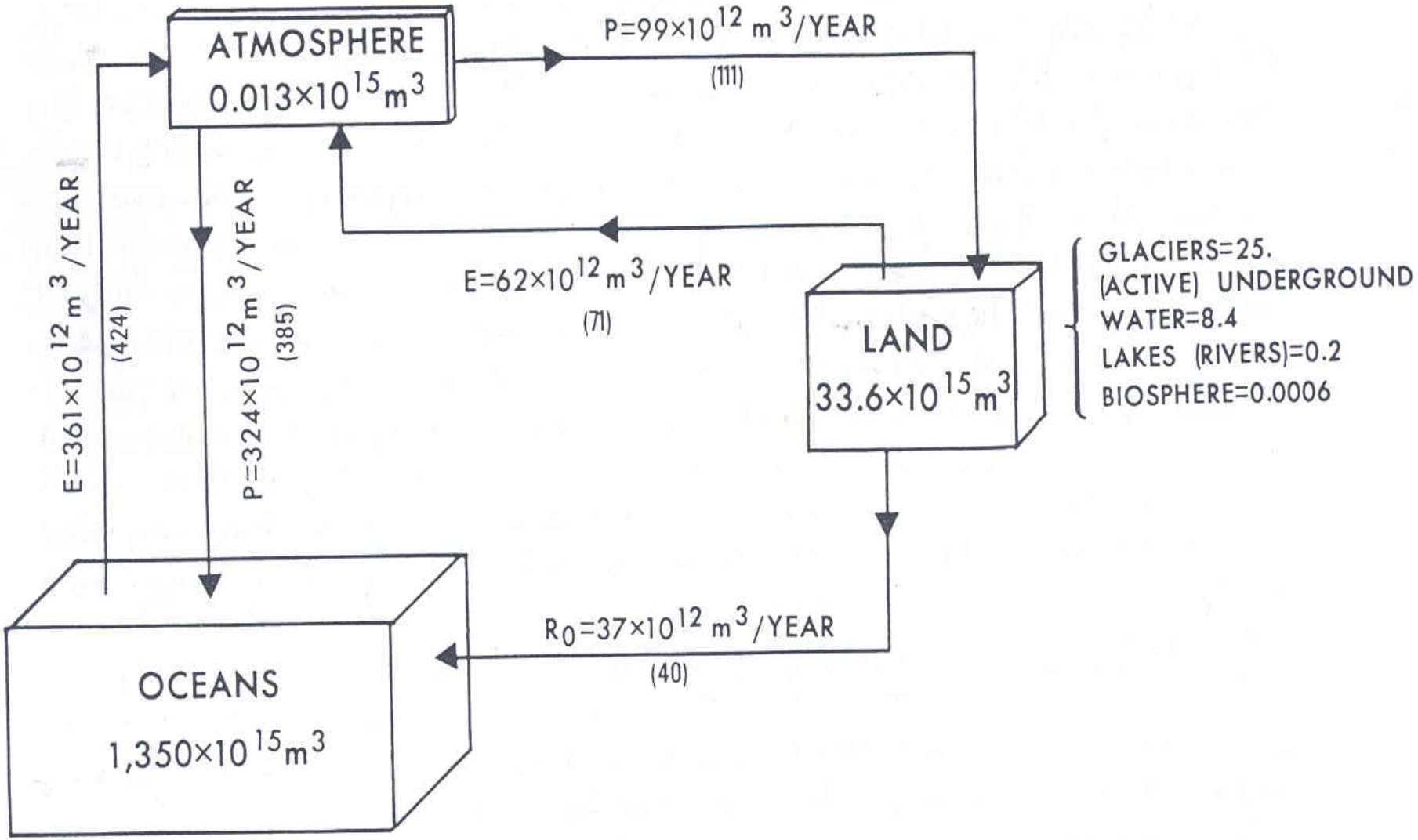
Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

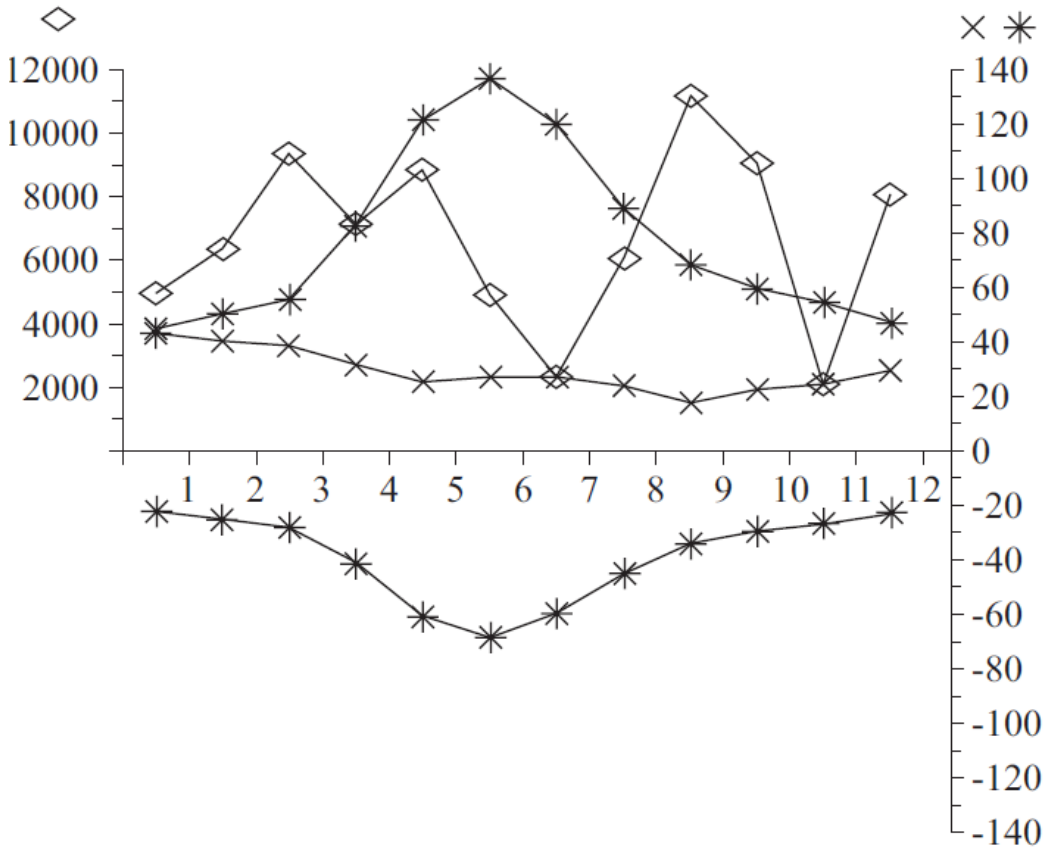
Physical processes in straits and estuaries. Results from unstructured-grid numerical modeling

Emil Stanev

Coastal Hydrology and Surface Processes linked to Air/Sea Modeling:
1st community of users workshop


ATMOSPHERE
0.013×10^15 m^3
P=99×10^12 m^3/YEAR
(111)
E=361×10^12 m^3/YEAR
(424)
P=324×10^12 m^3/YEAR
(385)
E=62×10^12 m^3/YEAR
(71)
LAND
33.6×10^15 m^3
GLACIERS=25.
(ACTIVE) UNDERGROUND WATER=8.4
LAKES (RIVERS)=0.2
BIOSPHERE=0.0006
R0=37×10^12 m^3/YEAR
(40)
OCEANS
1,350×10^15 m^3

Climatological seasonal variation of North Sea waterbudget [10^12kg month^−1]



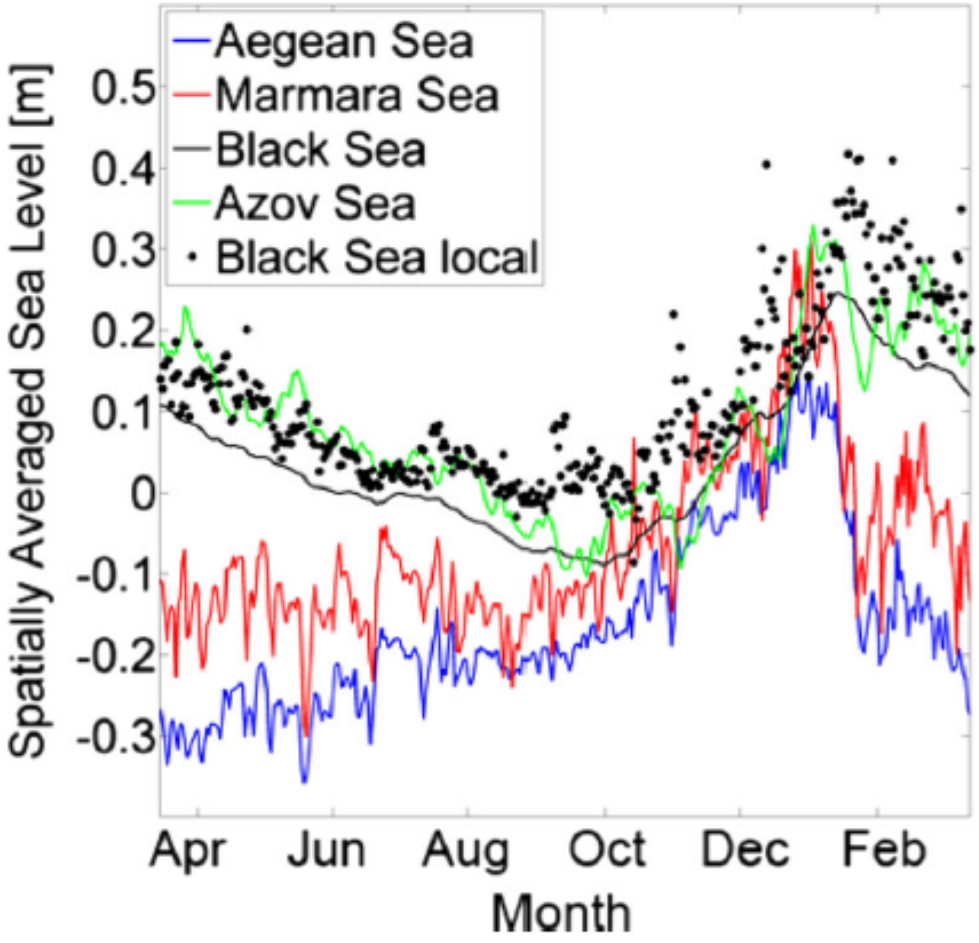
◇ *· inflow of Atlantic water*

× *- fresh water from continental discharge, precipitation and evaporation*

✳ *- positive: inflow from the Baltic (salinity 8.7), negative: outflow into the Baltic (salinity 17.4)*

(Sündermann and Pohlmann, 2011)

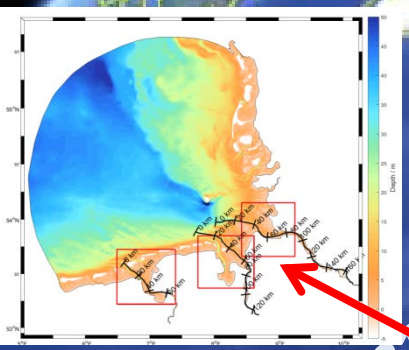
While Baltic inflow dominates the seasonal cycle of salinity, Atlantic inflow is thought to dominate mean salinity of the North Sea

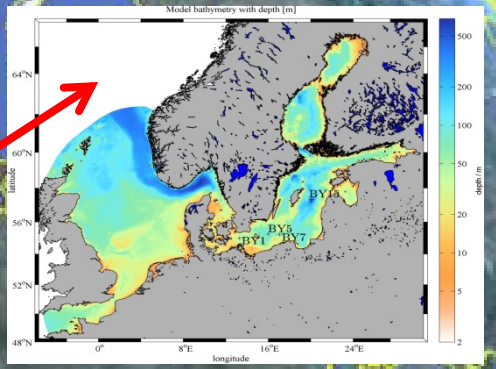


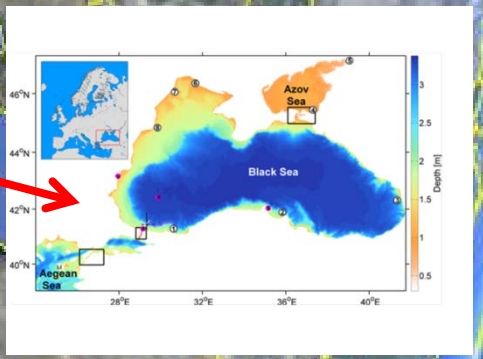
Stanev et al. (2017): "Obviously, the use of a mixture of the 6-hourly atmospheric reanalysis data, daily data at the open boundaries, and climatological runoff data decreases the realism of simulations. Of particular concern is the missing short-term variability of river runoff, for which no reliable data for all important rivers in the studied region exist"

From Marsili (1681) to (Knudsen (1900) and beyond)

Water cycle and the challenge of basin inter-connections







The model

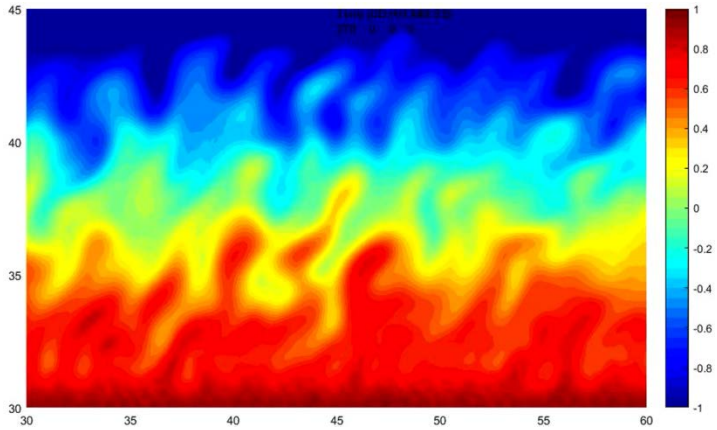
Semi-implicit Cross-scale Hydroscience Integrated System Model; www.schism.wiki

3D, primitive equations, unstructured-grid.

- Upgrade from an existing model (SELFE, : A Semi-implicit Eulerian-Lagrangian Finite Element model for cross-scale ocean circulation).

- Uses hybrid finite element and finite volume approach.

- New viscosity formulation (effectively filter out spurious modes without introducing excessive dissipation).

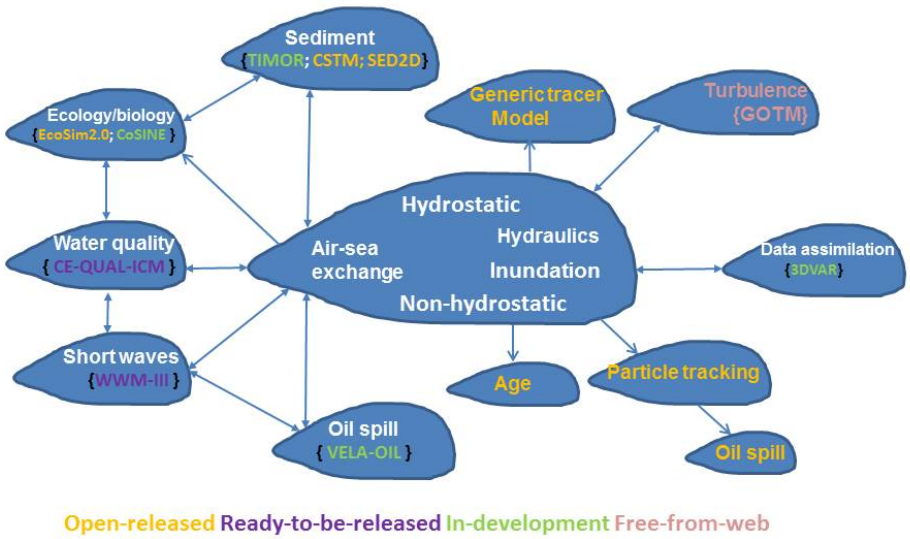


- New higher-order implicit advection scheme for transport (TVD^2) is proposed to effectively handle a wide range of Courant numbers

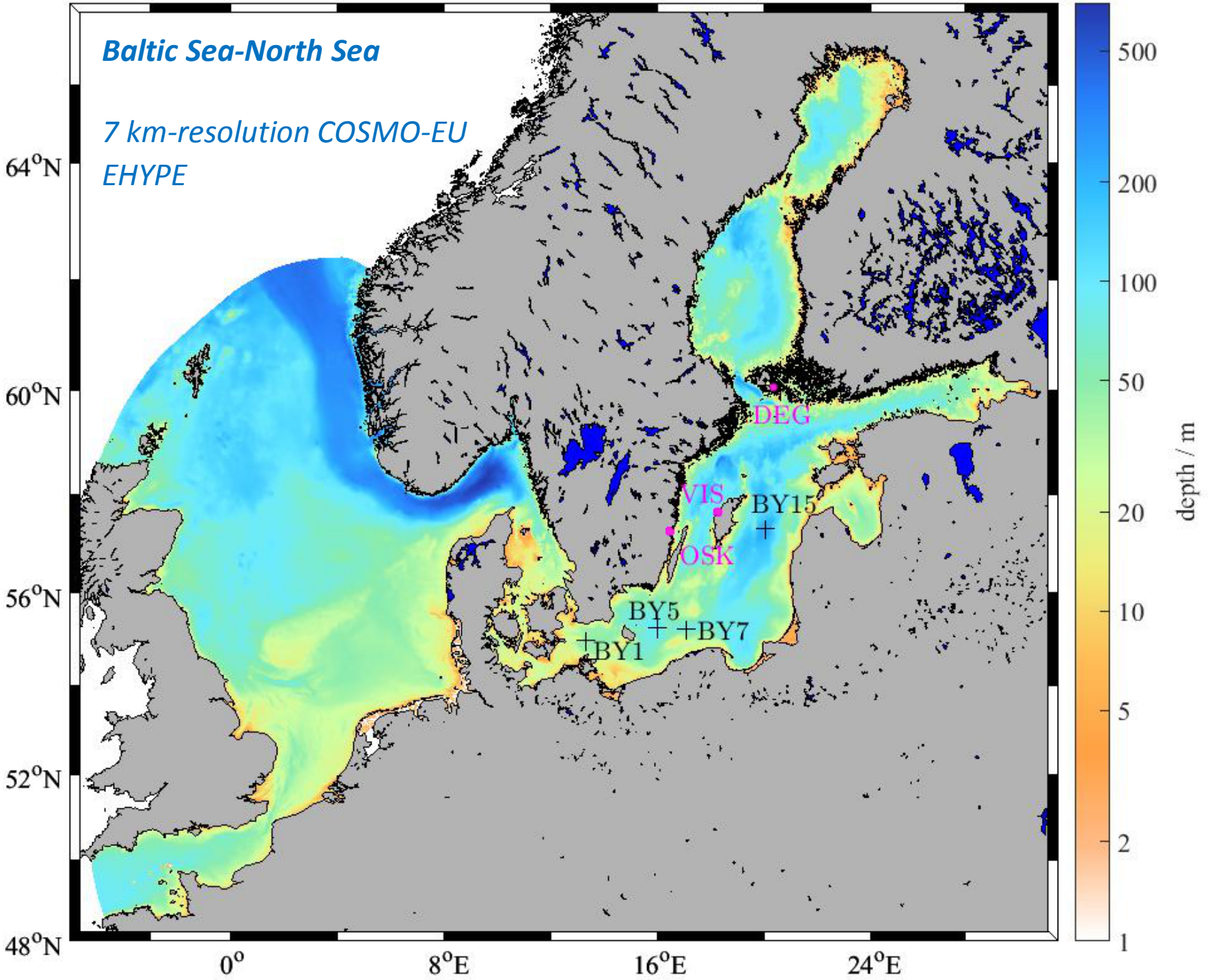
- Addition of quadrangular elements into the model

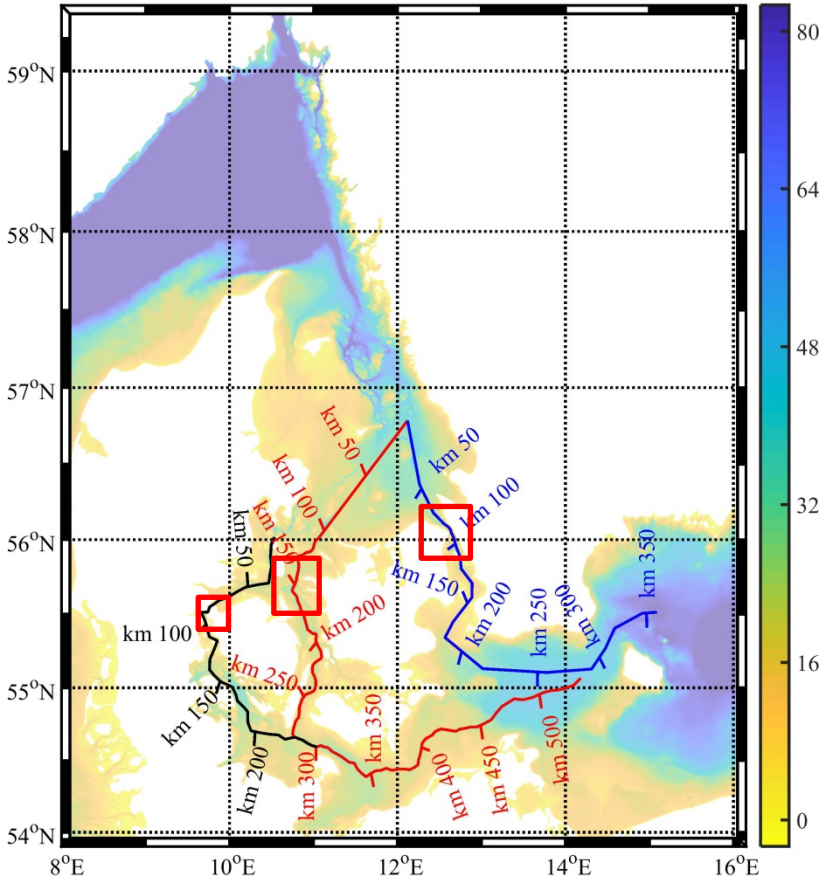
- Flexible vertical grid system (Zhang et al. 2015, OM)

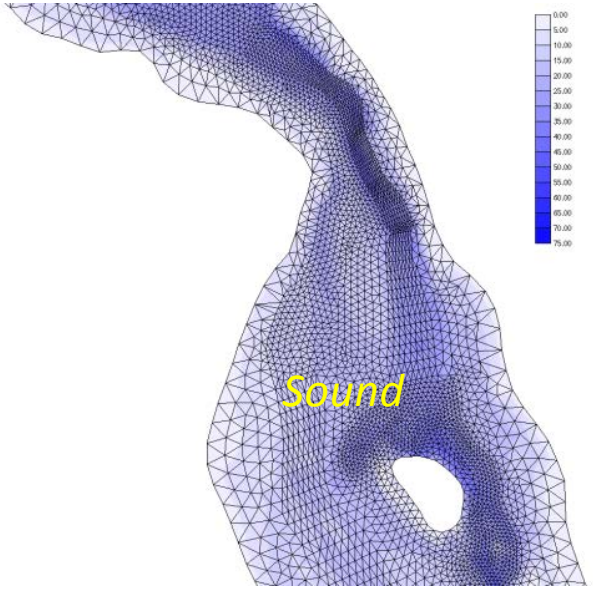
- Model polymorphism that unifies 1D/2DH/2DV/3D cells in a single model grid.



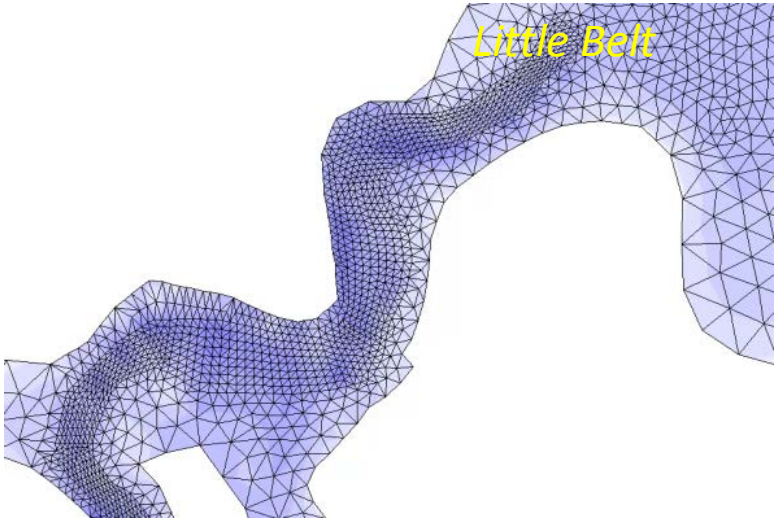
Zhang Y.J., F. Ye, E. V. Stanev, and S. Grashorn (2016a): Ocean Modelling.

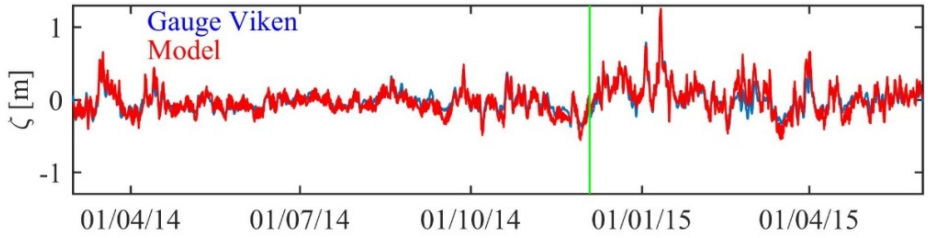

Baltic Sea-North Sea
7 km-resolution COSMO-EU
EHYPE
64°N
60°N
56°N
52°N
48°N
0°
8°E
16°E
24°E
DEG
VIS
BY15
OSK
BY5
BY7
BY1
500
200
100
50
20
10
5
2
1
depth / m

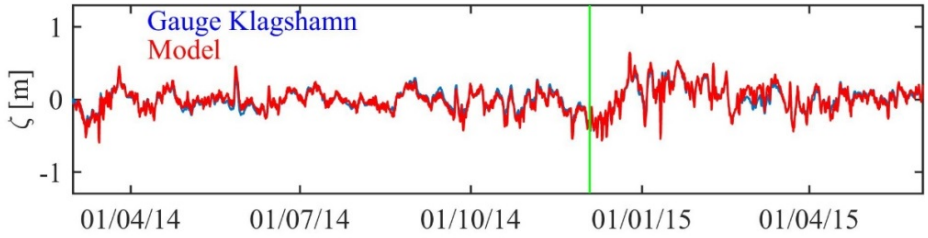

59°N
58°N
57°N
56°N
55°N
54°N
8°E
10°E
12°E
14°E
16°E
80
64
48
32
16
0
km 50
km 100
km 150
km 200
km 250
km 300
km 350
km 400
km 450
km 500

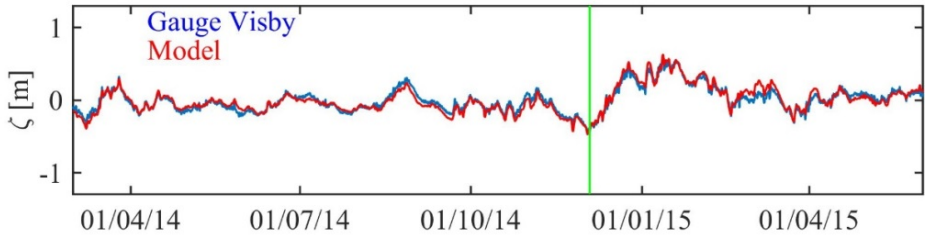

Sound

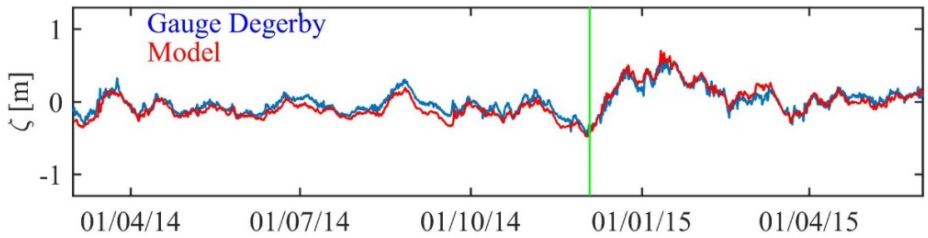
Great Belt

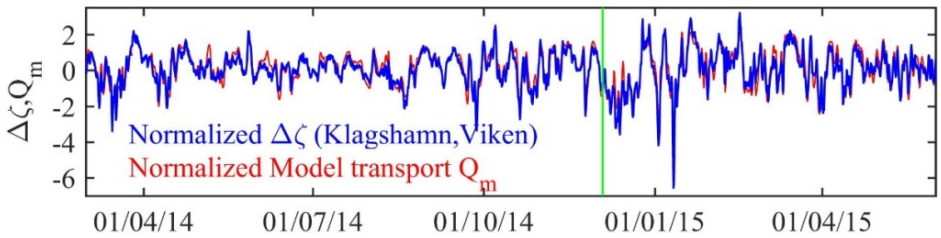

Little Belt

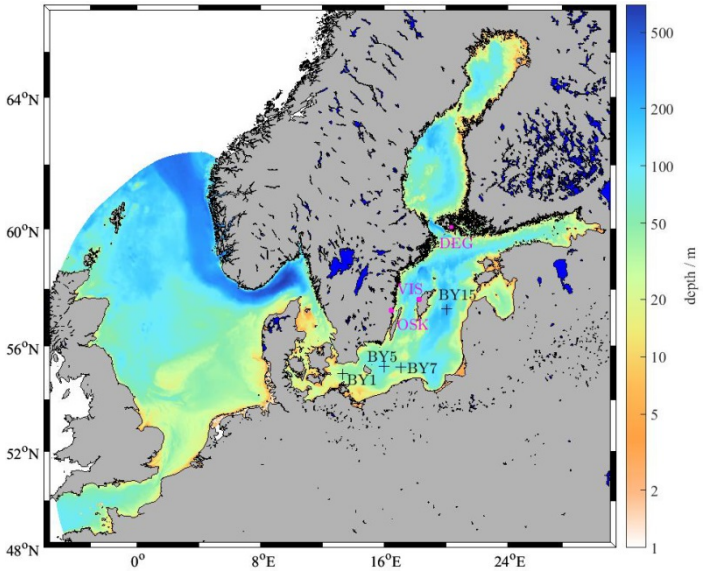






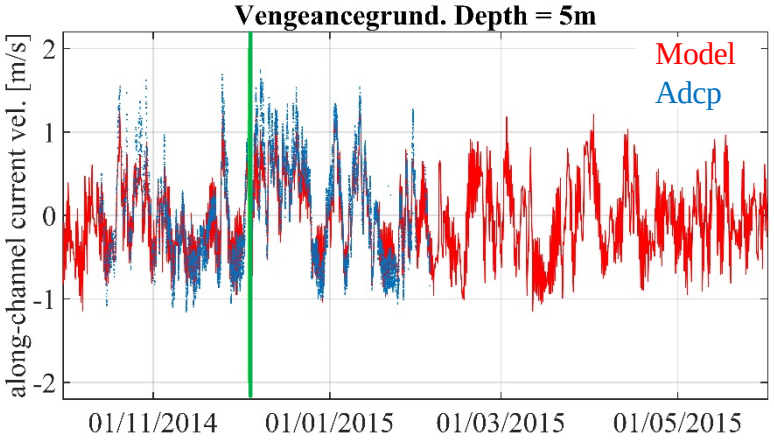


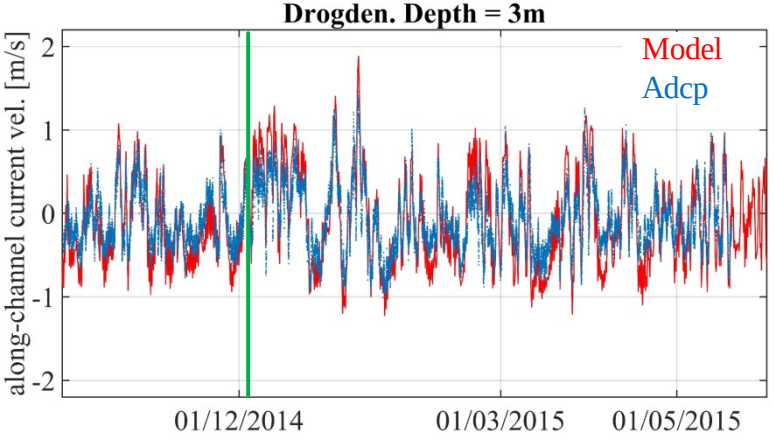


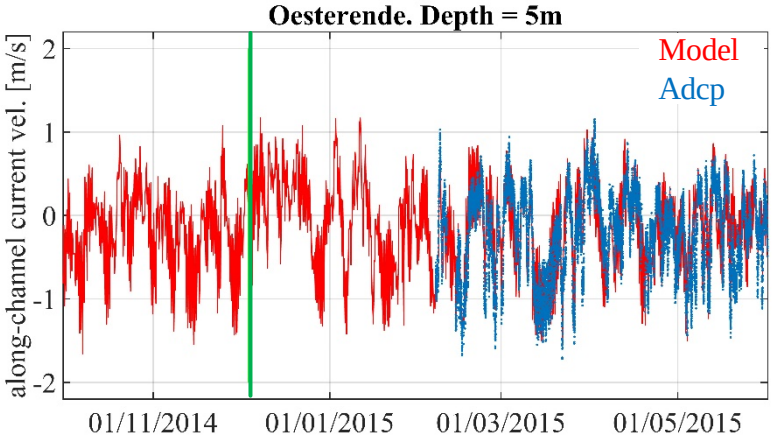


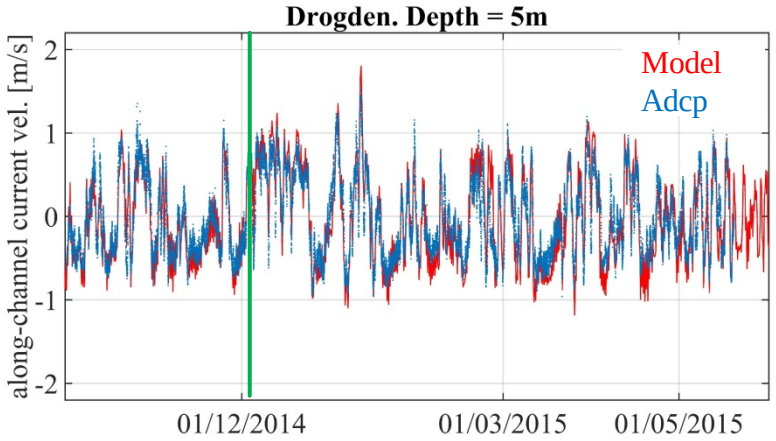
Validation (sea level)

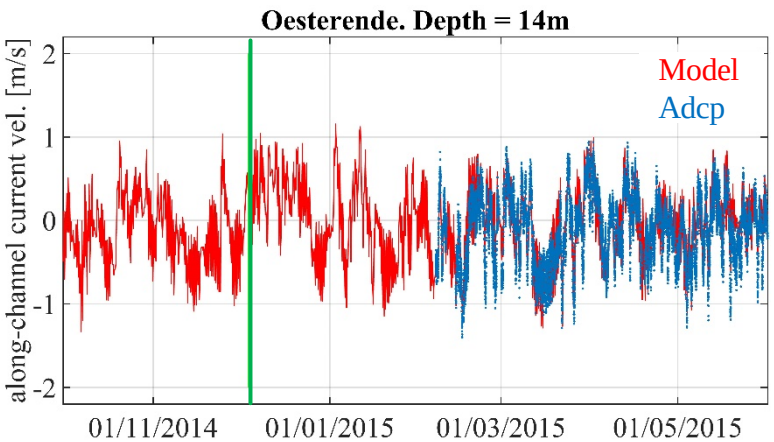
Validation (velocities)

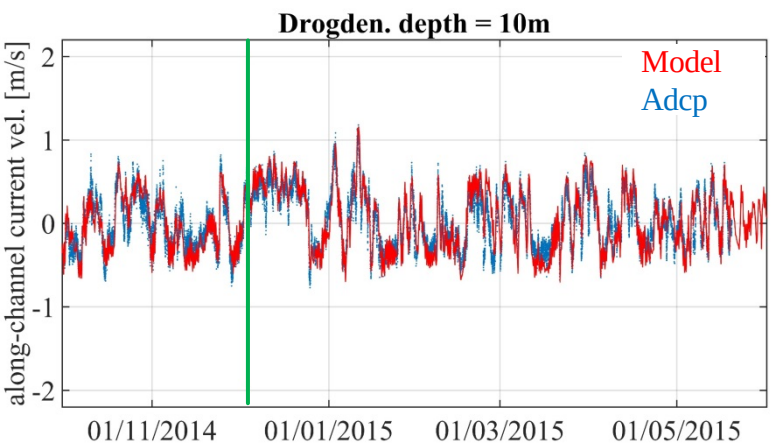


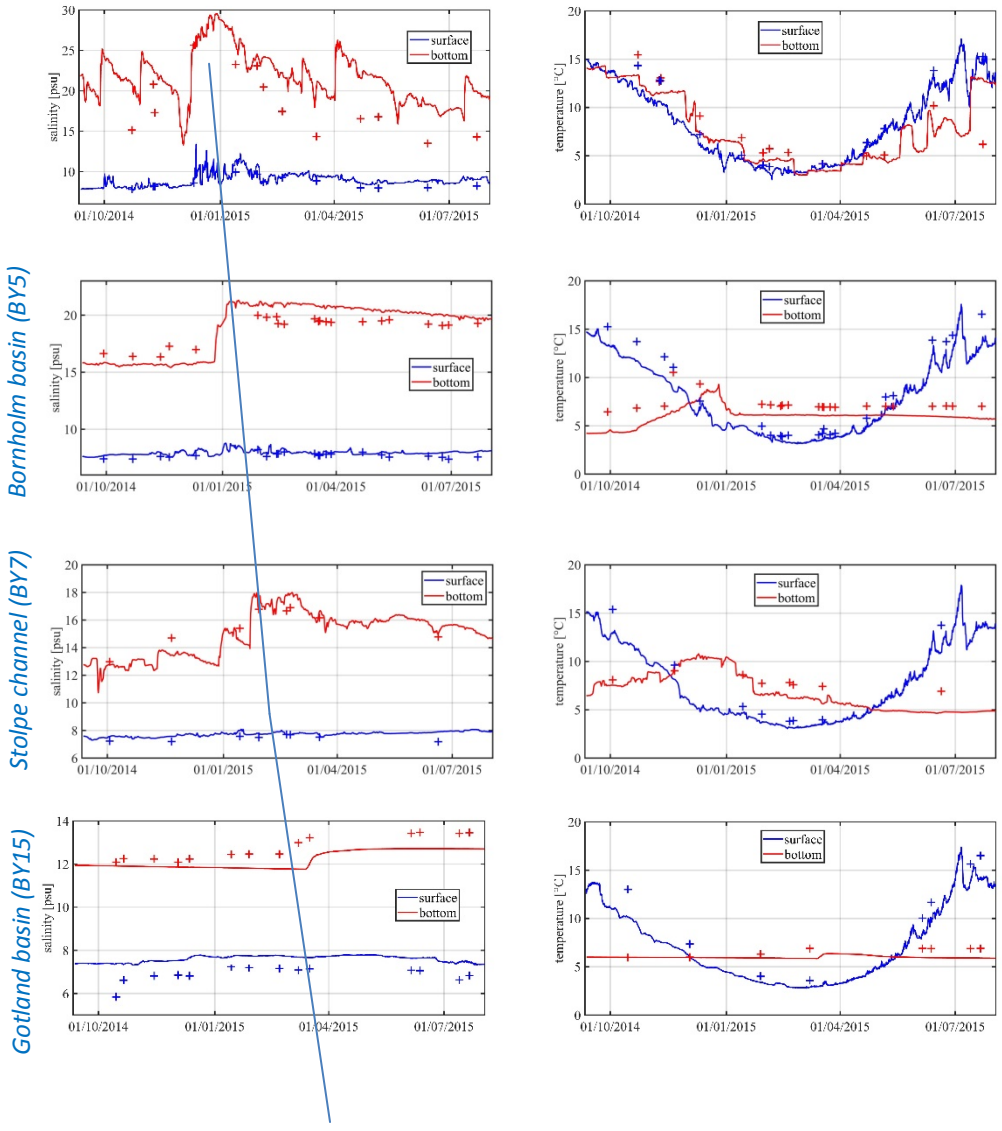








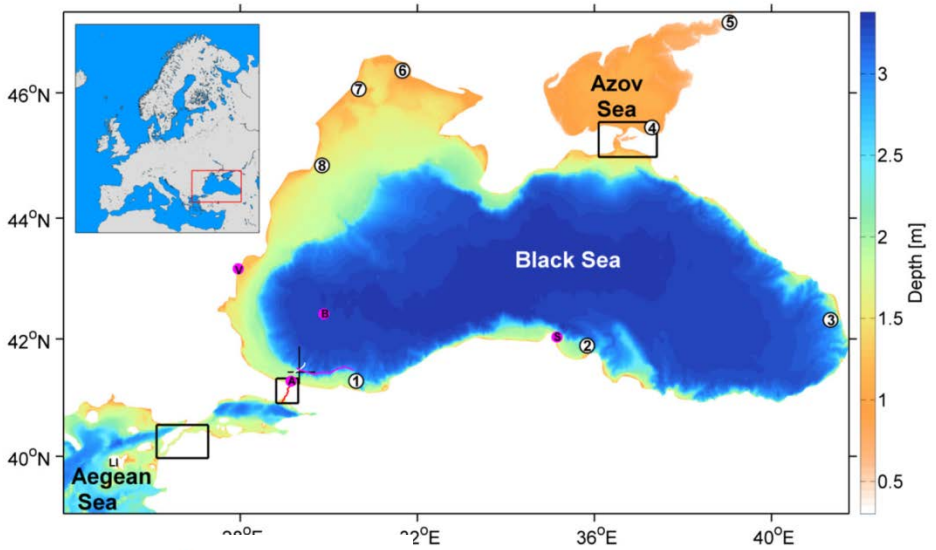


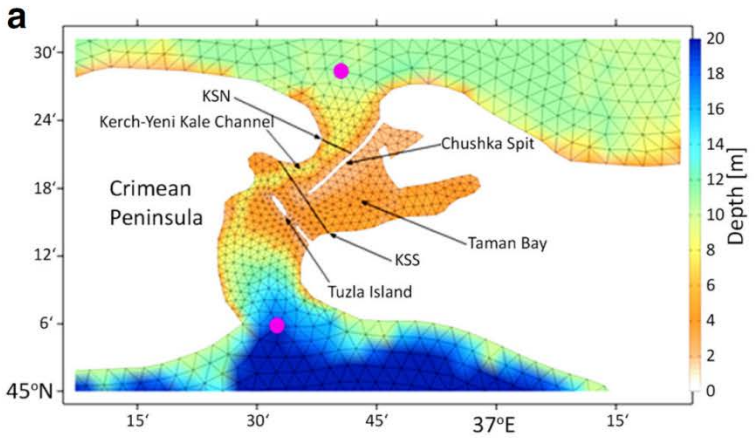


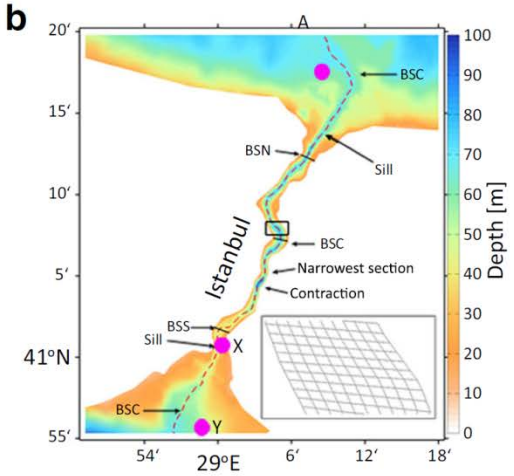
Validation (salinity and temperature)

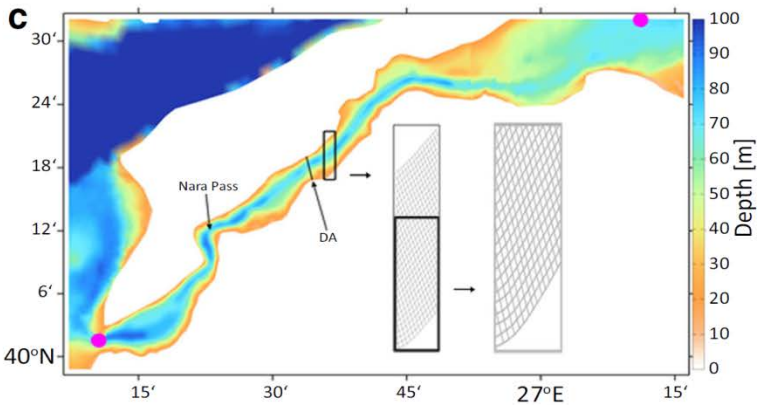
Black Sea-Mediterranean

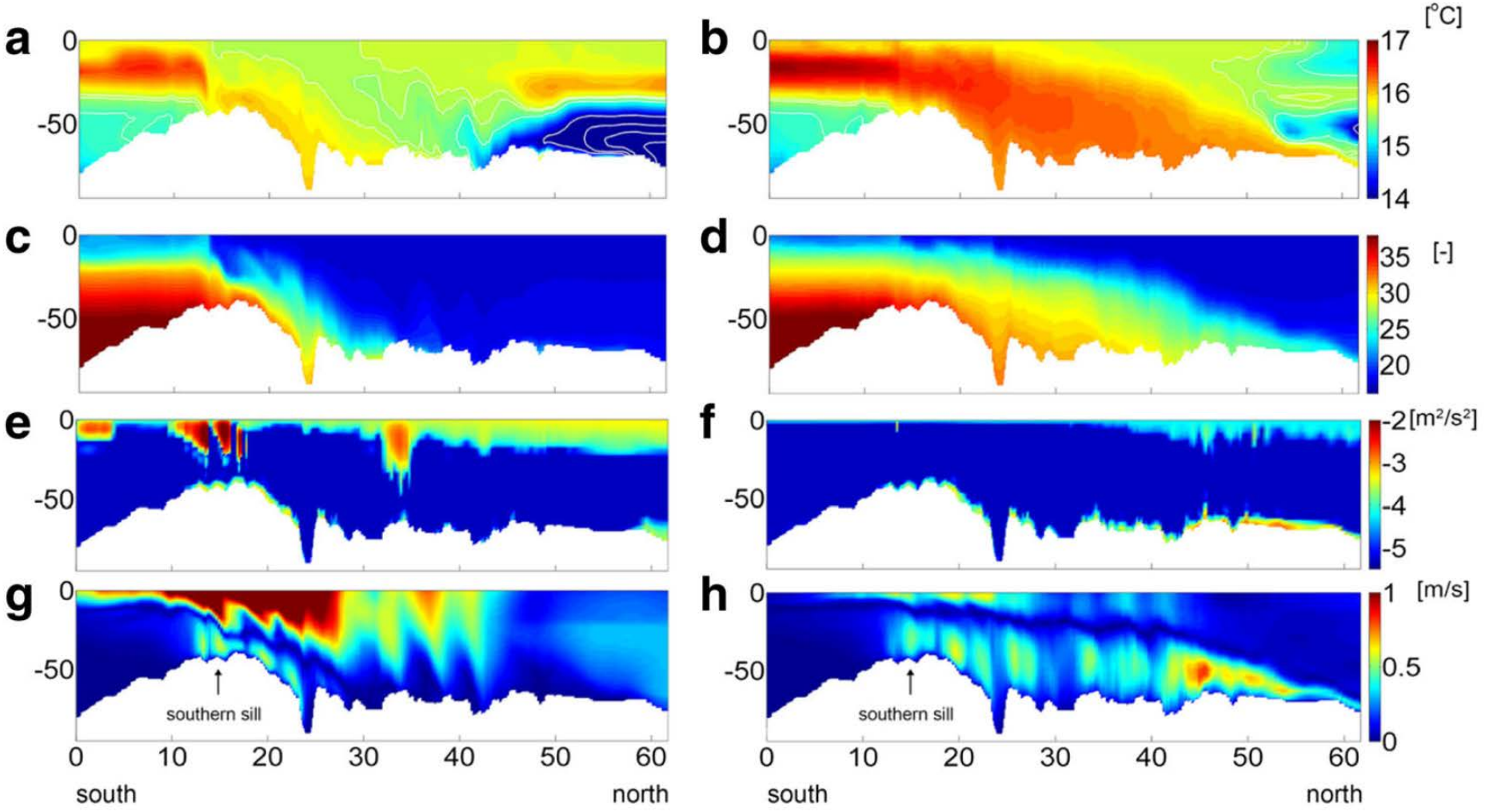
Êarlier problelems and what/how has been sonved

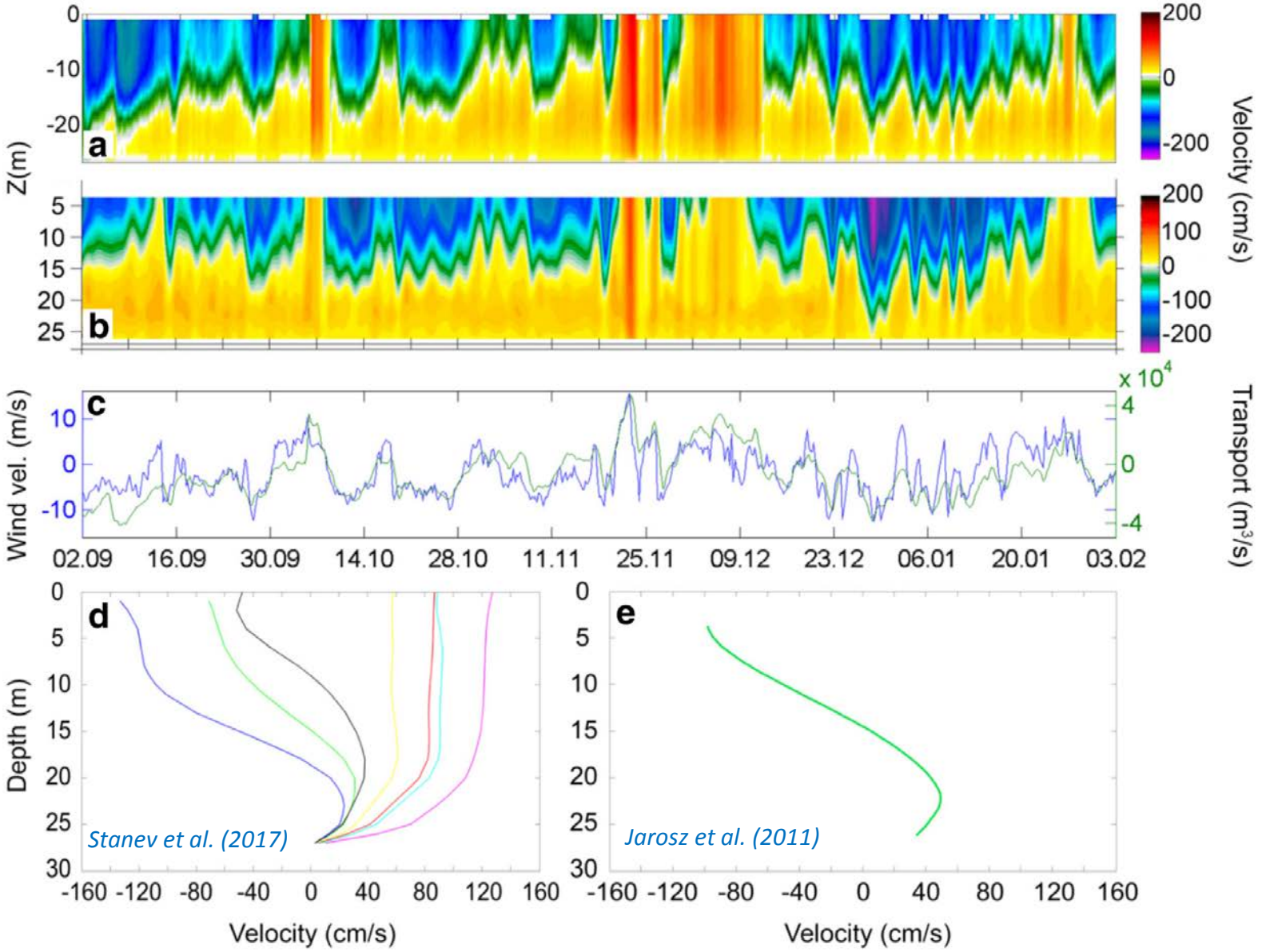








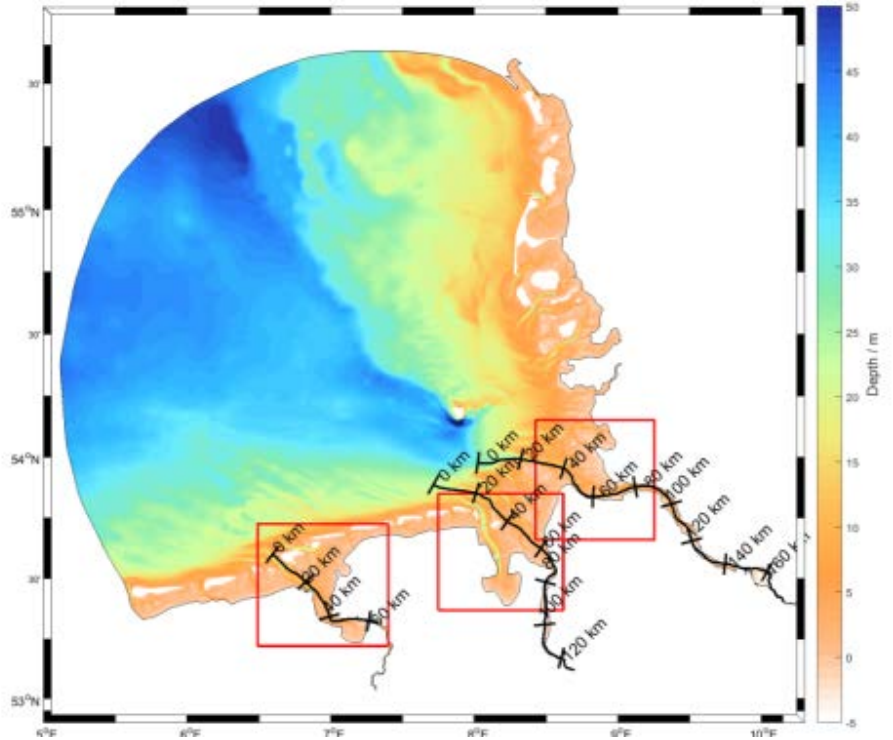

a
b
c
d
e
f
g
h
0
-50
[°C]
17
16
15
14
[-]
35
30
25
20
-2
-3
-4
-5
[m²/s²]
1
0.5
0
[m/s]
southern sill
southern sill
0
10
20
30
40
50
60
south
north

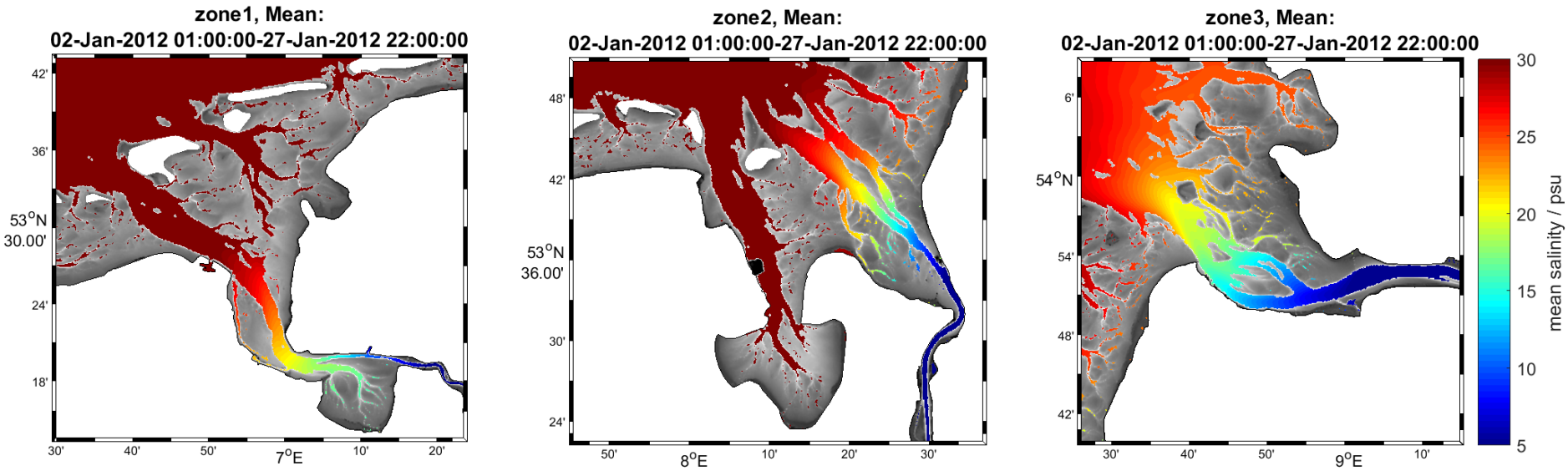


Stanev et al. (2017)

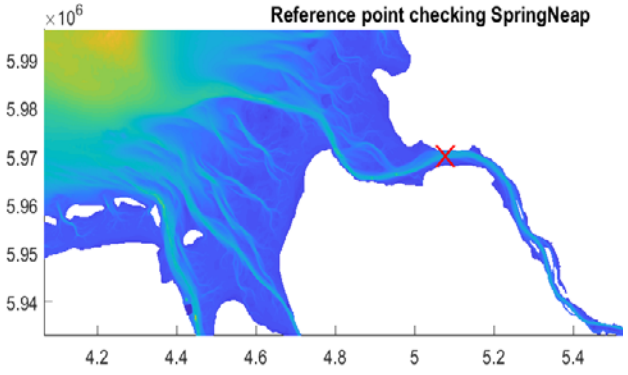
Jarosz et al. (2011)

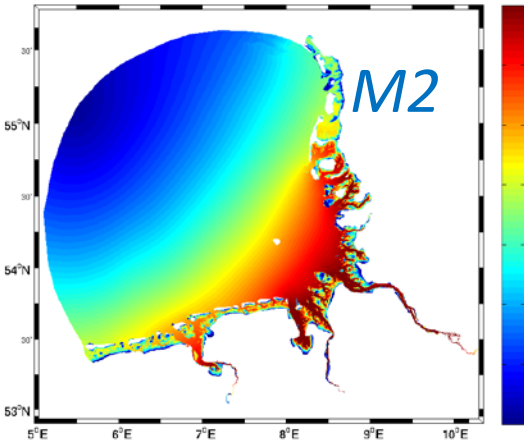
(Small) Estuaries

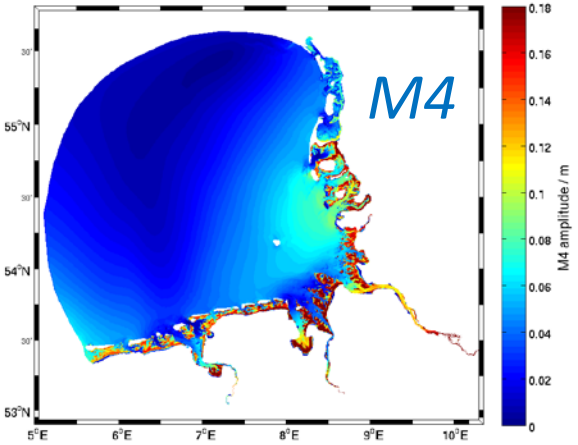




Average Salinity

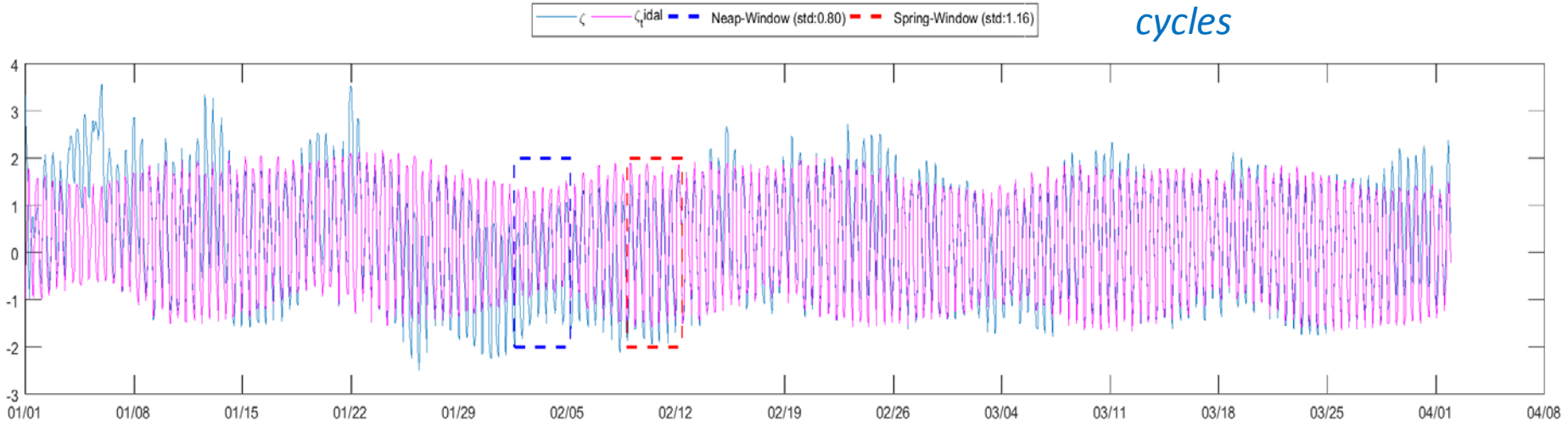


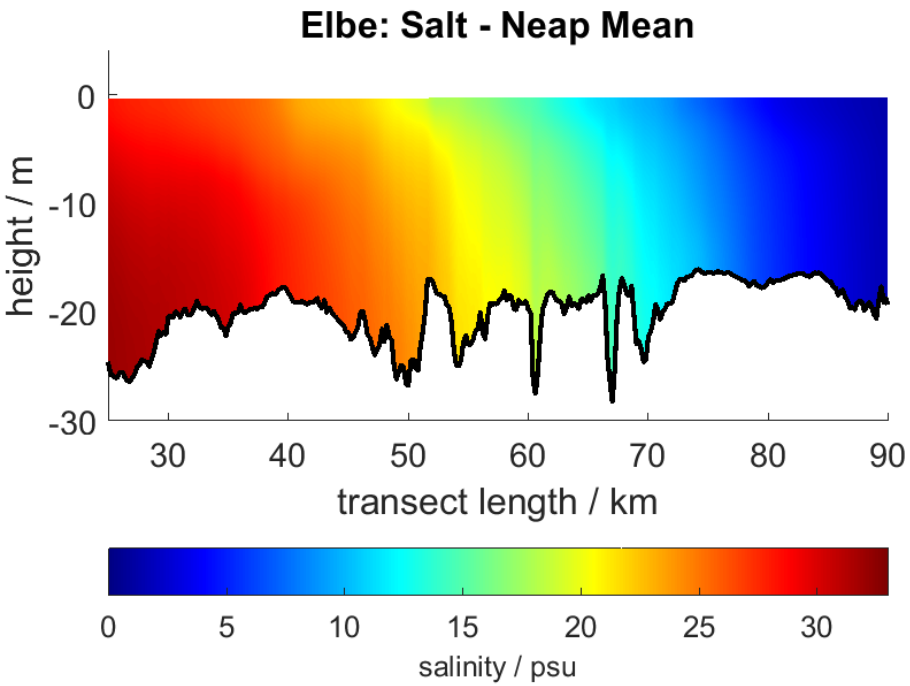


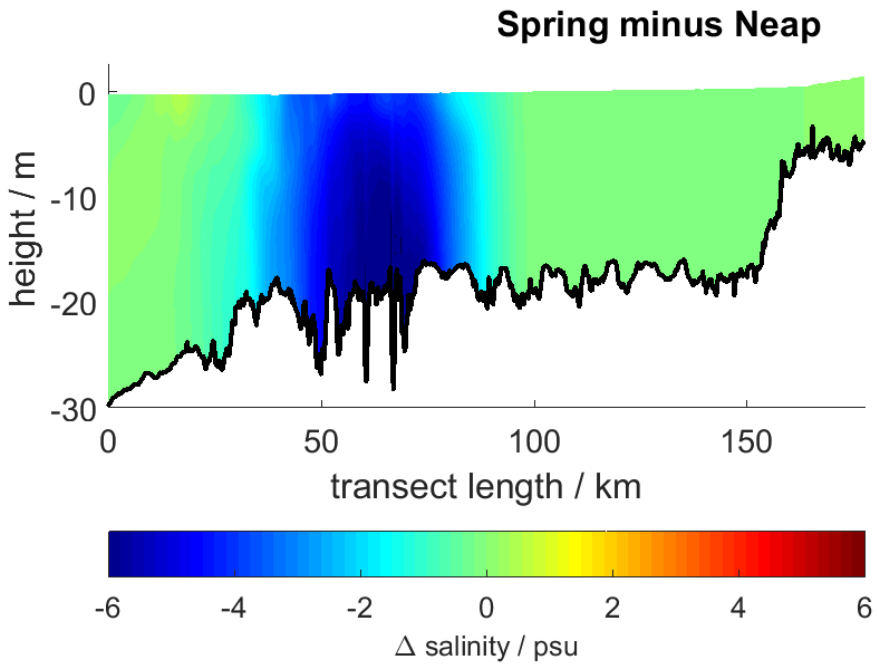


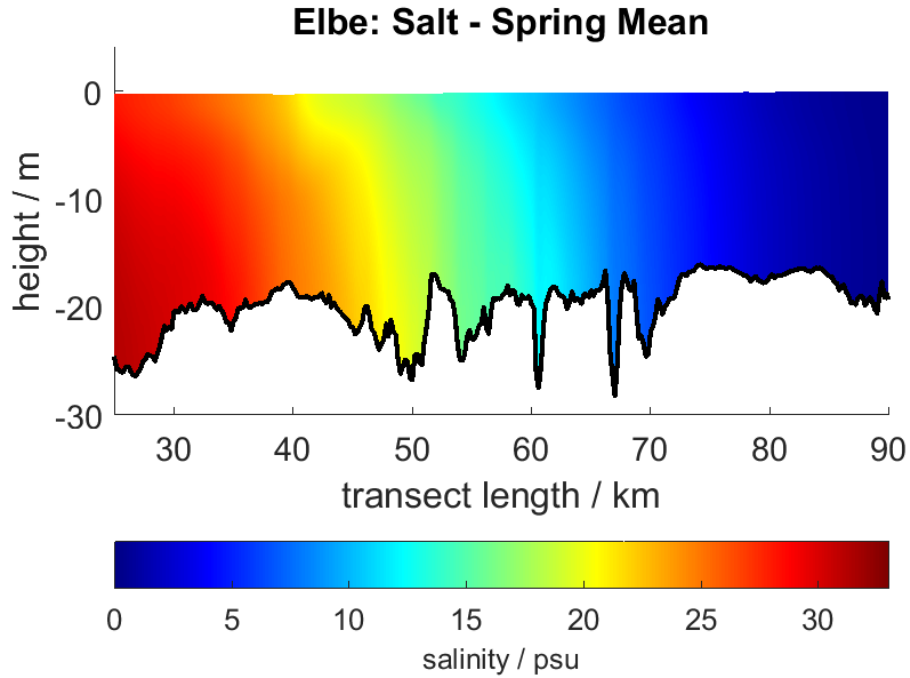
Spring Neap period
selected based on harmonic analysis (purple)
for time Series (blue) taken at marked Point.

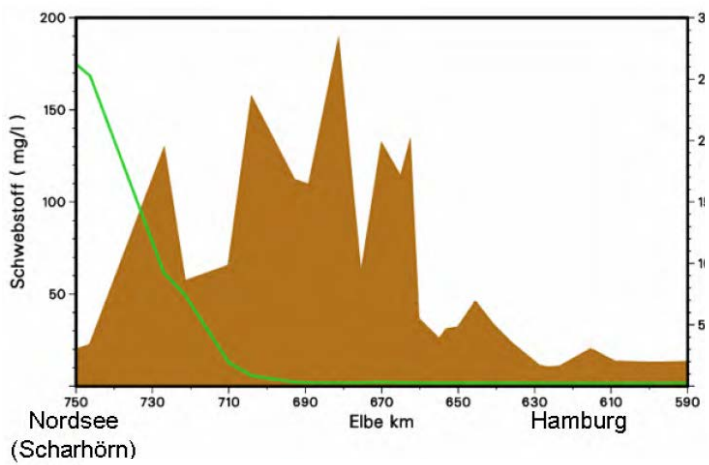
Windows cover 87 hours = 7.005 M2 cycles

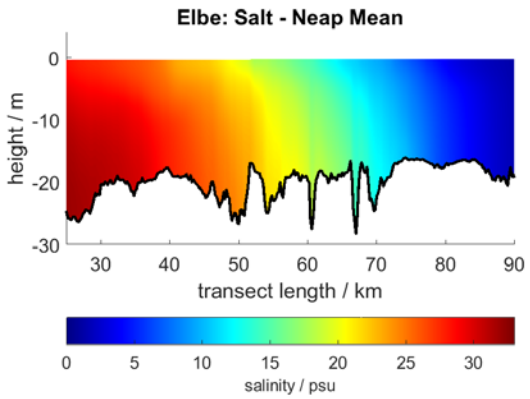


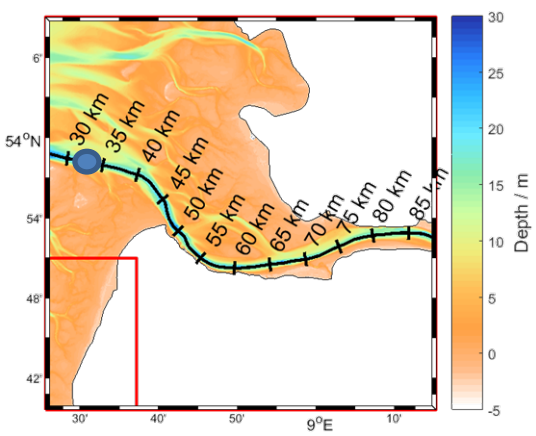

Elbe: Salt - Neap Mean
height / m
0
-10
-20
-30
30
40
50
60
70
80
90
transect length / km
0
5
10
15
20
25
30
salinity / psu

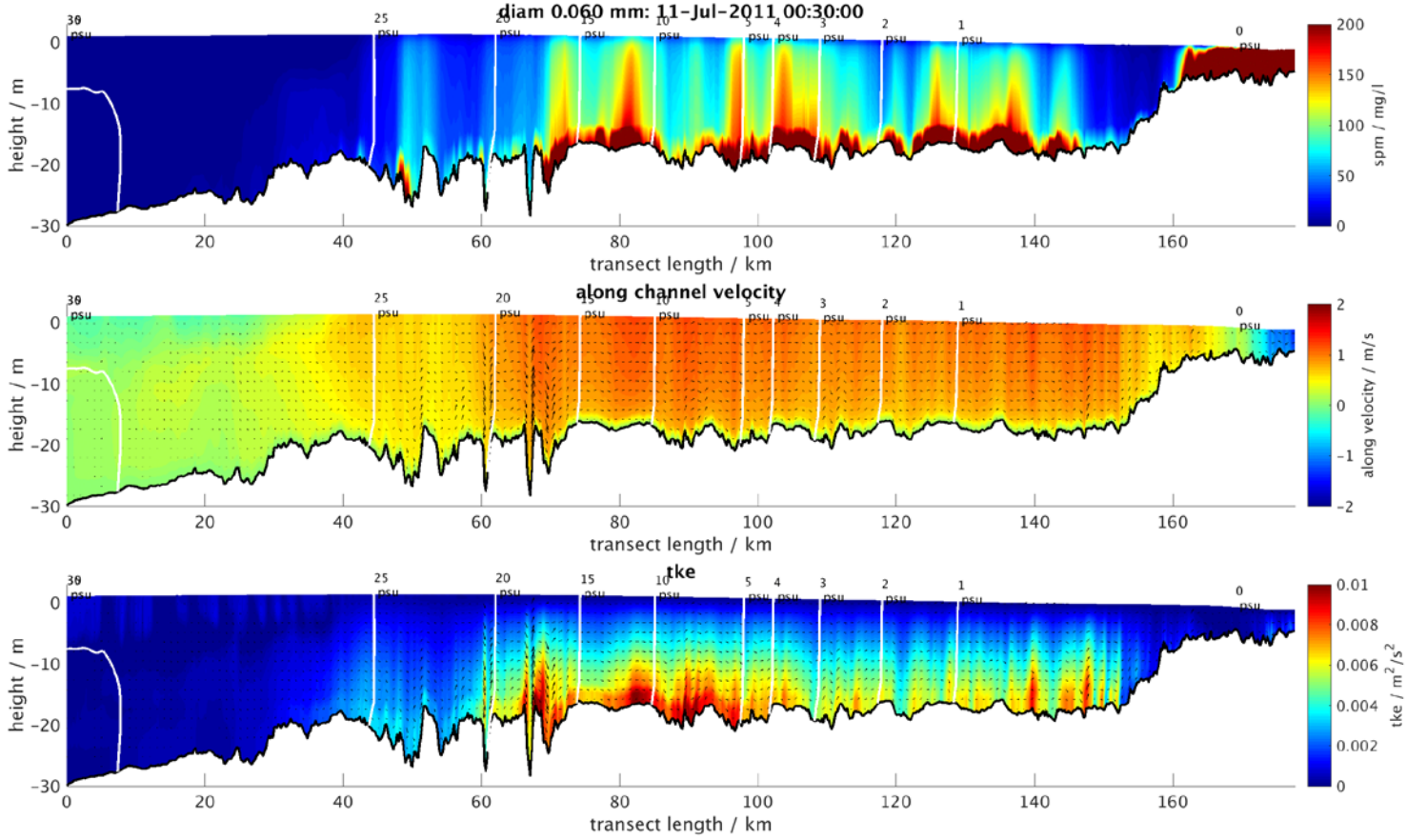

Spring minus Neap
height / m
0
-10
-20
-30
0
50
100
150
transect length / km
-6
-4
-2
0
2
4
6
Δ salinity / psu

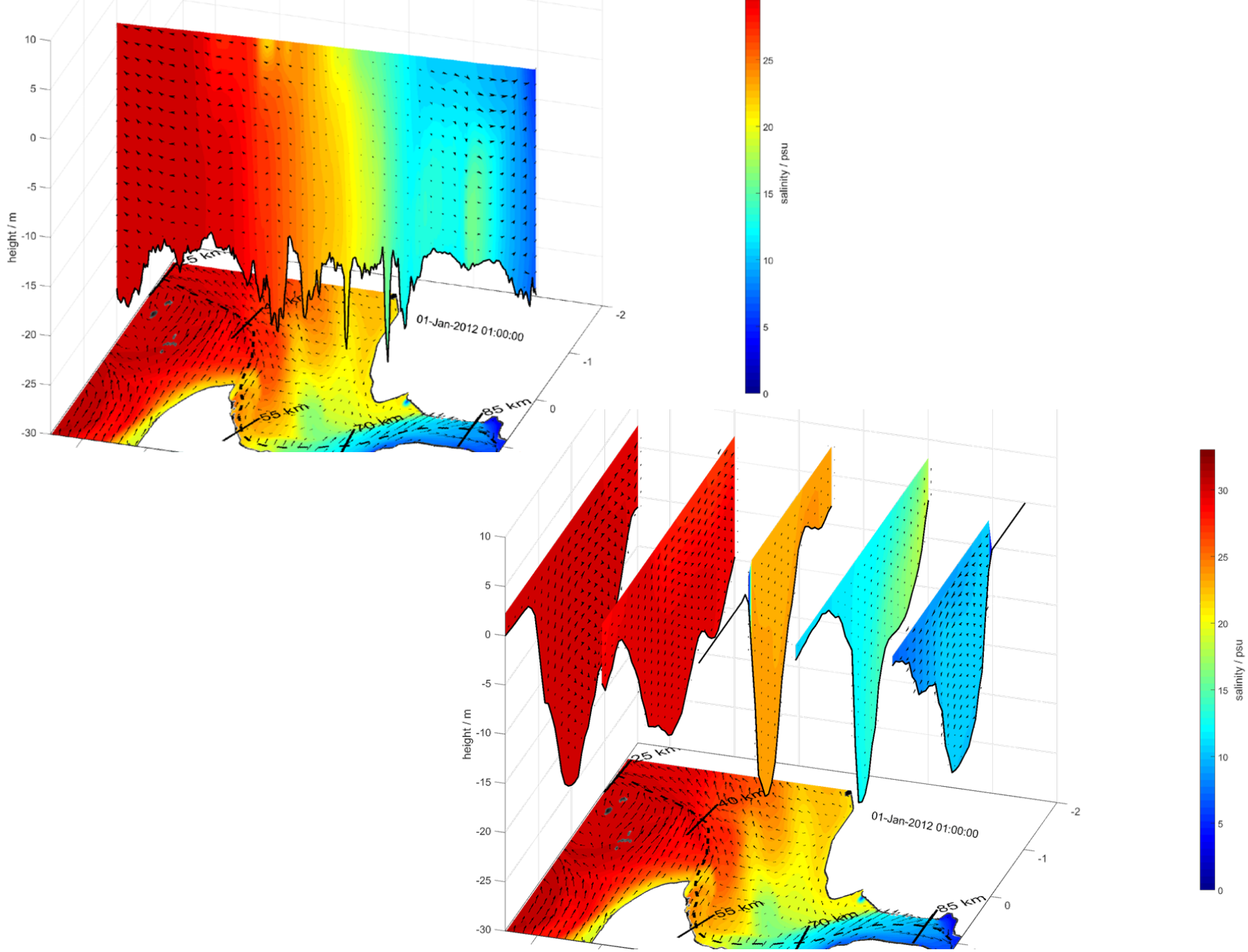

Elbe: Salt - Spring Mean
height / m
0
-10
-20
-30
30
40
50
60
70
80
90
transect length / km
0
5
10
15
20
25
30
salinity / psu


Schwebstoff (mg/l)
Elbe km
Nordsee
(Scharhörn)
Hamburg

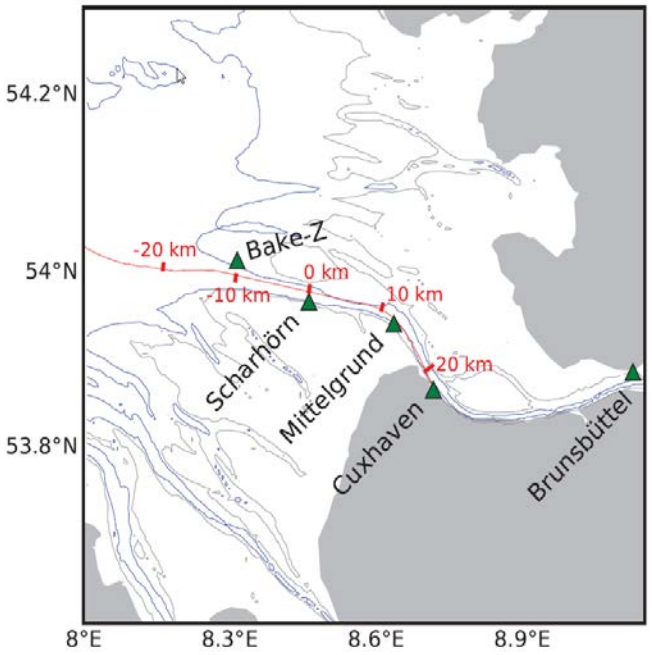

Elbe: Salt - Neap Mean
height / m
transect length / km
salinity / psu

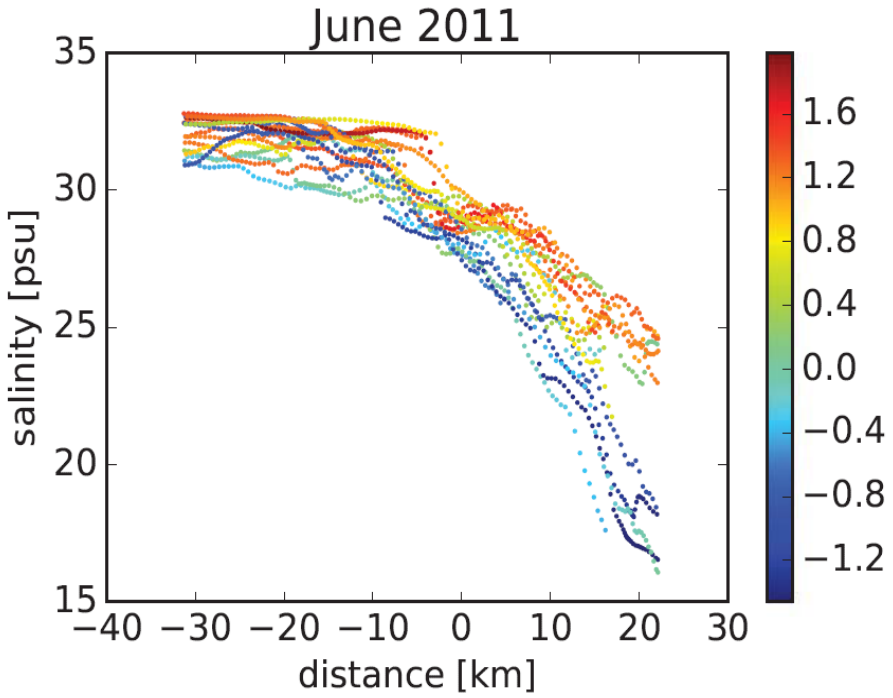

30 km
35 km
40 km
45 km
50 km
55 km
60 km
65 km
70 km
75 km
80 km
85 km
54°N
9°E
Depth / m

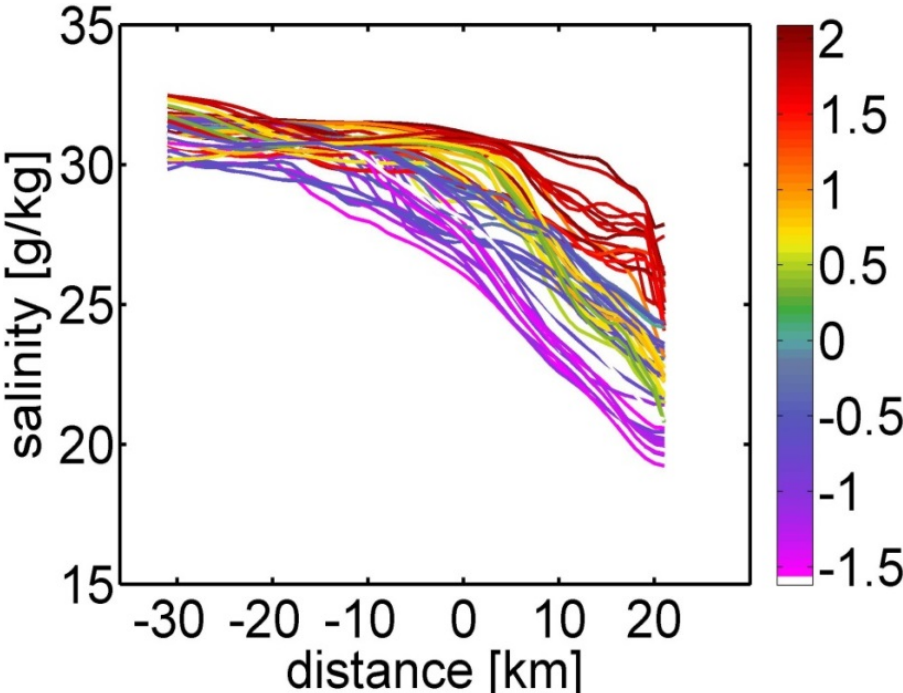

diam 0.060 mm: 11-Jul-2011 00:30:00
height / m
transect length / km
spm / mg/l
along channel velocity
along velocity / m/s
tke
tke / m²/s²

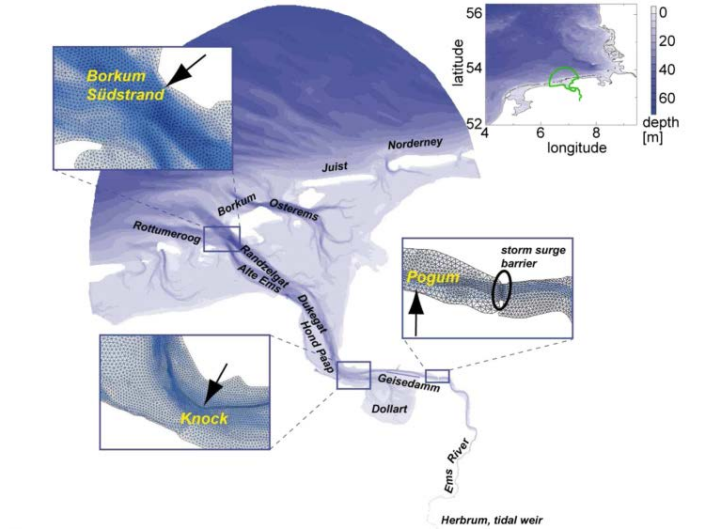

height / m
10
5
0
-5
-10
-15
-20
-25
-30
5 km
01-Jan-2012 01:00:00
55 km
70 km
85 km
-2
-1
0
salinity / psu
0
5
10
15
20
25
30
height / m
10
5
0
-5
-10
-15
-20
-25
-30
25 km
40 km
01-Jan-2012 01:00:00
55 km
70 km
85 km
-2
-1
0
salinity / psu
0
5
10
15
20
25
30

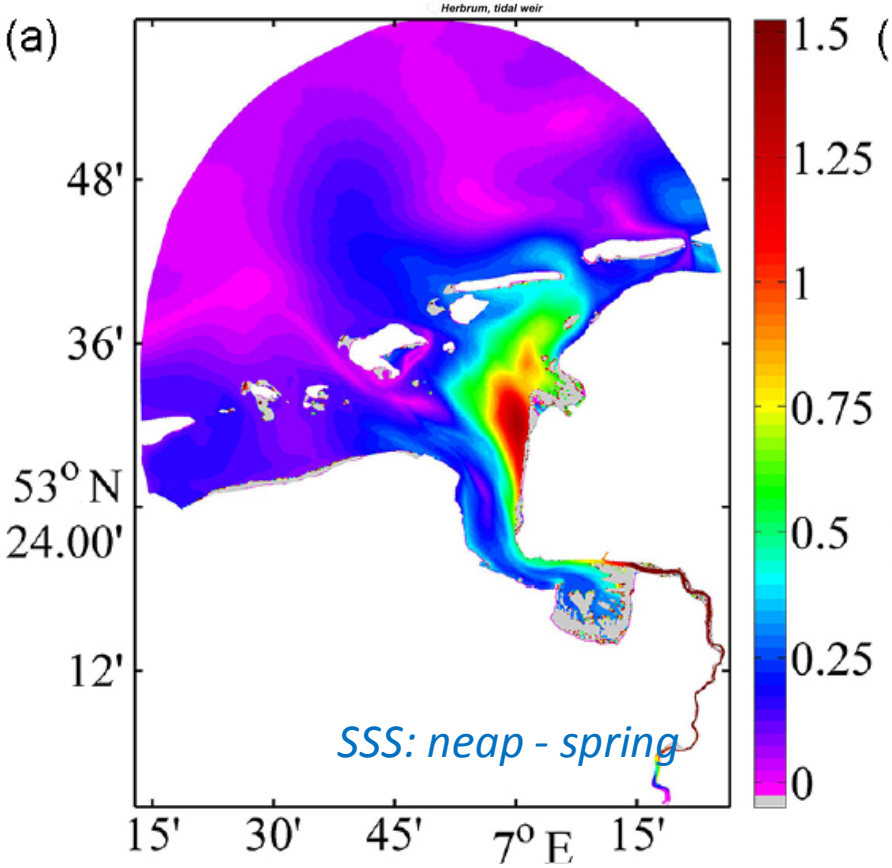
Model validation: Salinity front as seen by the model and observations

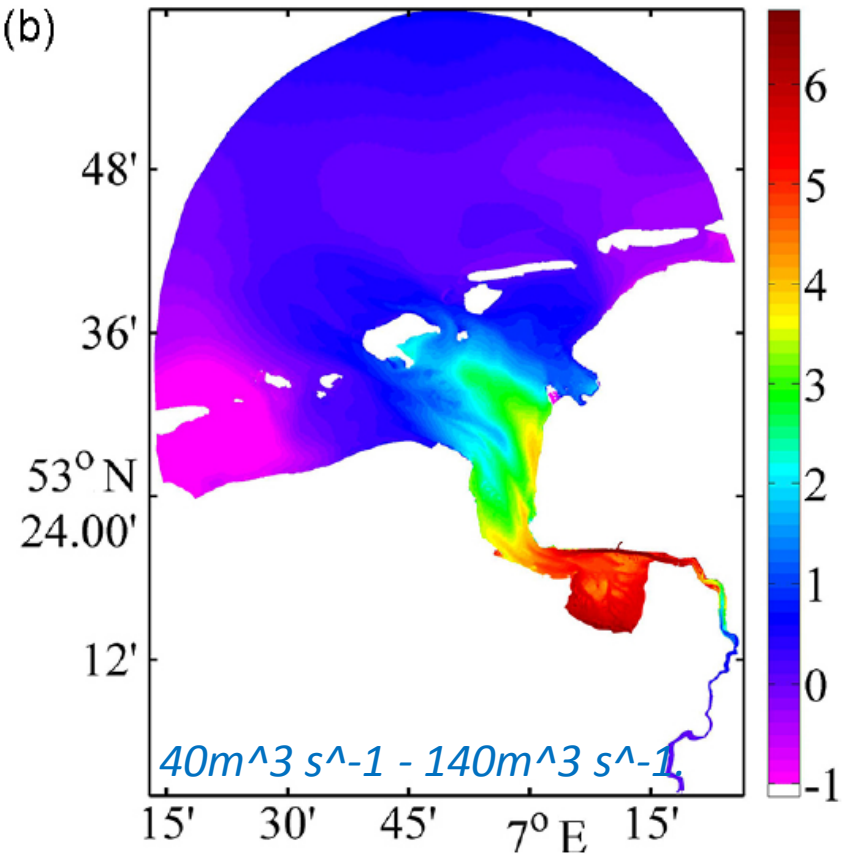








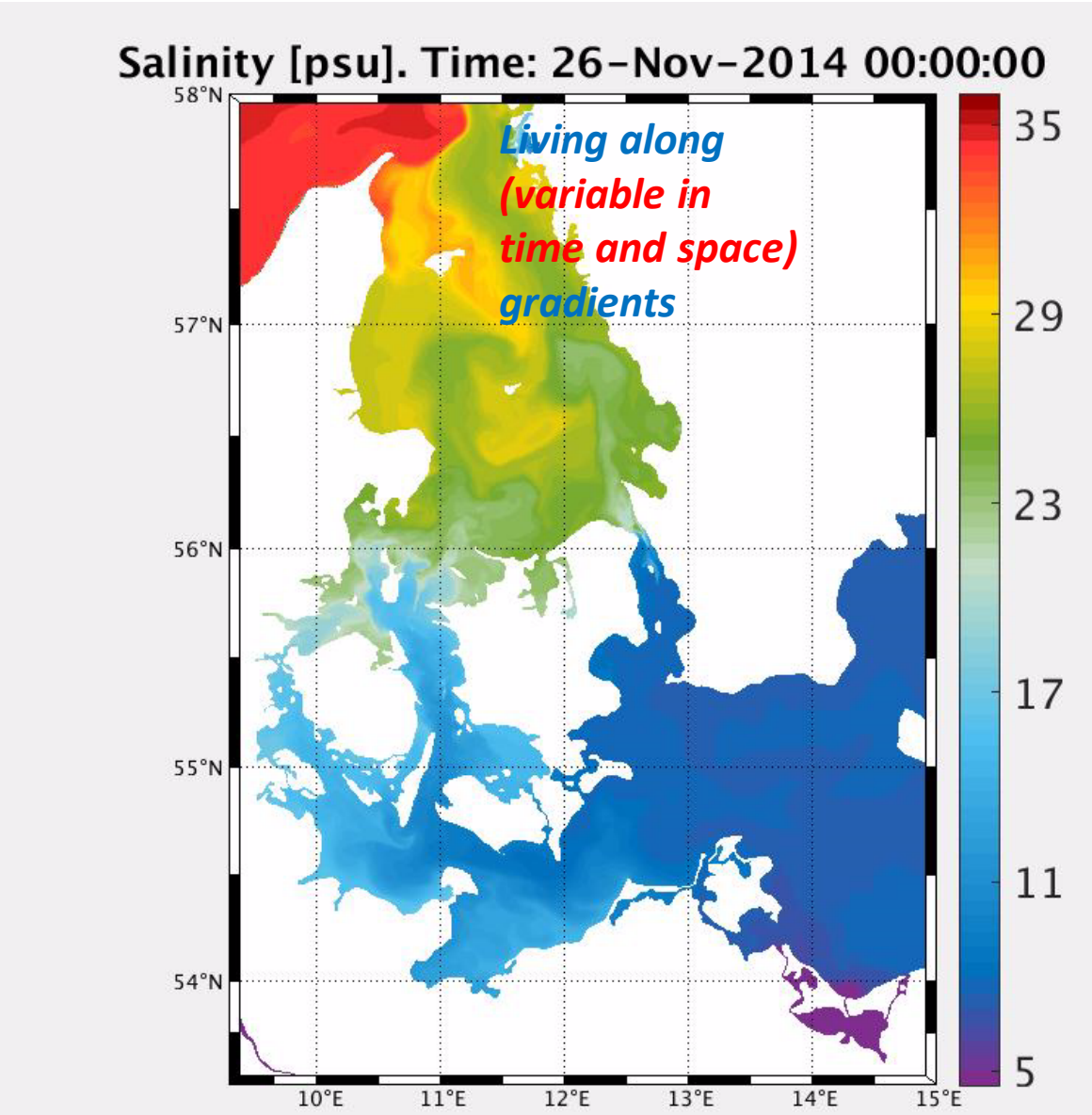




Stanev et al. (2016,ODYN)

Conclusions:

1. *The benefit of using unstructured-grid models*
2. *Validation of exchanges in the straits simulated in different models*
3. *Understanding of physics of estuaries and straits.*
4. *Adequately account for the coupling between hydrology and oceanography*



bottom Salinity