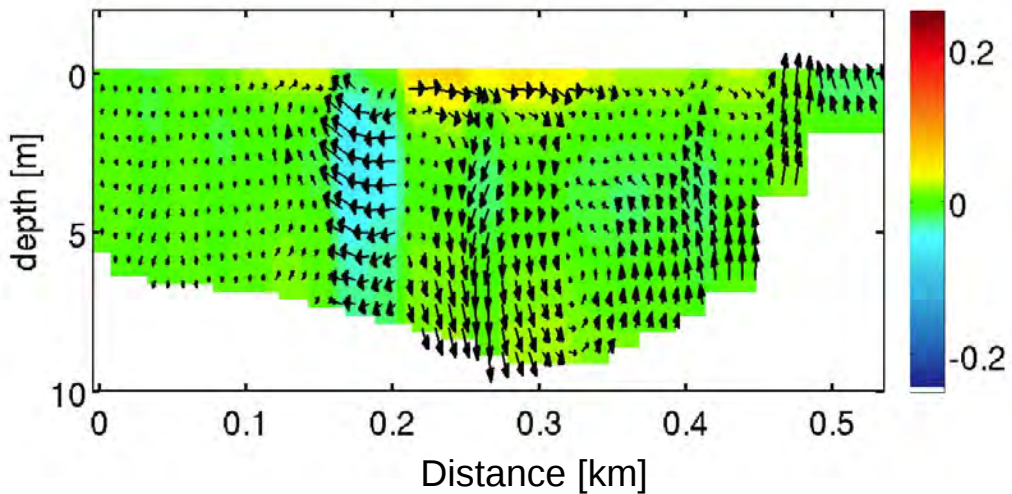
Flood



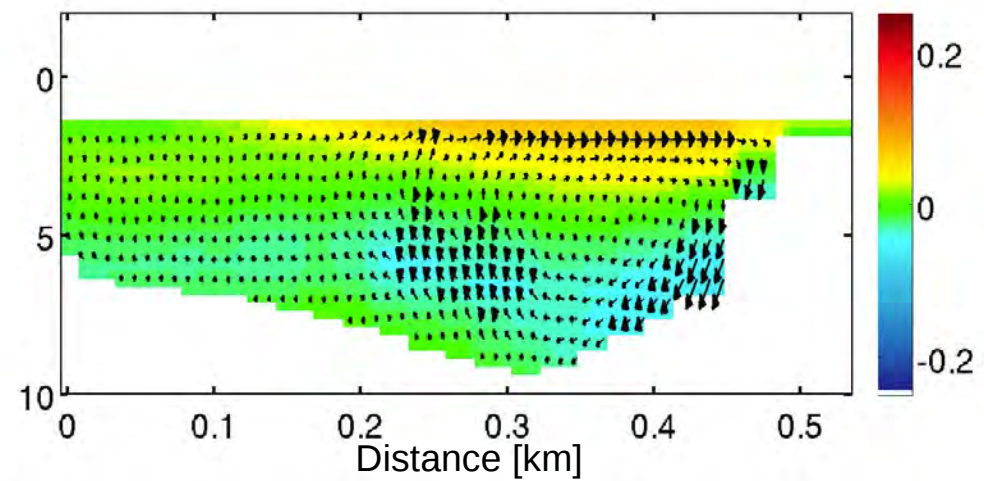
High water



Ebb

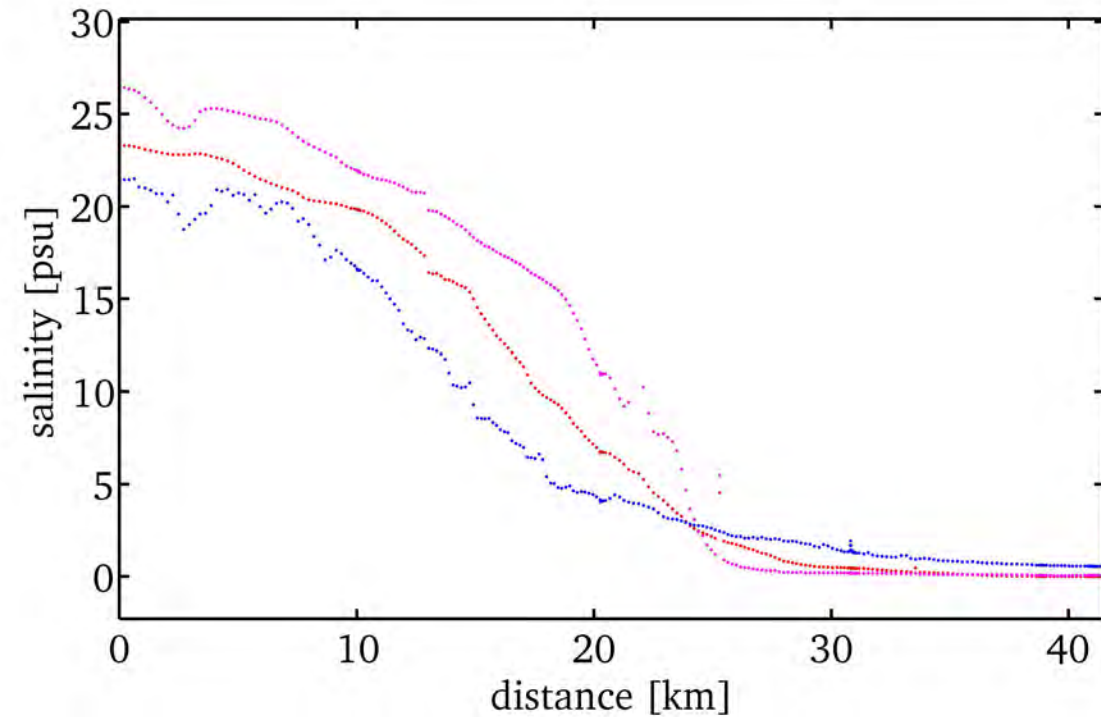


Low water



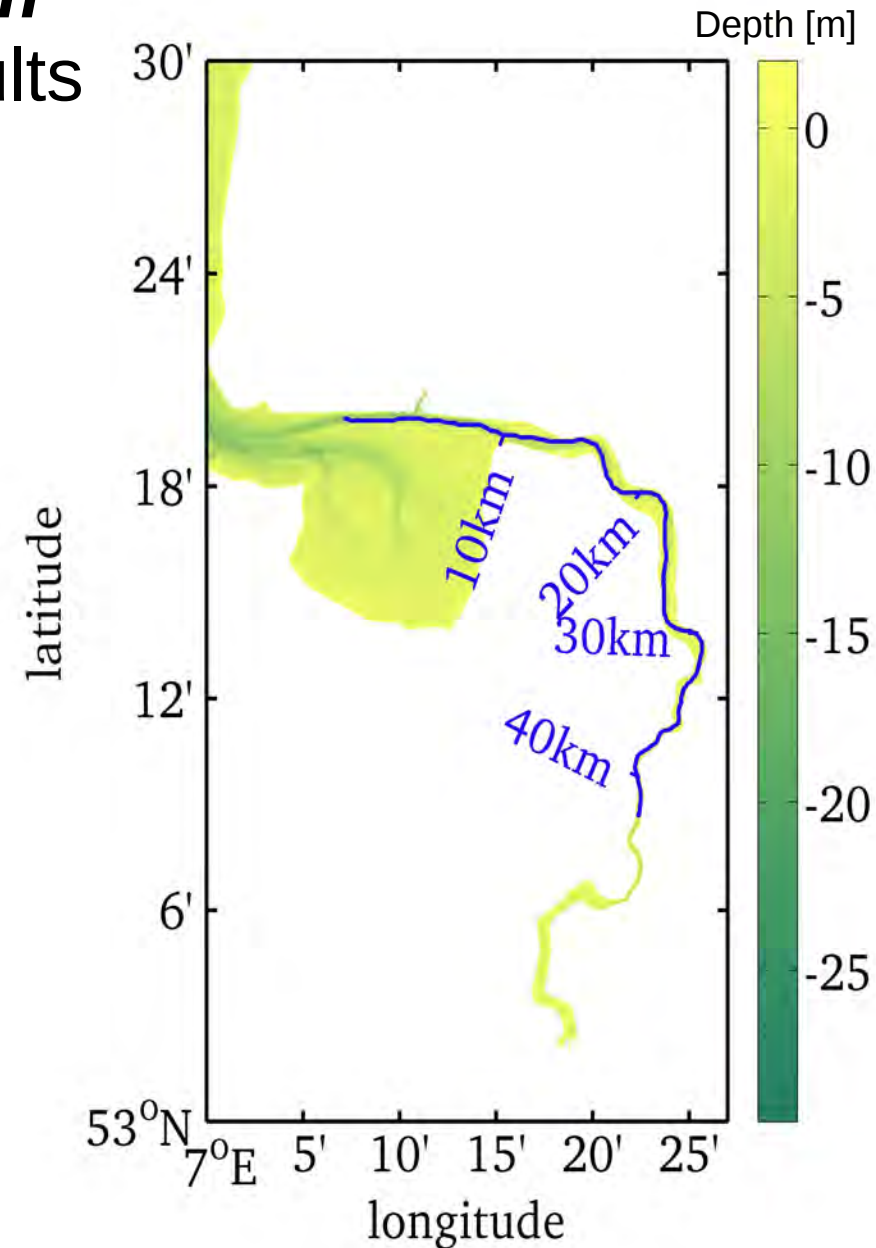
Ship survey, Jun 2012 *MS Otzum*

CTD observations and model results

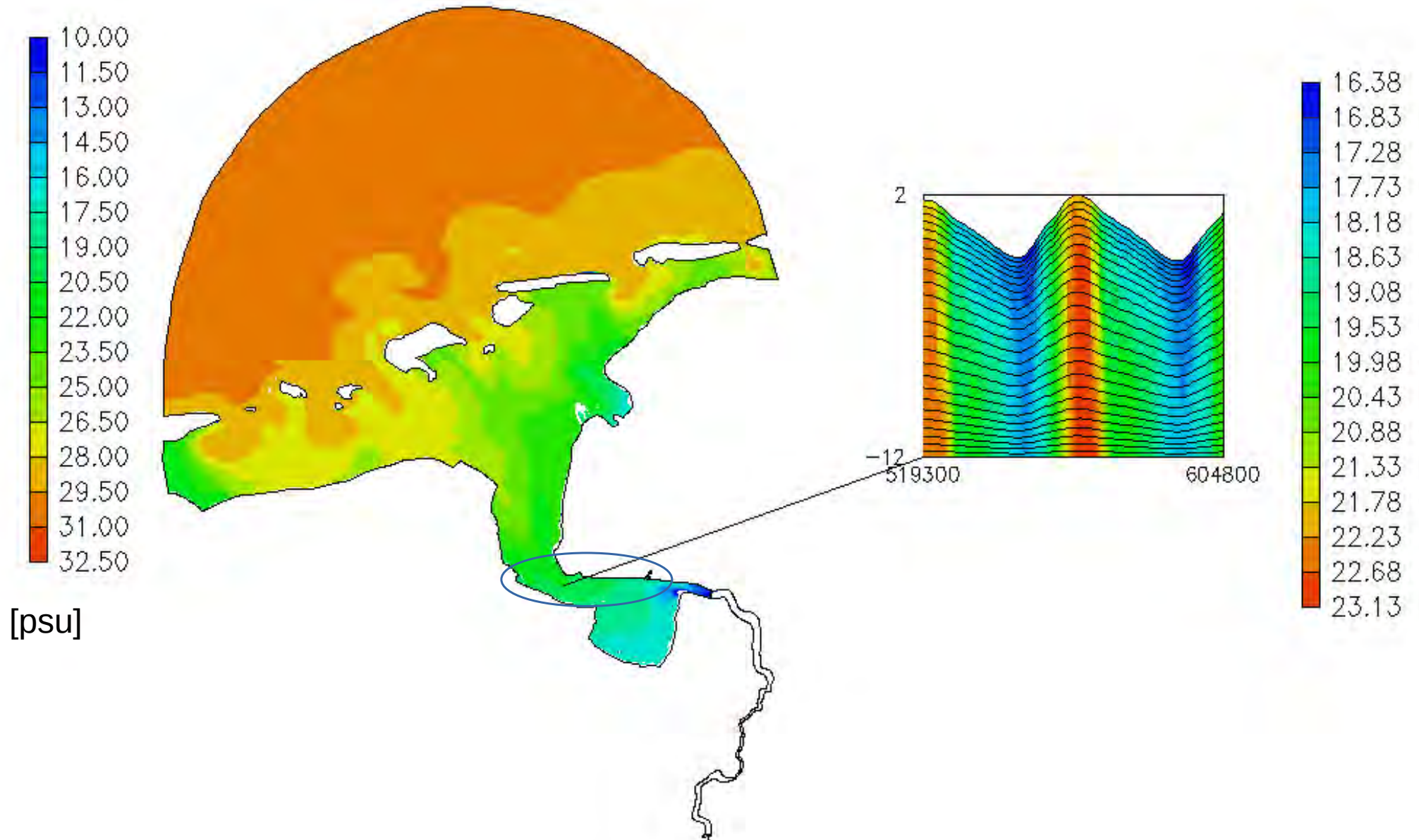


The ferrybox samples water from the sea surface.

Observations are better reproduced by the high resolution model than by the low resolution model.



Sea surface salinity and salinity stratification Ems River Plume



Ocean Dynamics (2014) 64:1719–1741

DOI 10.1007/s10236-014-0772-z

The tidal asymmetries and residual flows in Ems Estuary

Johannes Ulrich Pein · Emil Vassilev Stanev ·
Yinglong Joseph Zhang



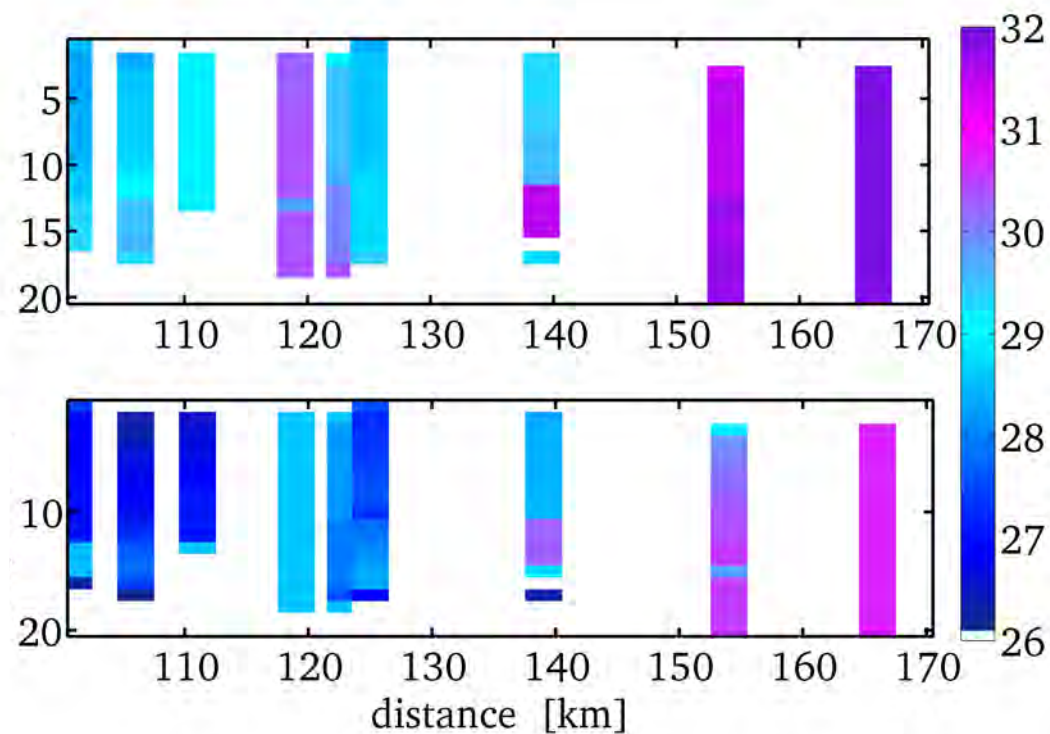
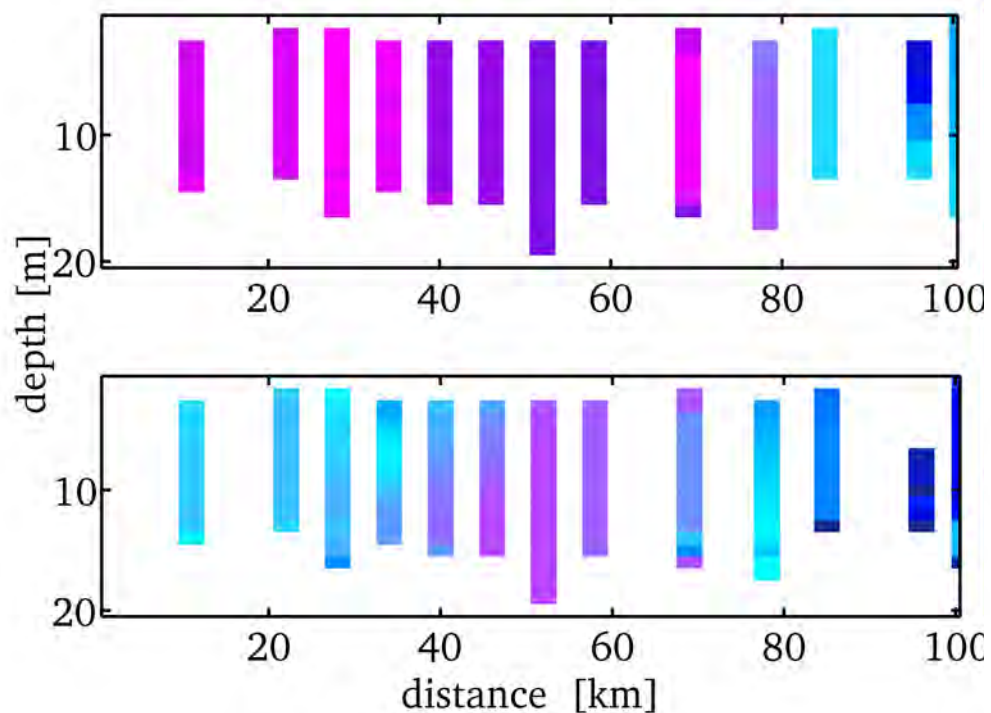
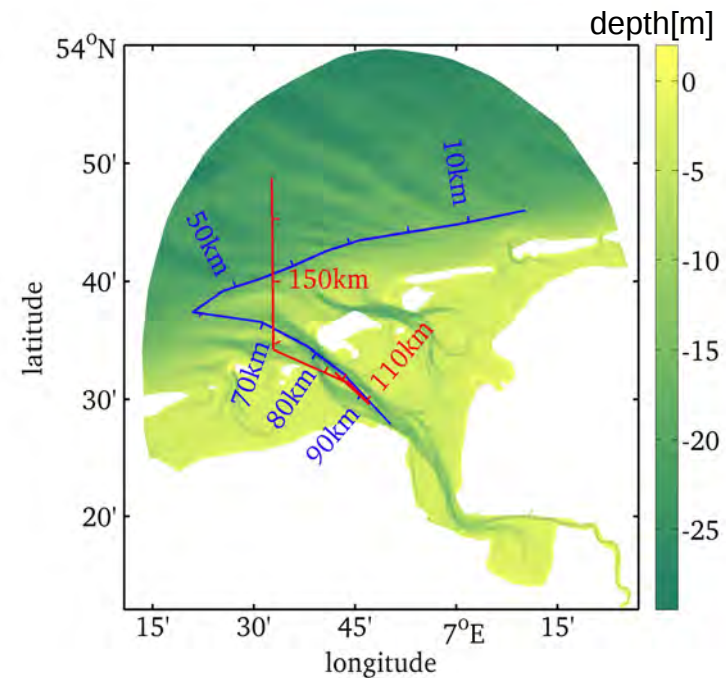
Thank you for your
attention!

Questions?



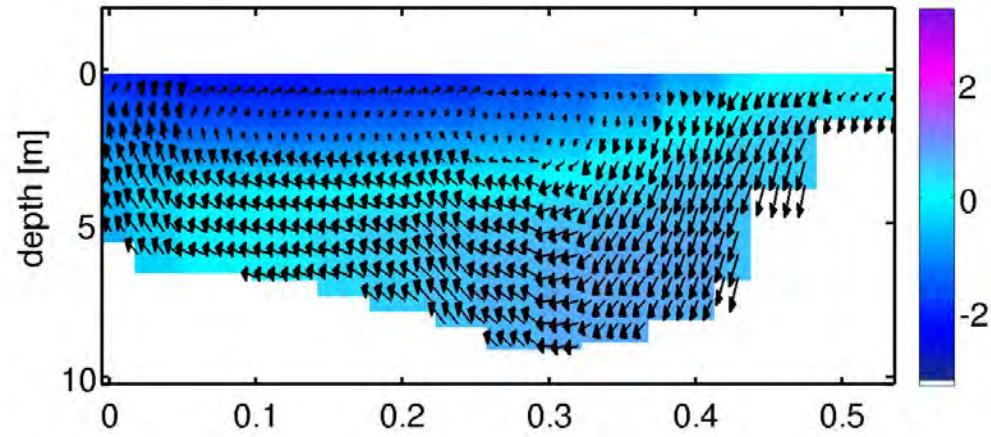
Ship survey, Oct 2013 *MS Heincke* CTD observations and model results

Top: profiles of observed salinity [psu]
Along the **blue** and **red** transect lines
Bottom: model results

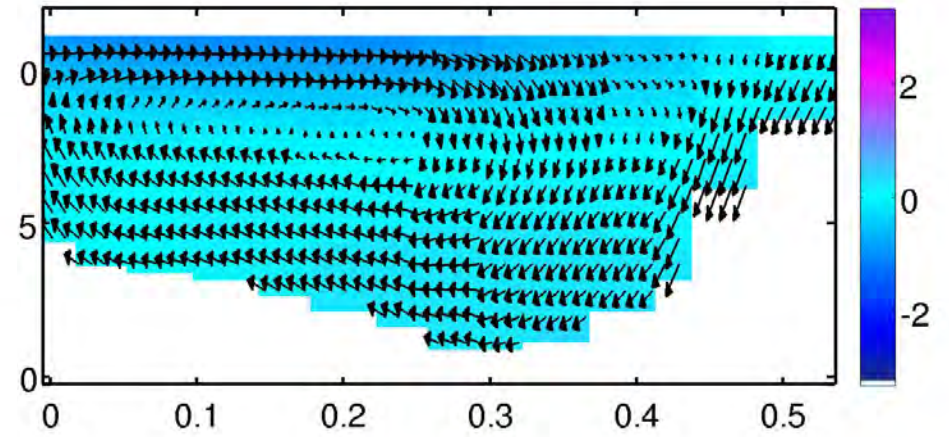


Secondary circulation and salinity field – high resolution deviation from the cross-sectional mean [psu]

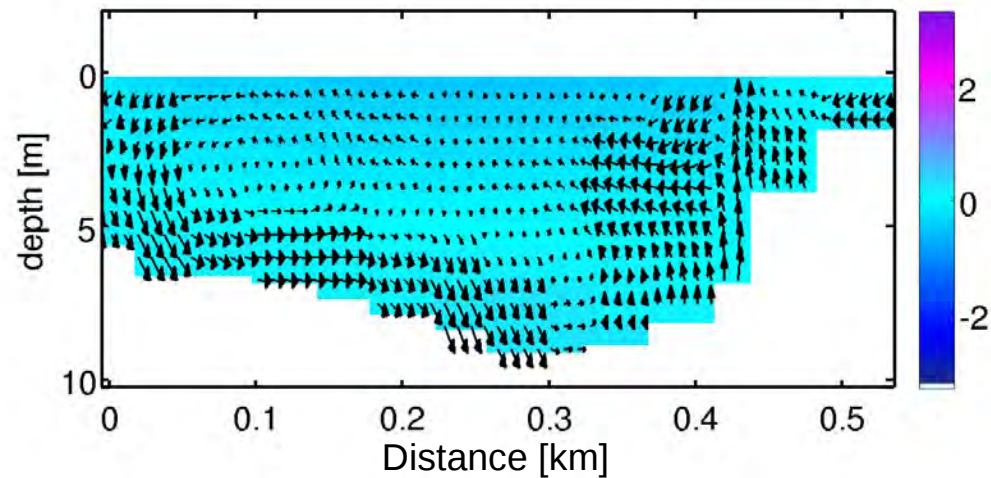
Flood



HW



Ebb



LW

