Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Spatial evolution of tidal spectra: From shelf seas to estuaries

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with contributions of

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Motivation:

Mesoscale and submesoscale dynamics

Dynamics of spectral composition, tidal wave transformations and generation of overtides

Address open sea and estuarine dynamics in one study.

Tidal spectroscopy of shallow coastal areas and nonlinear distortion and friction: Munk and Cartwright (1966),Gallagher and Munk (1971), Ianniello (1977),Jay and Smith (1990), Le Provost (1991), Parker (1991).

In coastal regions, differently from the open ocean, the tidal spectrum is more complex (overtides and compound tides).

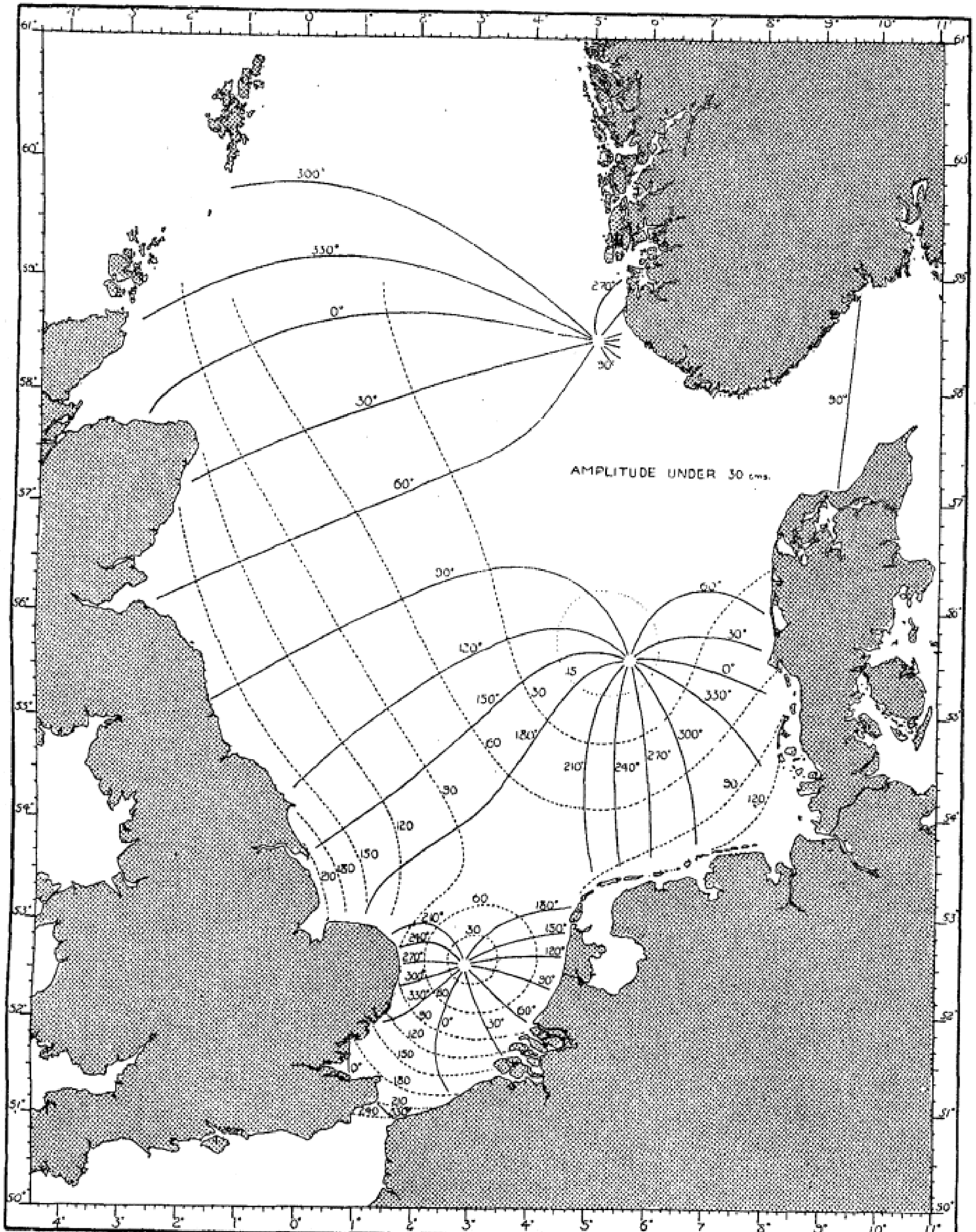
Nonlinear advection terms are responsible for the generation of even harmonic overtides (M4).

Nonlinear friction is responsible for producing odd harmonic overtides (M6).

Past works have overlooked:

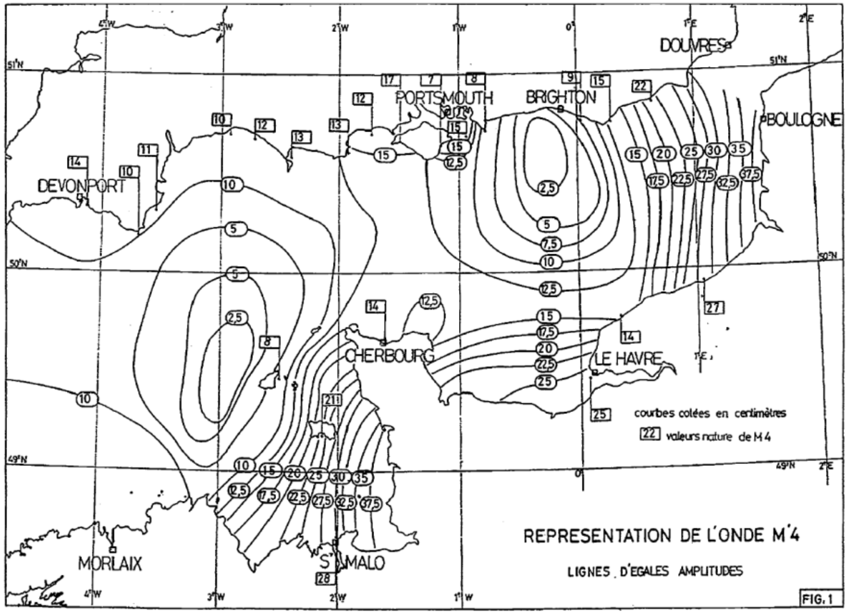
(1) the horizontal patterns of overtides at the transition between the coastal zone and the open ocean,
(2) the role of bathymetric channels,
(3) the role of baroclinicity,
(4) the seamless approach.

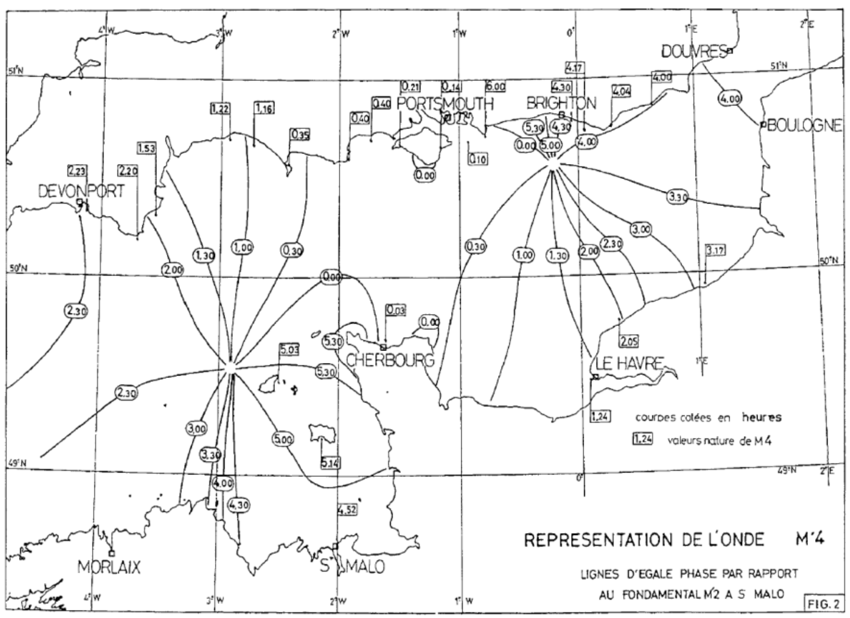
One basic practical problem is the assimilation of altimetry into numerical tidal models (Le Provost et al. 1994; Le Provost 2001).



1924

Proudman and Doodson: How the fundamental dynamical equations of the tides may be used to obtain a knowledge of the distribution of surface elevation from observations.



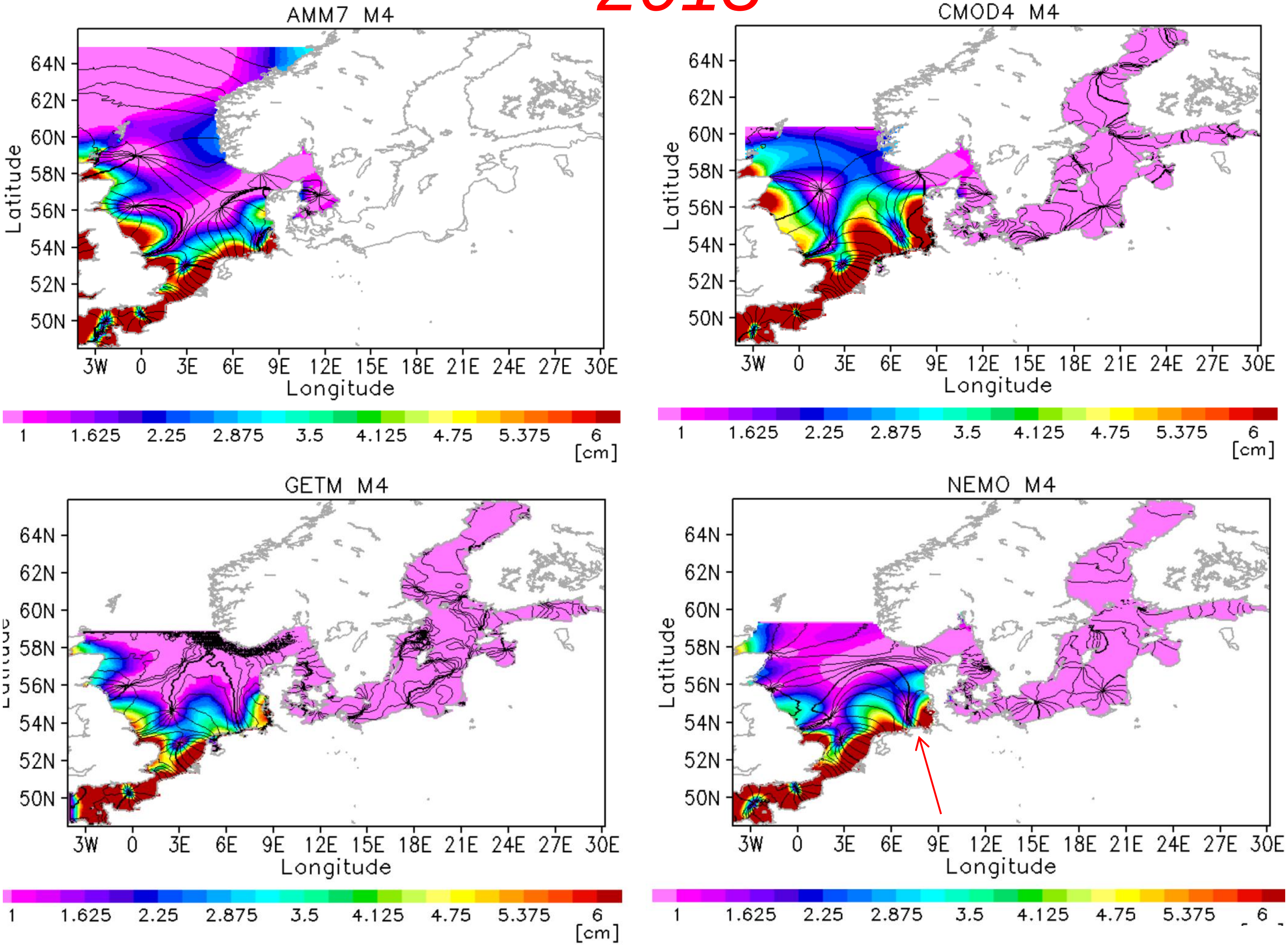


1970

The first cotidal chart of M4 in this region

Chabert d'Hières and Le Provost

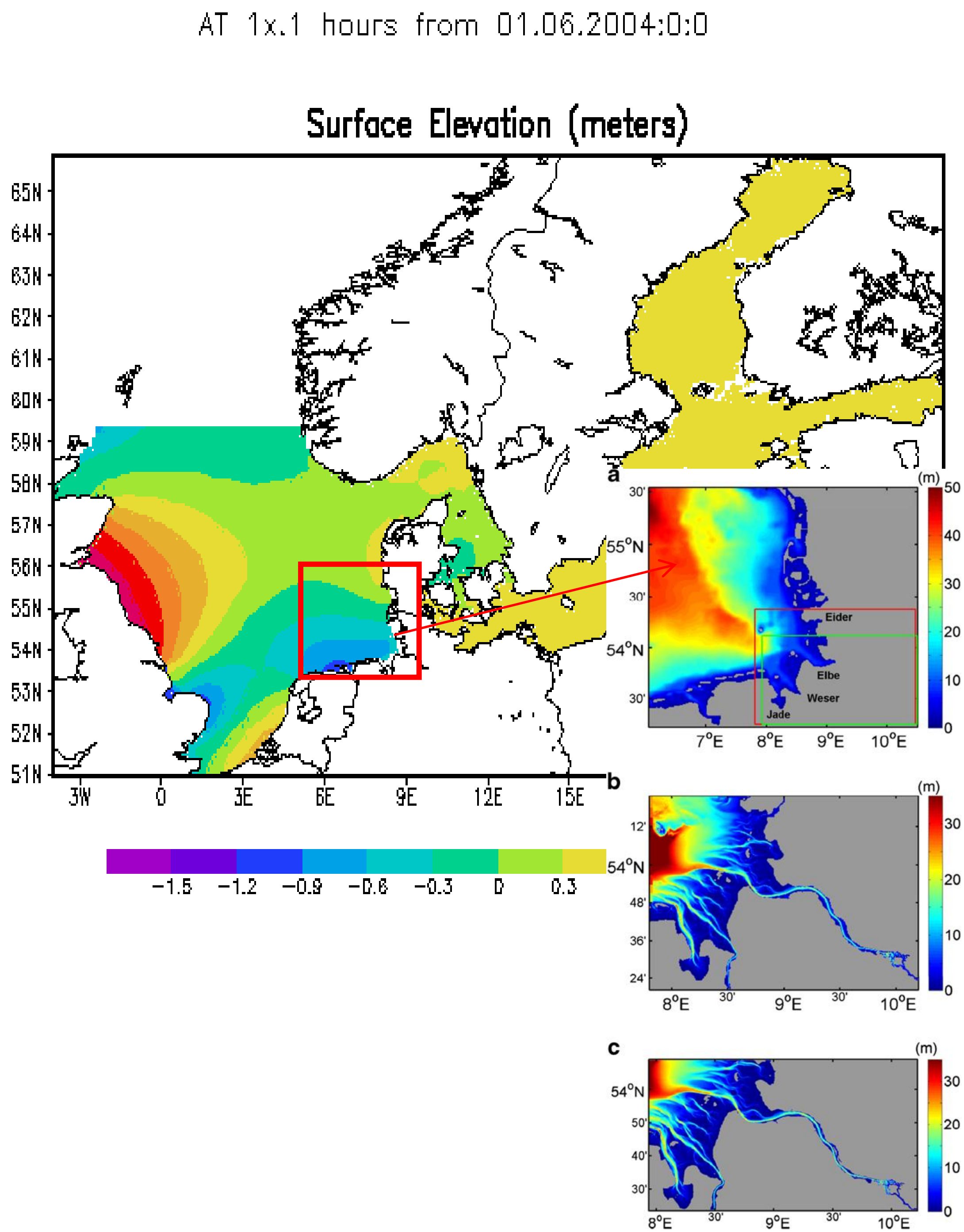
2015

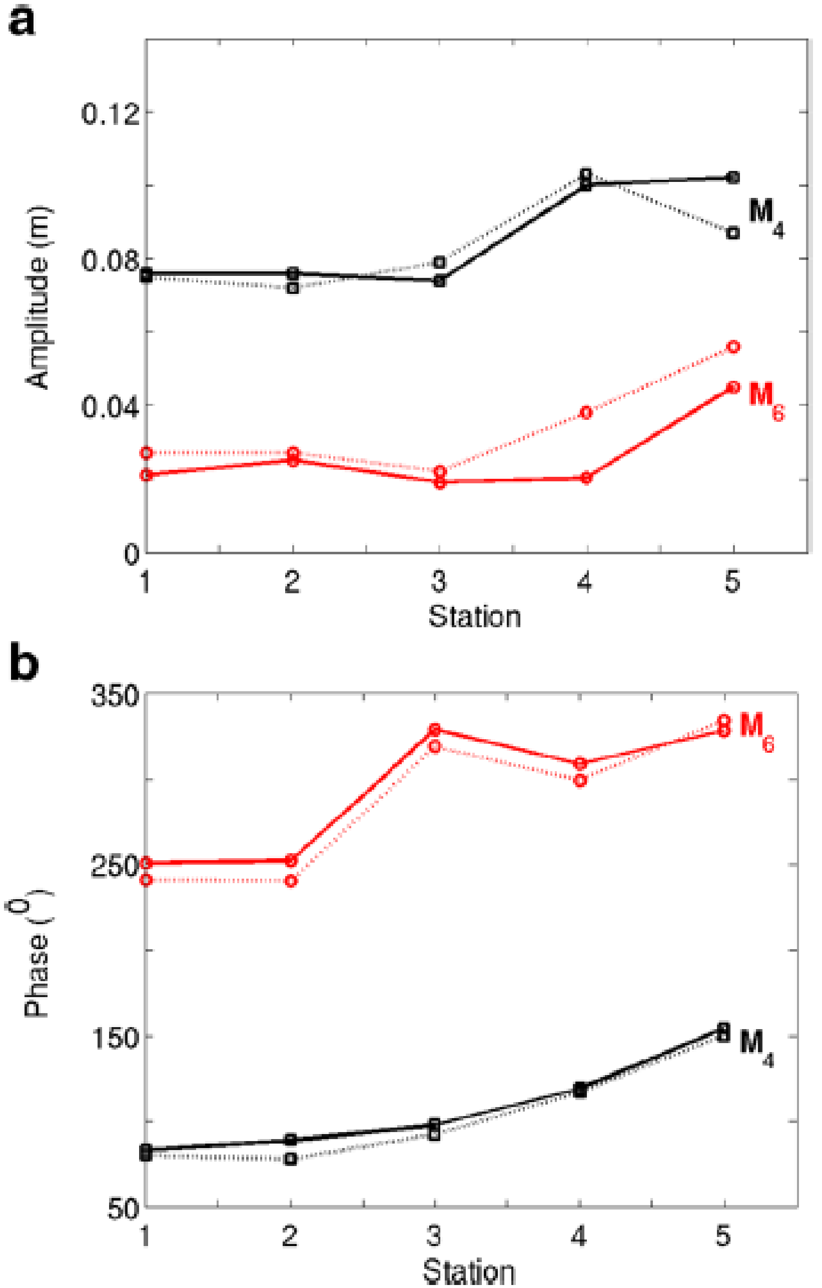

AMM7 M4
CMOD4 M4
GETM M4
NEMO M4
64N
62N
60N
58N
56N
54N
52N
50N
Latitude
3W
0
3E
6E
9E
12E
15E
18E
21E
24E
27E
30E
Longitude
1
1.625
2.25
2.875
3.5
4.125
4.75
5.375
6
[cm]

Nested Modeling System: GETM

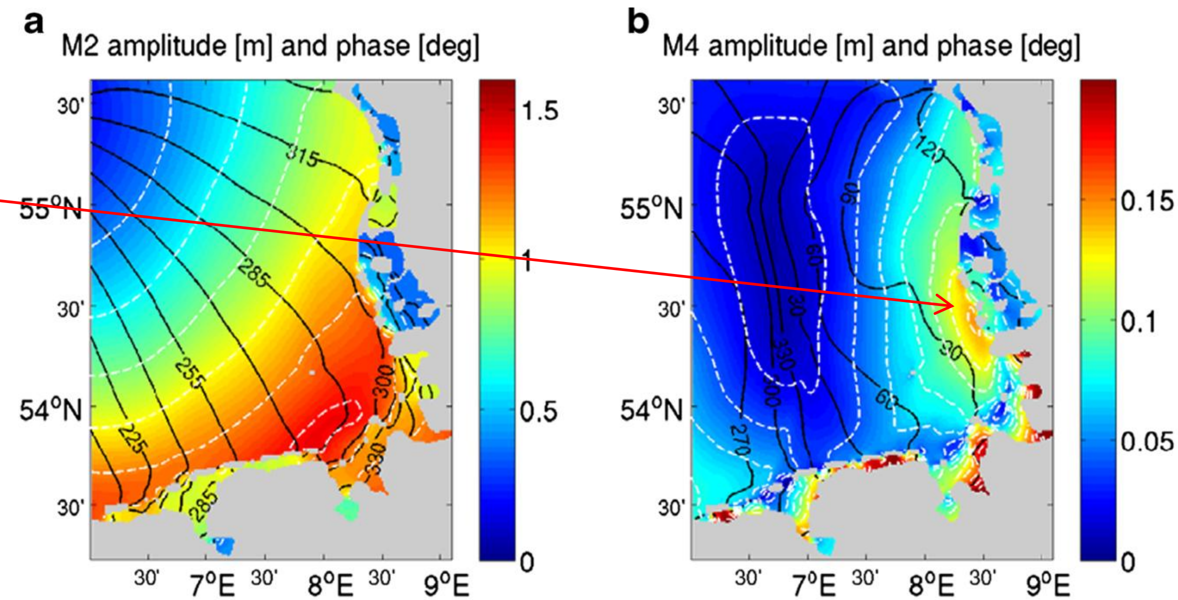
The modeling system consists of three nested models:

- ***North Sea-Baltic Sea model (5 km)***
- ***German Bight model (0.8 km)***
- ***Wadden Sea model (200 m)***
- ***Forcing***
  - *Atmospheric forcing (DWD 1-hr atmospheric forecasts),*
  - *River run-off – hourly data,*
  - *Open BC – tides, T and S*

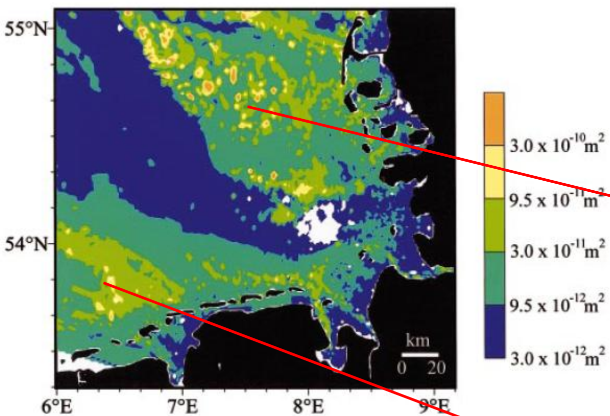




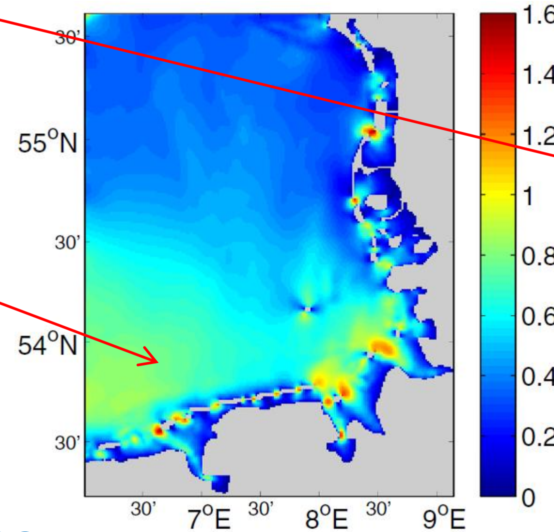
Validation: Stanev et al. (2014), ODYN, Observations-full line



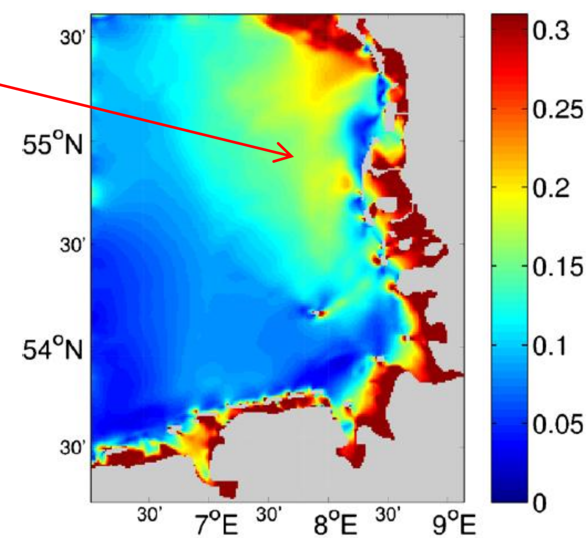
The region of strongest *generation of overtides* *(reflection and refraction of a Kelvin wave)*



Janssen et al., 2005



Amplitudes of the major axes currents (M2)

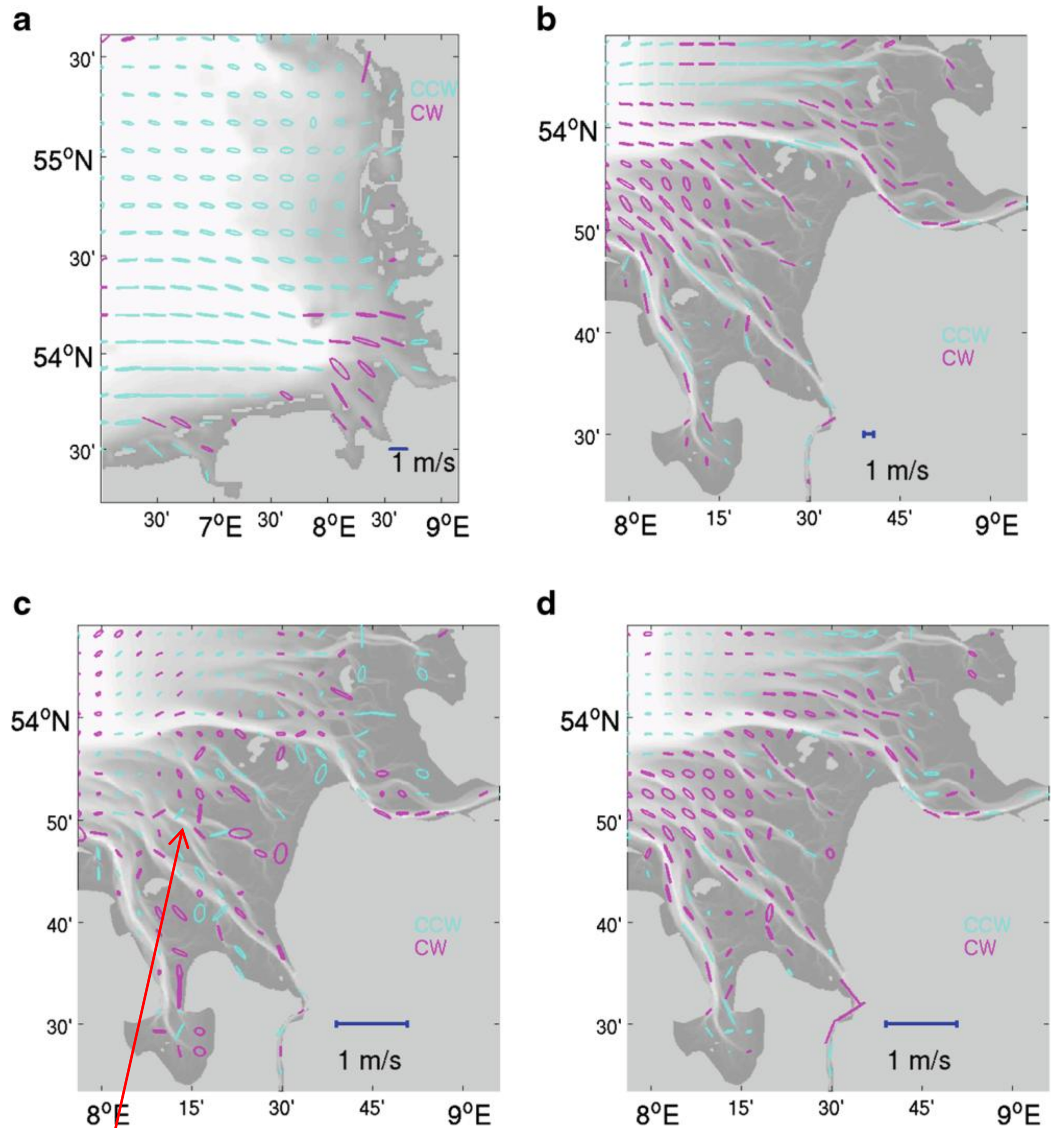


M4/M2 (tidal distortion) roughly represents the effect of energy transfer from M2 to M4

Stanev et al. (2014), ODYN

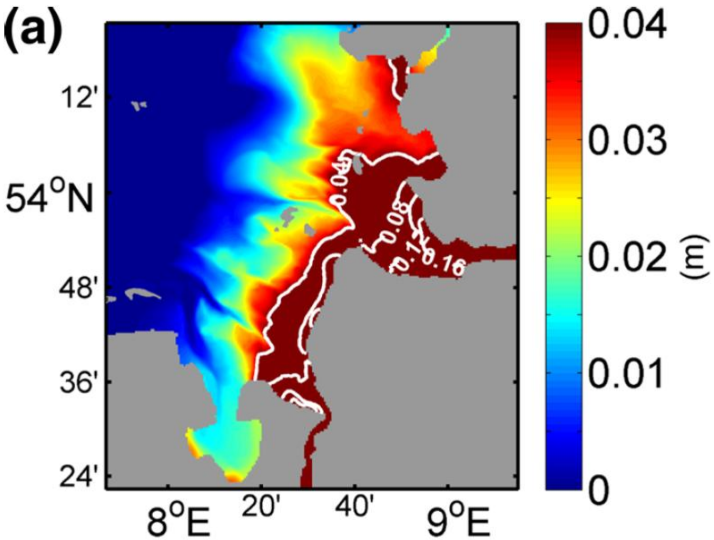
Conclusion:
It is not only the energy, but also the tidal distortion which shapes the governing processes (tidal asymmetry)

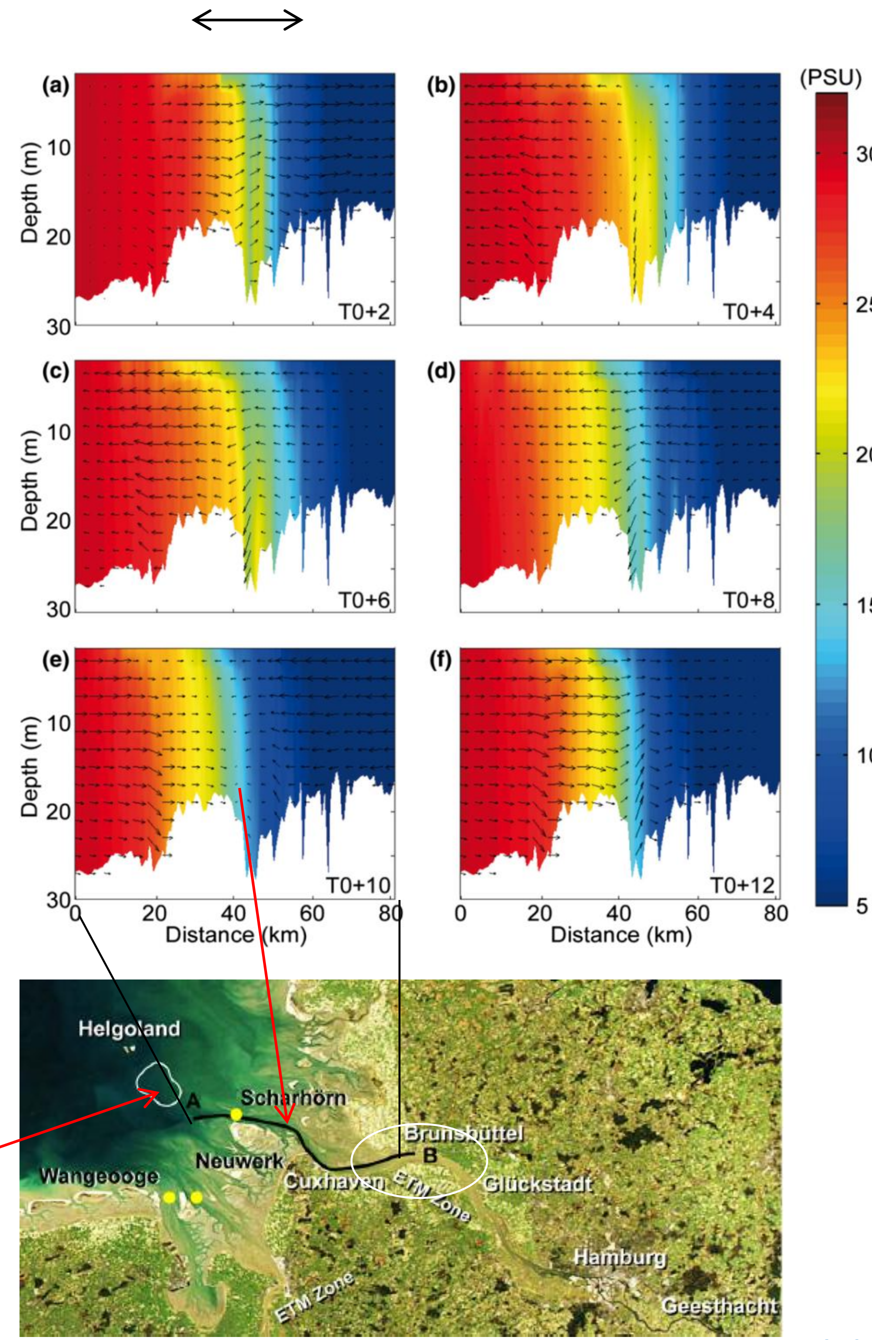
The controll of bathymetry



higher harmonics reveal "orthogonal" patterns, which could drive secondary circulation

The role of baroclinicity (salinity front/

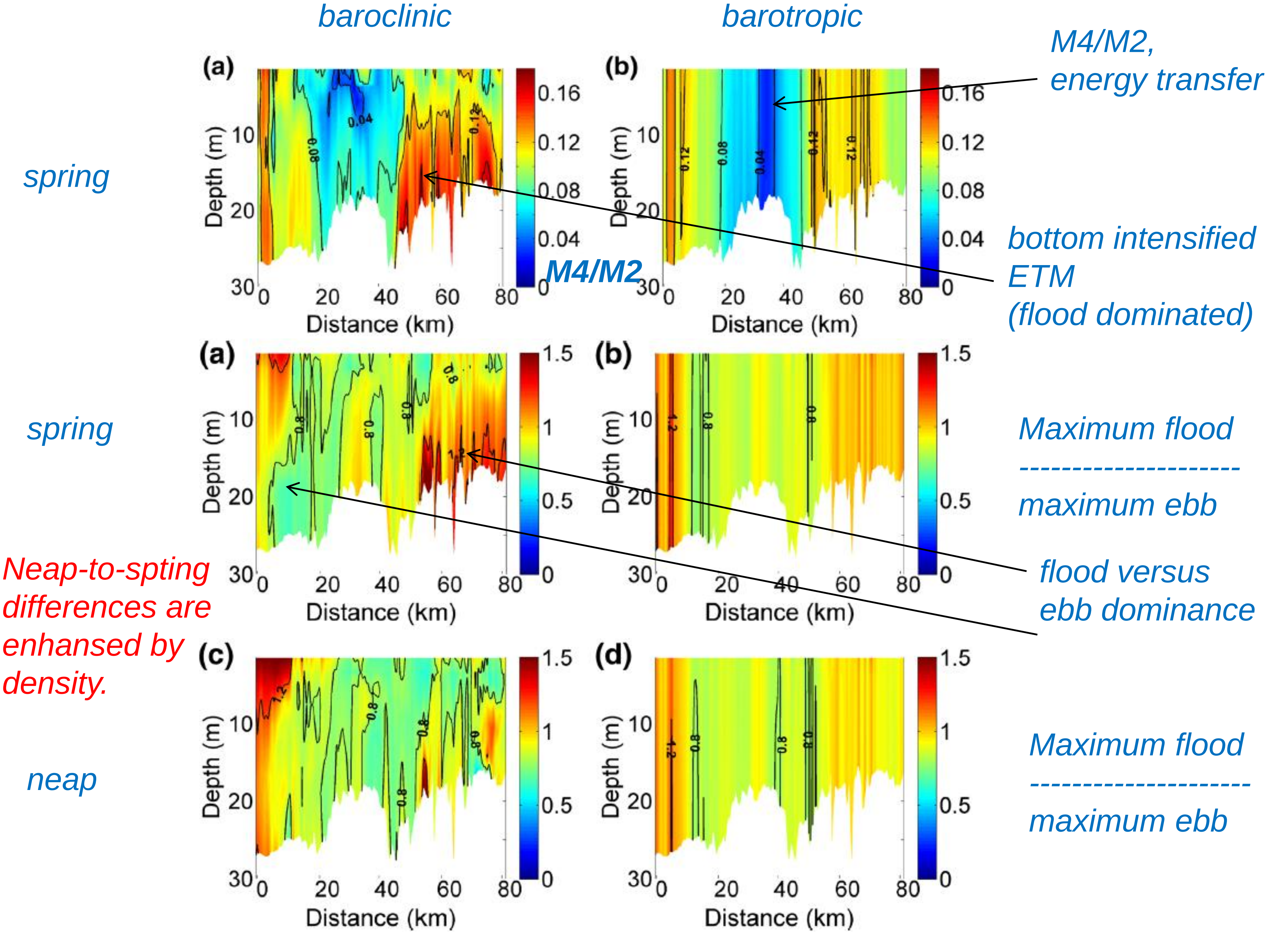




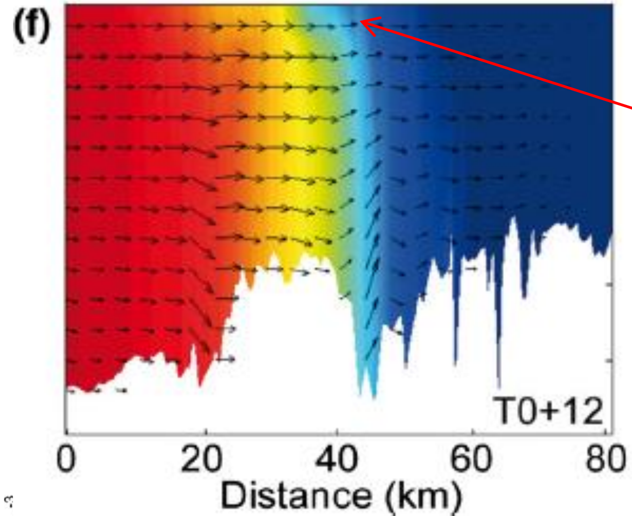
Roughly the net sediment transport is ebb- or flood dominated in cases of short ebb or flood, respectively

Zone of accumulation of sediment

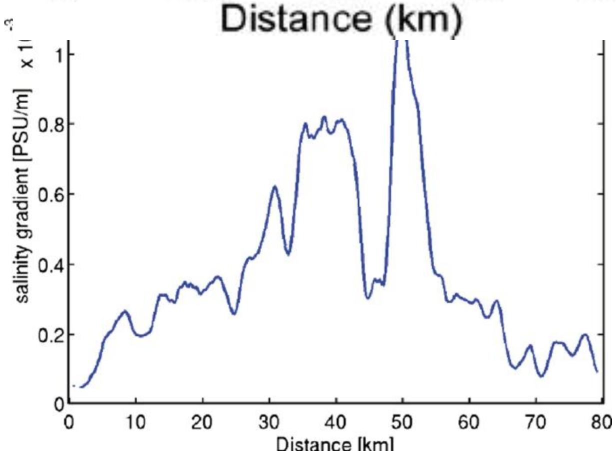
Stanev et al. (2015)



baroclinic
barotropic
M4/M2,
energy transfer
spring
(a)
(b)
Depth (m)
Distance (km)
M4/M2
bottom intensified
ETM
(flood dominated)
spring
Maximum flood
maximum ebb
flood versus
ebb dominance
Neap-to-spting
differences are
enhansed by
density.
(c)
(d)
neap
Maximum flood
maximum ebb



gravitational circulation



$$Si = \frac{b_x H^2}{C_D U_T^2}$$

competition between baroclinic and barotropic forcing

The non-linearities and the resulting distortion in the tidal signal occur in the area of the salinity front.

The largest tidal excursions are associated with the maximum divergence/convergence of currents in the mouth.

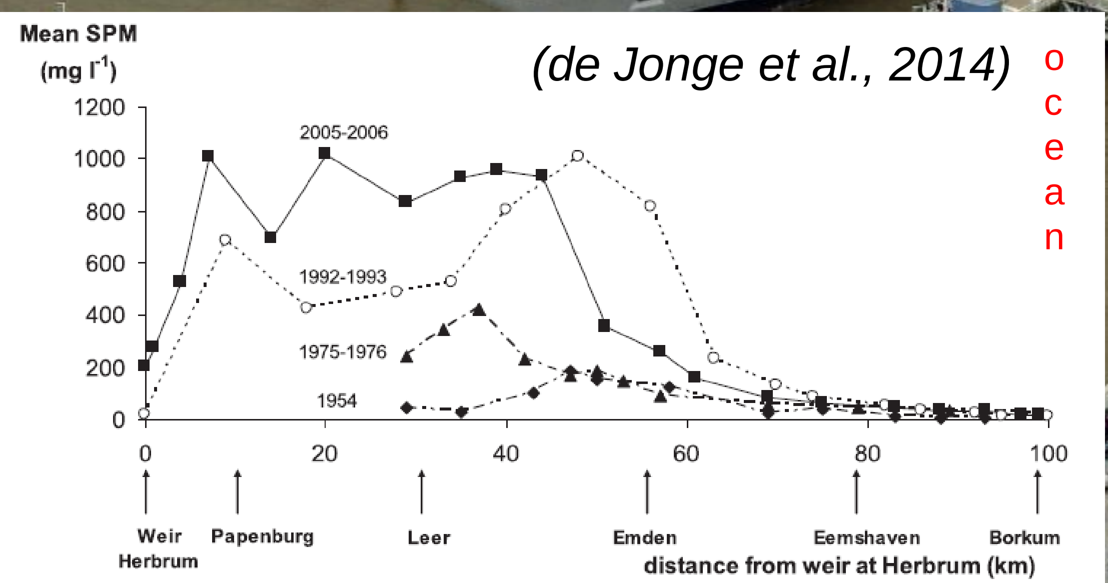
$$L_T = U_T T_T / \pi$$

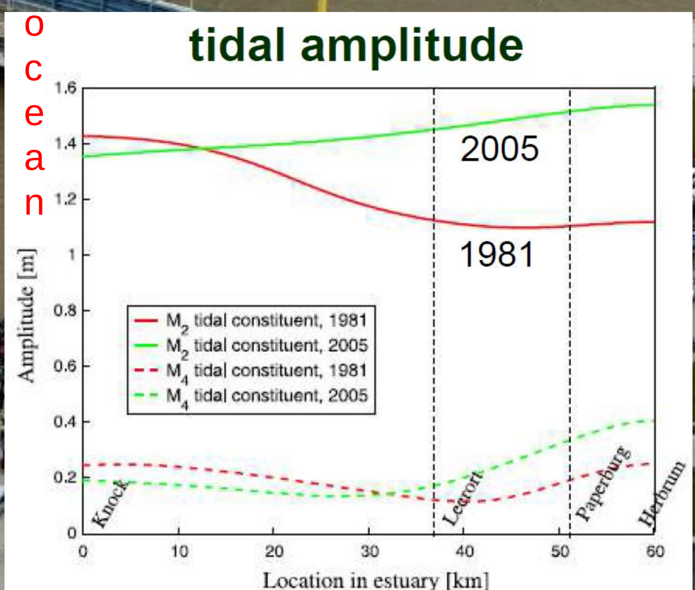
The correlation between salinity and velocity tended to enhance the vertical overturning.

Further estuarine applications

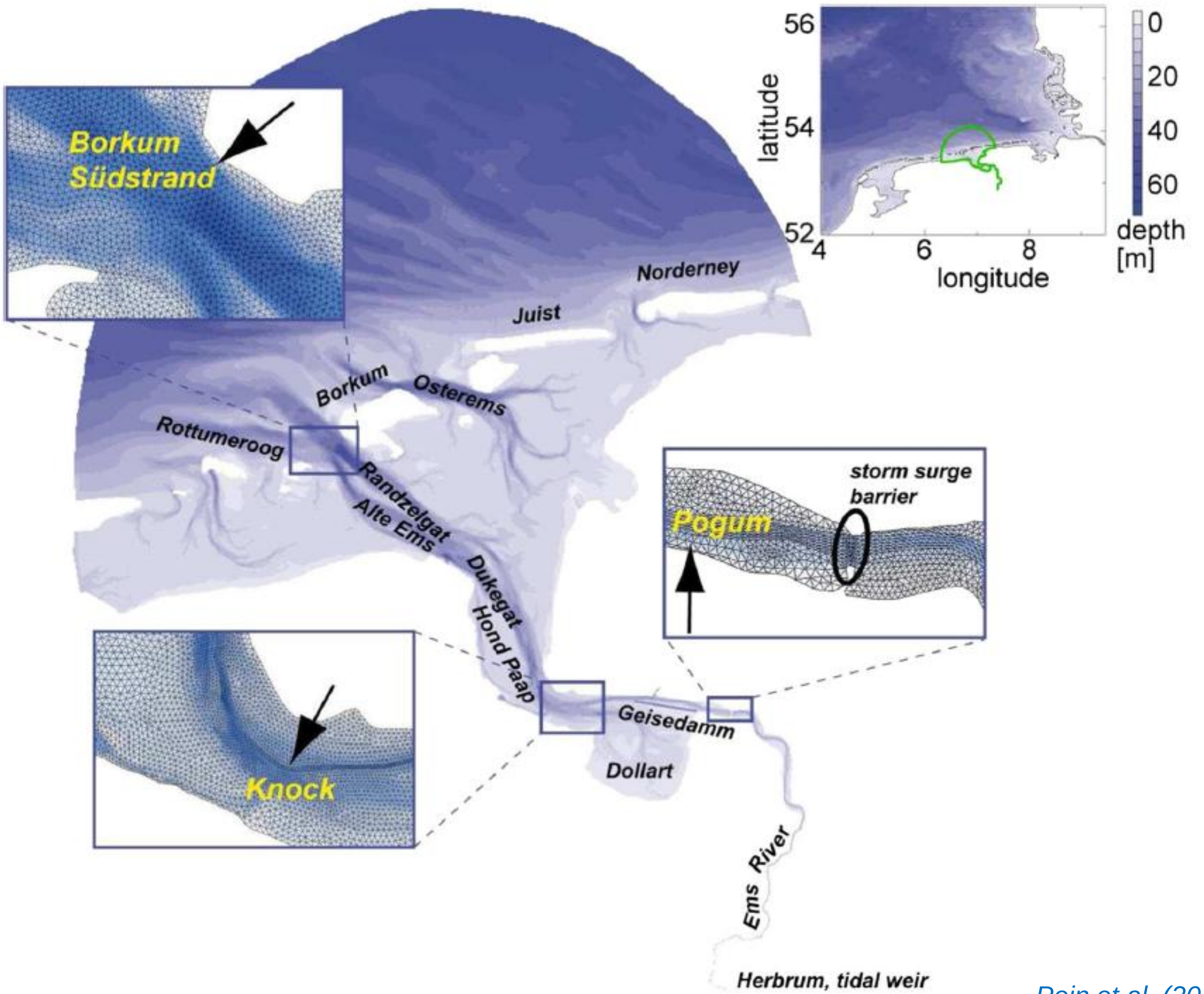
Welcome to Ems

Schuttelaars et al., 2012



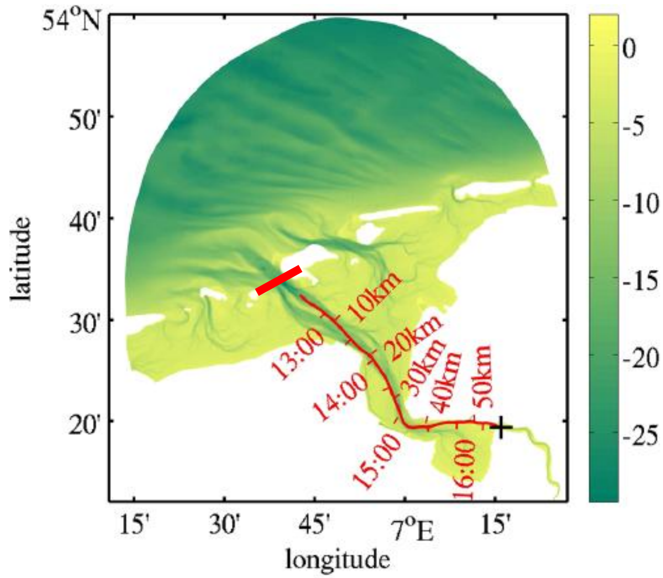


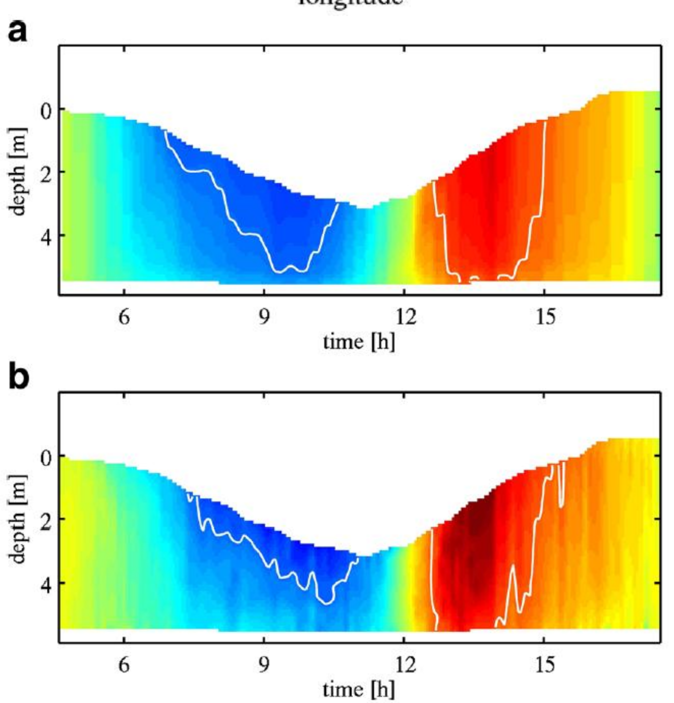
Semi-implicit
Cross-scale
Hydroscience
Integrated
System Model
(SHISM/SELFE)

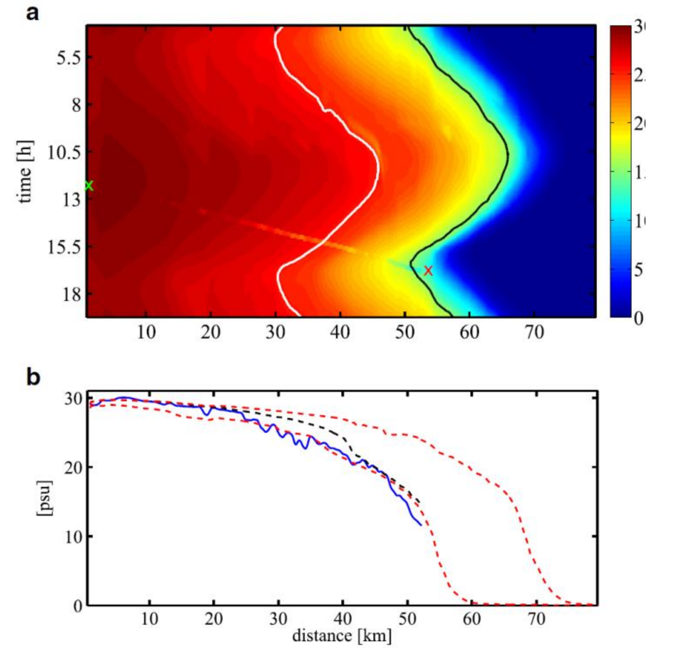


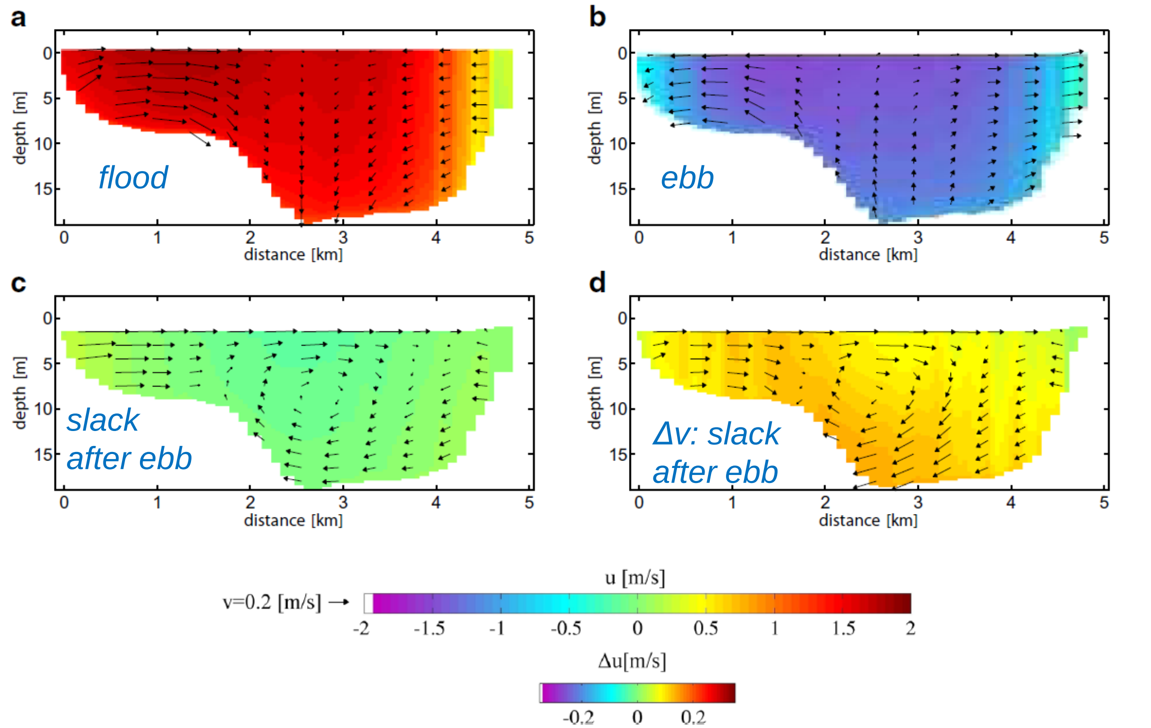
Pein et al. (2014)

Validations



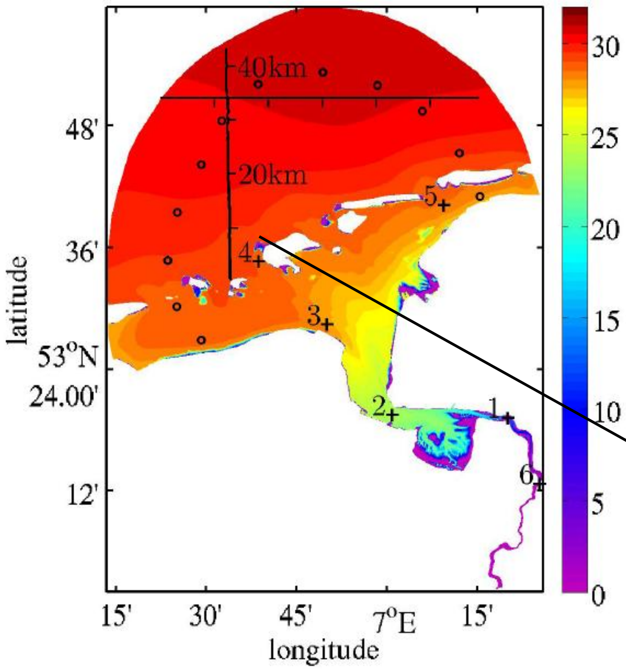




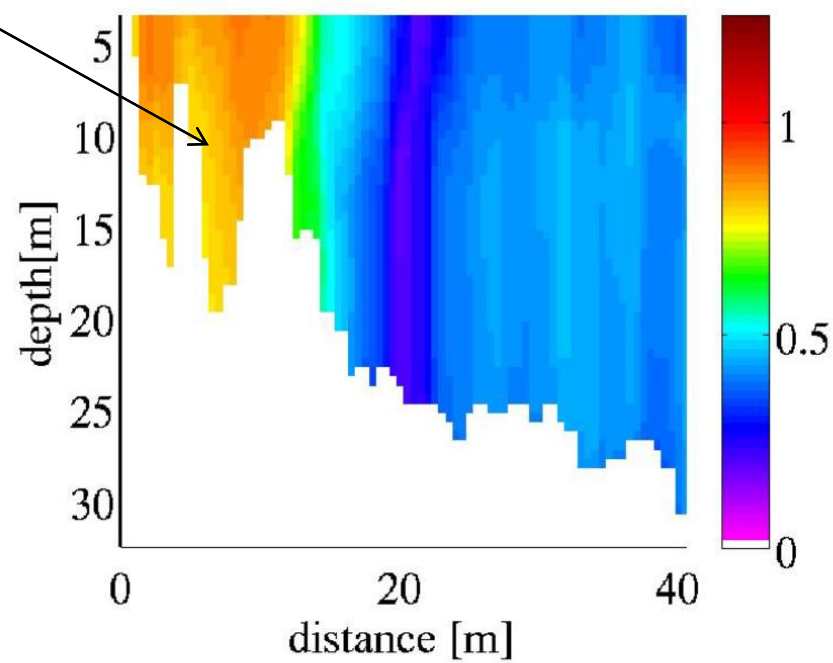


Non-canonical secondary circulation

Salinity



M4 Salinity



Conclusions:

- *The present research: an illustration of the interaction between the tidal flow and the density gradient in a region influenced by fresh water.*

- *Estuarine theories should probably account for the joint contributions of nonlinearities and baroclinicity.*

- *The vertical patterns of tidal asymmetries and their possible role for material transport and deposition deserve deeper consideration*