Coastal Observation and a Forecasting System for the German Bight

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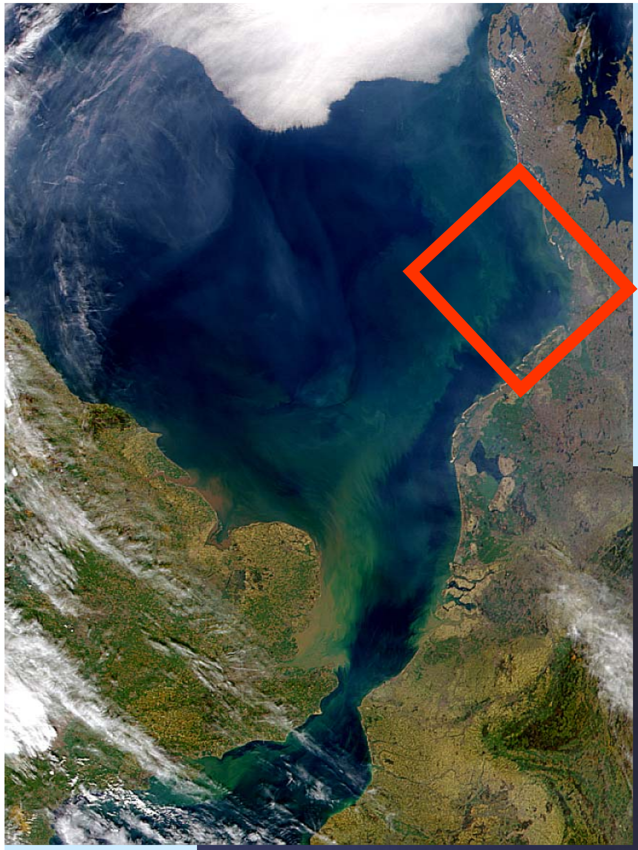
GKSS
FORSCHUNGSZENTRUM
in der HELMHOLTZ-GEMEINSCHAFT

North Sea
German Bight
Wadden Sea



How the coastal ocean will be affected by changes in the tidal currents and the sediment supply due to climatic change

Monitoring and forecasting these changes can only be addressed by a combination of state-of-the-art observations and modelling activities.

Objective measures of uncertainties in the state estimates and forecasts are needed.

Improving the performance of observing and forecasting systems requires a clear identification of relevant parameters and representation of multiple physical and biogeochemical processes in numerical models.

Outline

- Observations
- Numerical Modelling
- Model Validations
- States Estimates
- Conclusions

Aims of this Talk

Address regional observations and predictions with a focus on the German Bight and Wadden Sea

Identify further perspectives of (pre)operational oceanography

Integrated Coastal Observation Network (ICON)

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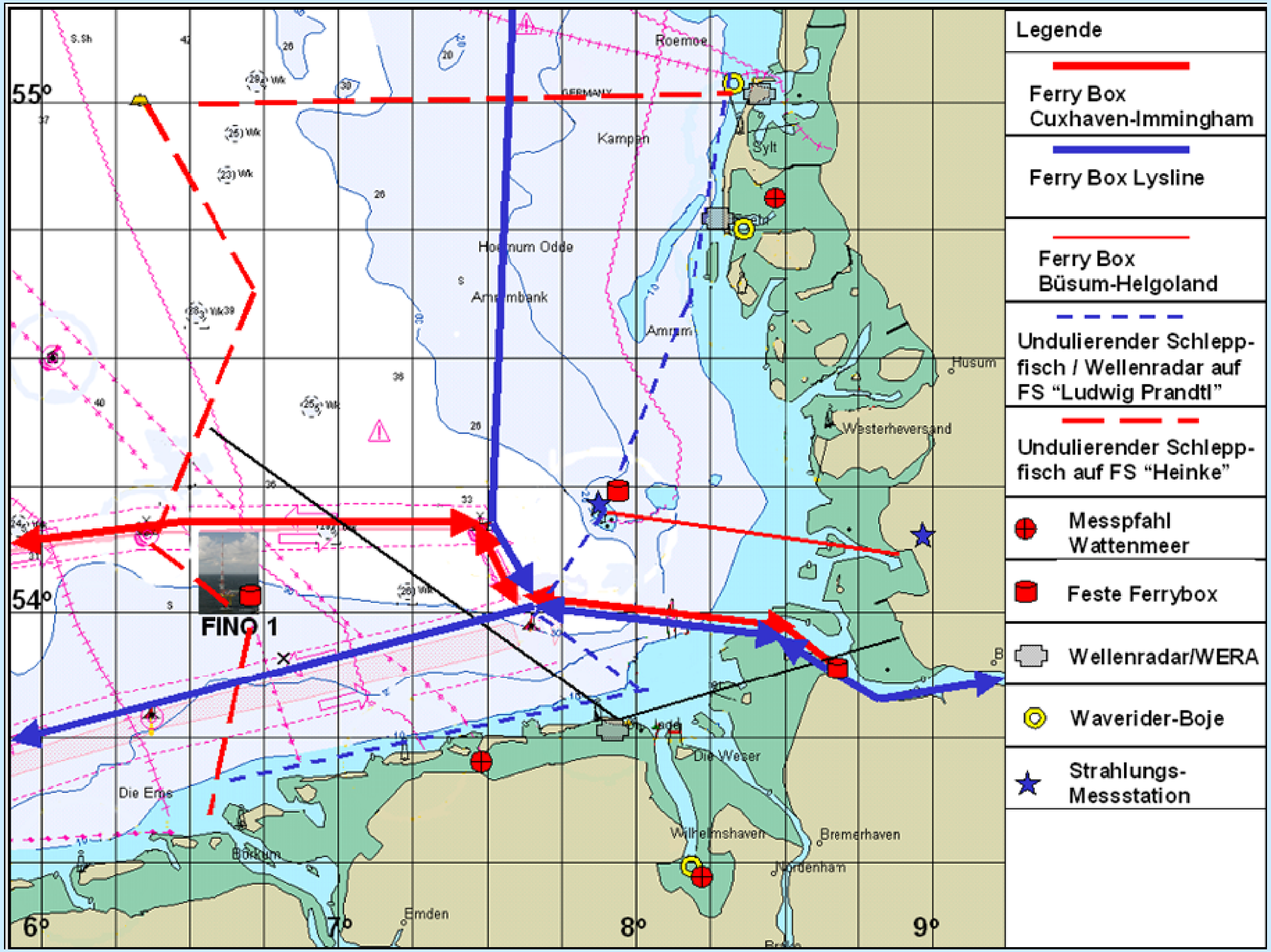
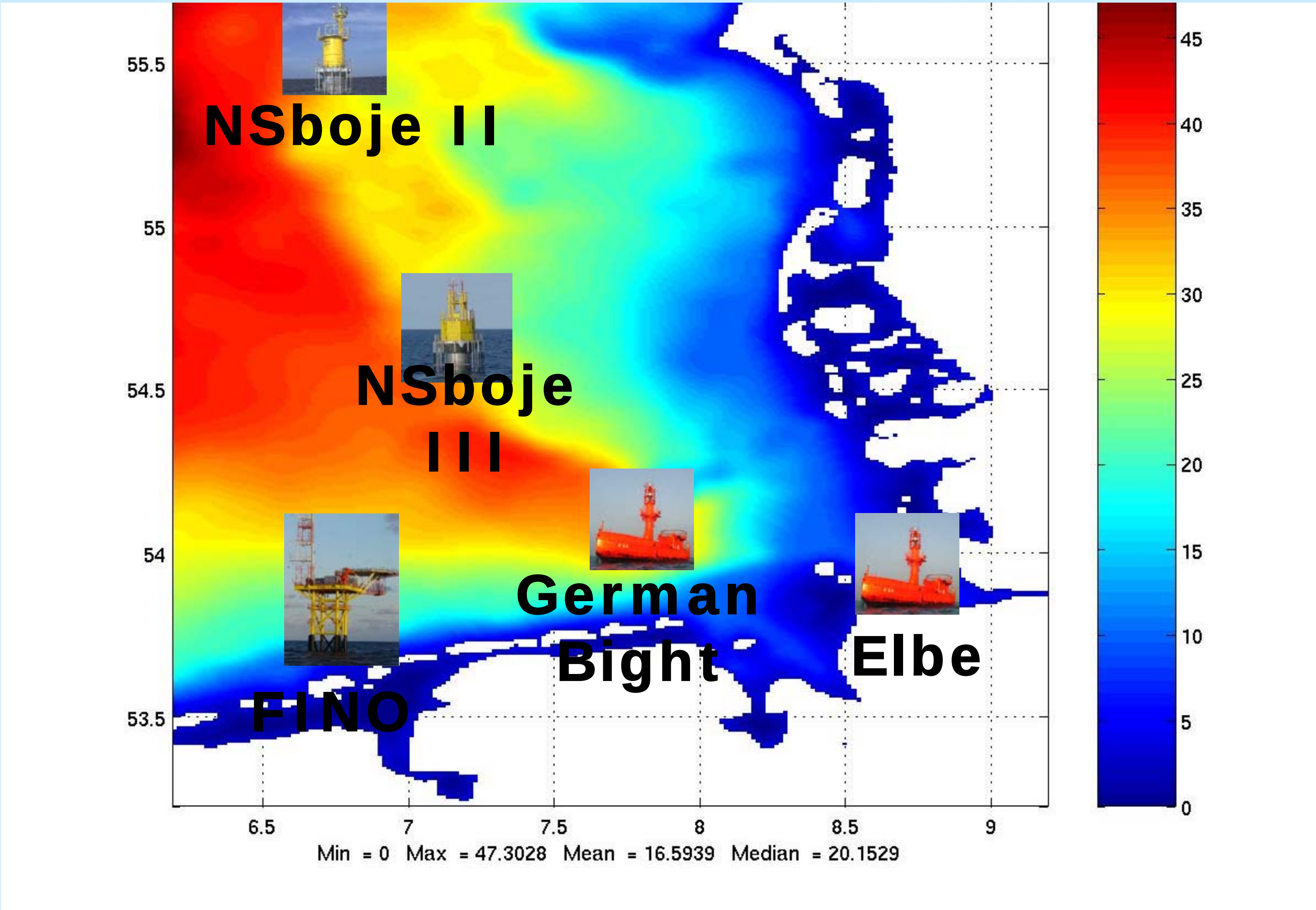
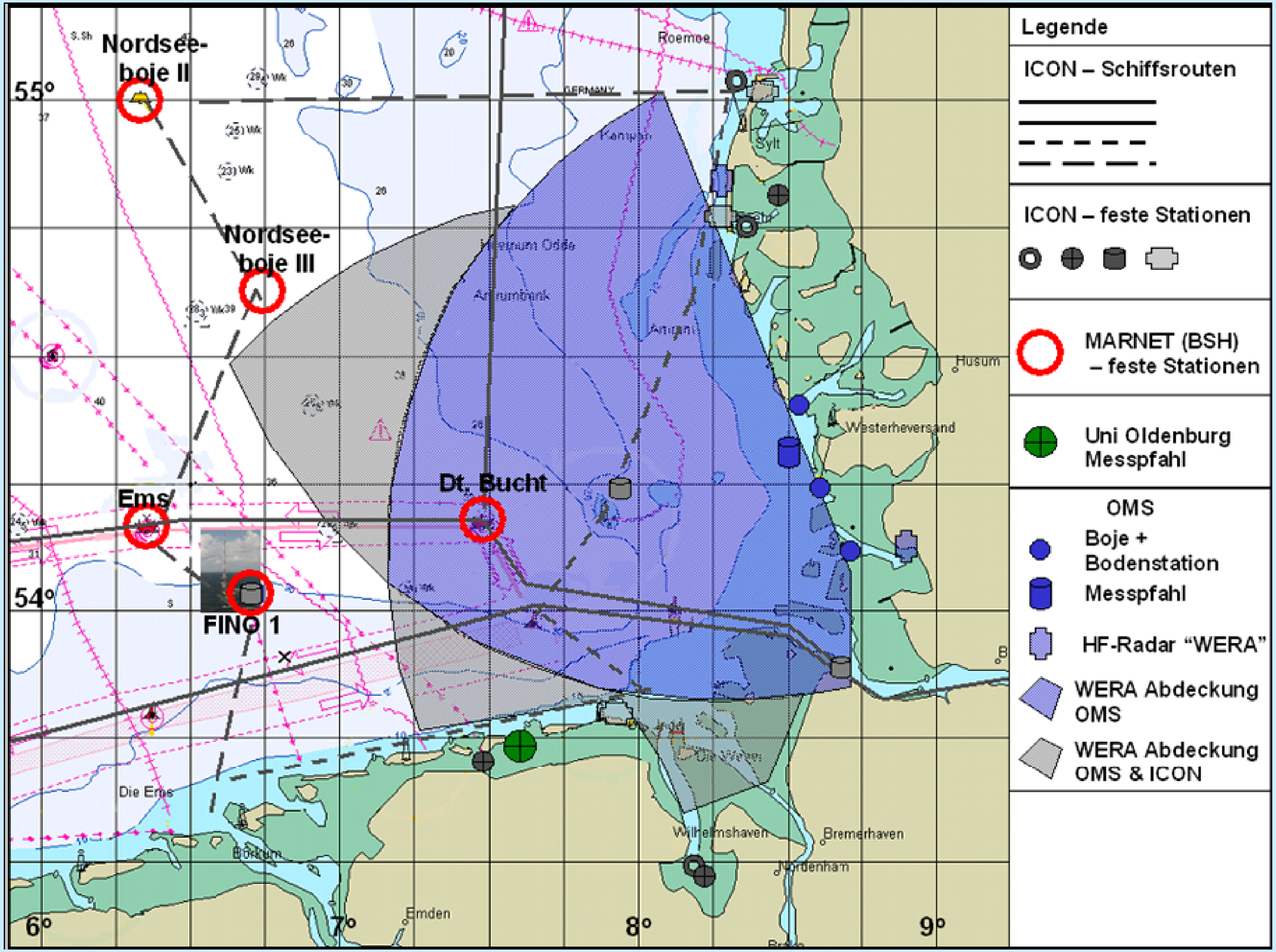


Buoy Data



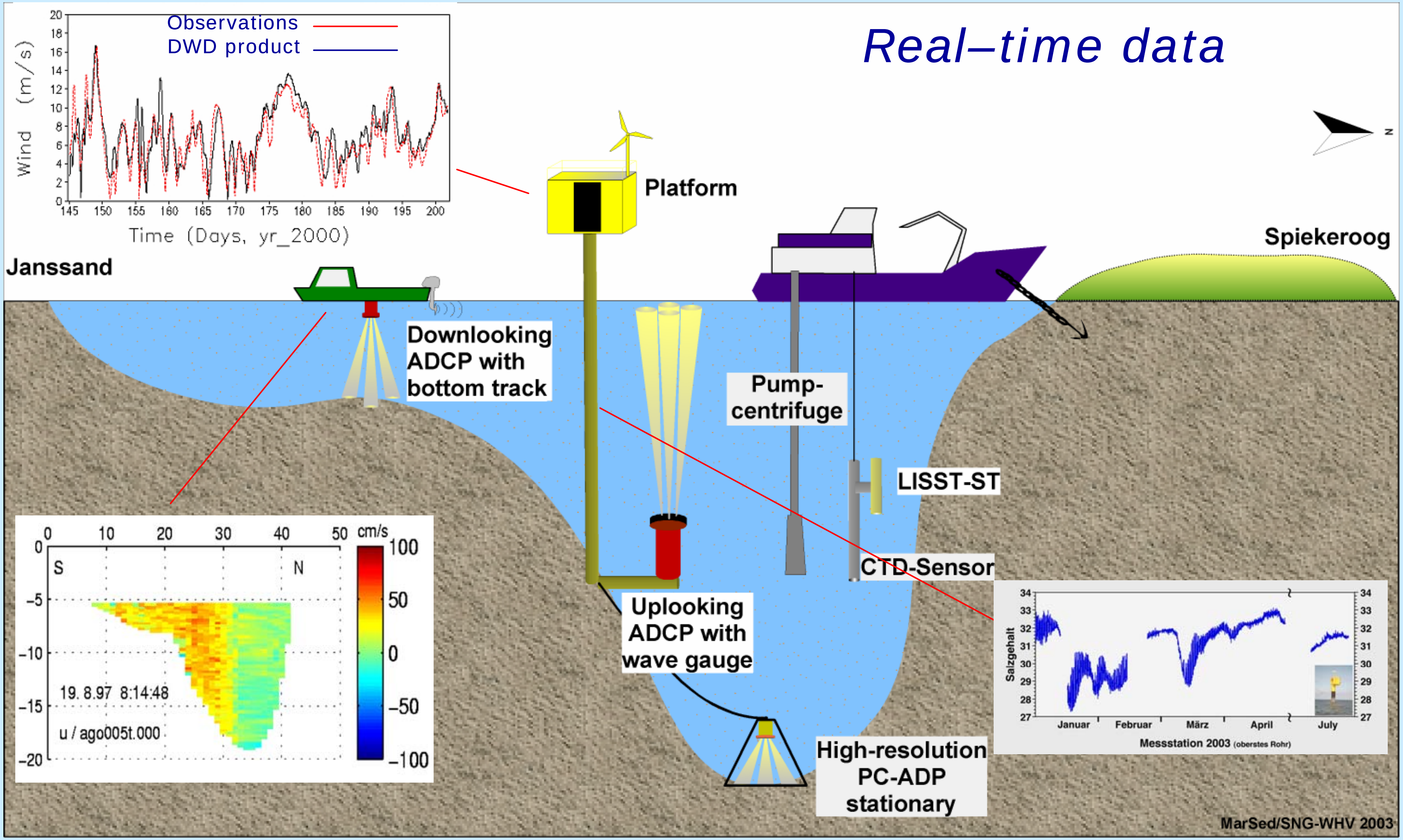
NSboje II
NSboje III
German Bight
FINO
Elbe
55.5
55
54.5
54
53.5
6.5
7
7.5
8
8.5
9
45
40
35
30
25
20
15
10
5
0
Min = 0 Max = 47.3028 Mean = 16.5939 Median = 20.1529

WERA Data

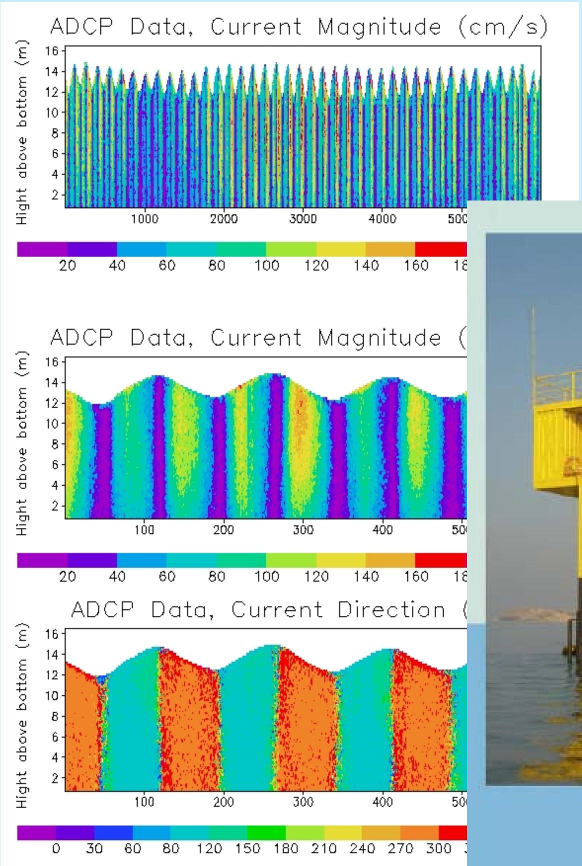


Nordsee-boje II
Nordsee-boje III
Ems
Dt. Bucht
FINO 1
55°
54°
6°
7°
8°
9°
Roemoe
Sylt
Husum
Westerheversand
Wilhelmshaven
Bremerhaven
Nordenham
Borkum
Emden
Die Ems
Legende
ICON – Schiffsrouten
ICON – feste Stationen
MARNET (BSH) – feste Stationen
Uni Oldenburg Messpfahl
OMS
Boje + Bodenstation
Messpfahl
HF-Radar "WERA"
WERA Abdeckung OMS
WERA Abdeckung OMS & ICON

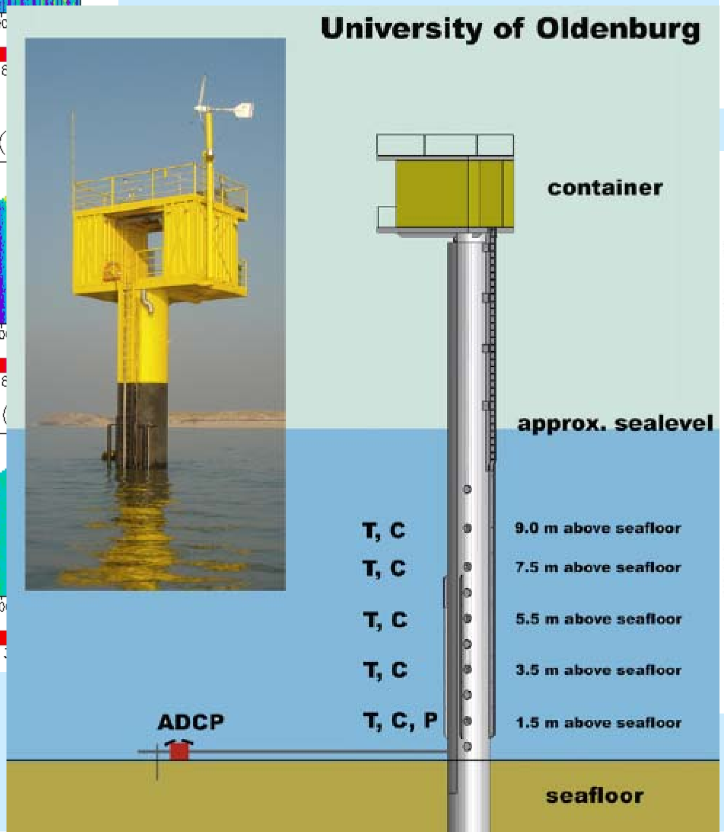
Other Data

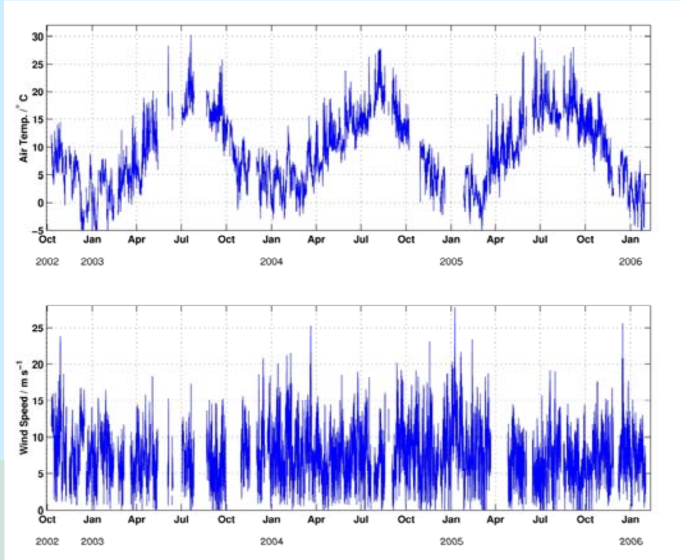

Real–time data
Observations
DWD product
Wind (m/s)
Time (Days, yr_2000)
Platform
Janssand
Spiekeroog
Downlooking ADCP with bottom track
Pump-centrifuge
LISST-ST
CTD-Sensor
Uplooking ADCP with wave gauge
High-resolution PC-ADP stationary
S
N
cm/s
19. 8.97 8:14:48
u / ago005t.000
Salzgehalt
Januar
Februar
März
April
July
Messstation 2003 (oberstes Rohr)
MarSed/SNG-WHV 2003

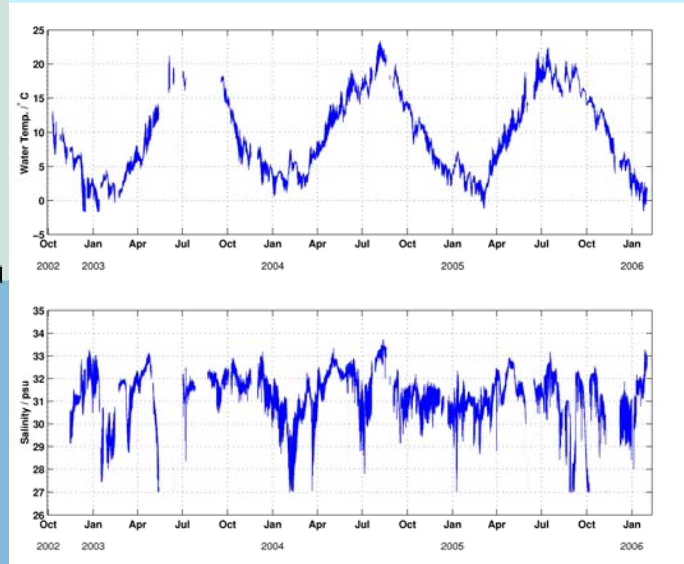
RG-WATT Data Station: Data are Already Extensively Used to Calibrate the WATT-Model



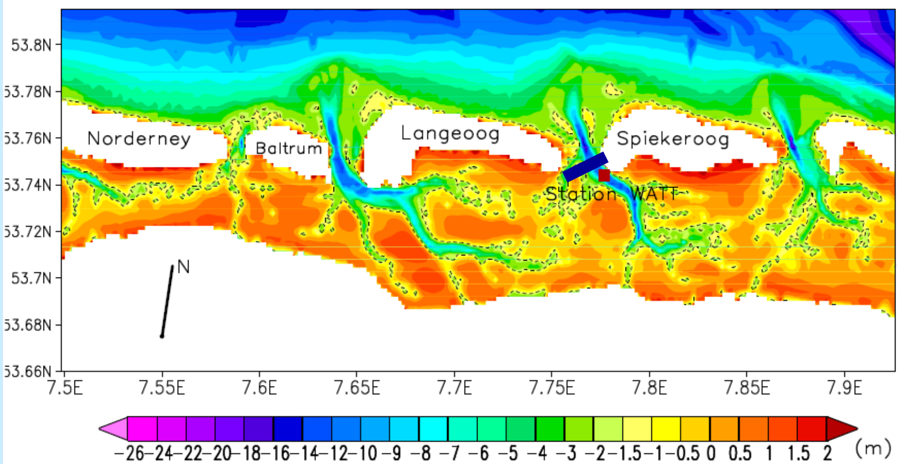
Senkenberg ADCP data



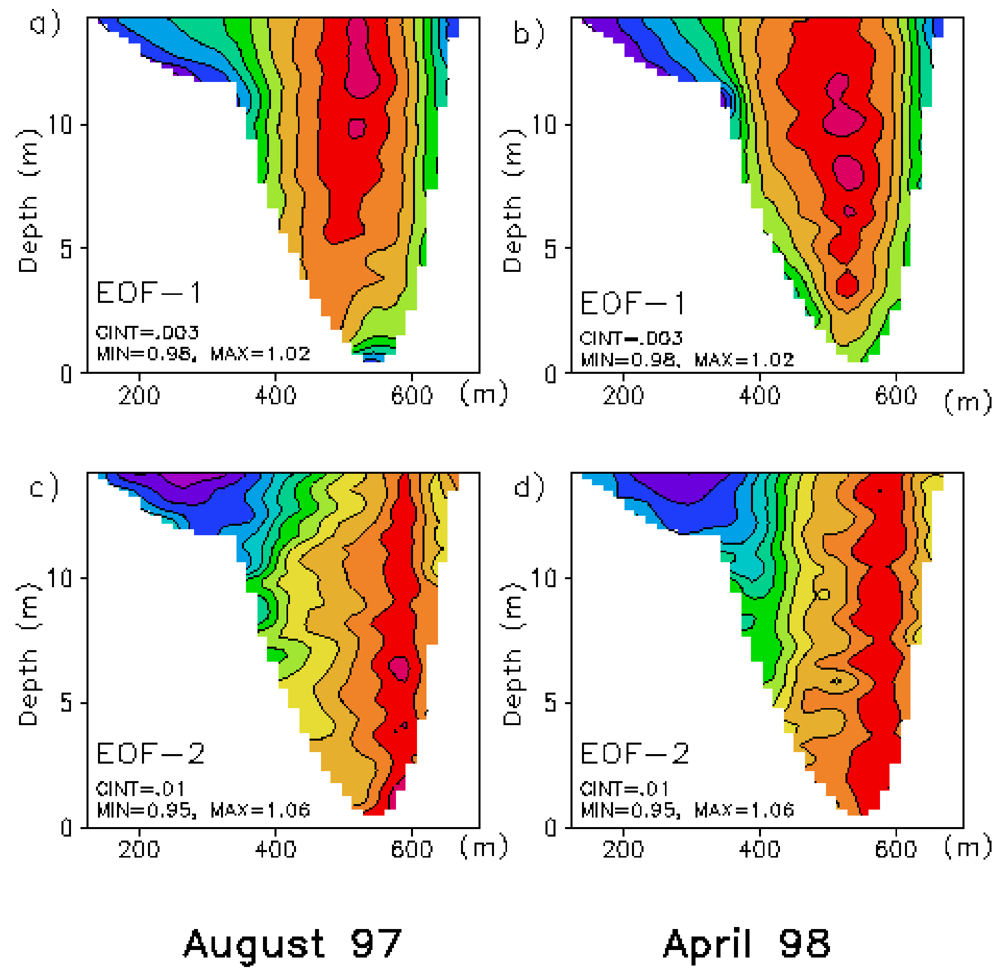




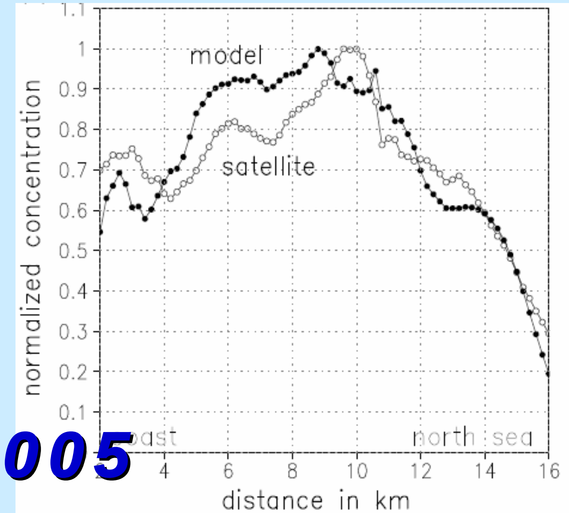
Uni-Oldenburg meteo- and hydro physical data



ADCP Transects

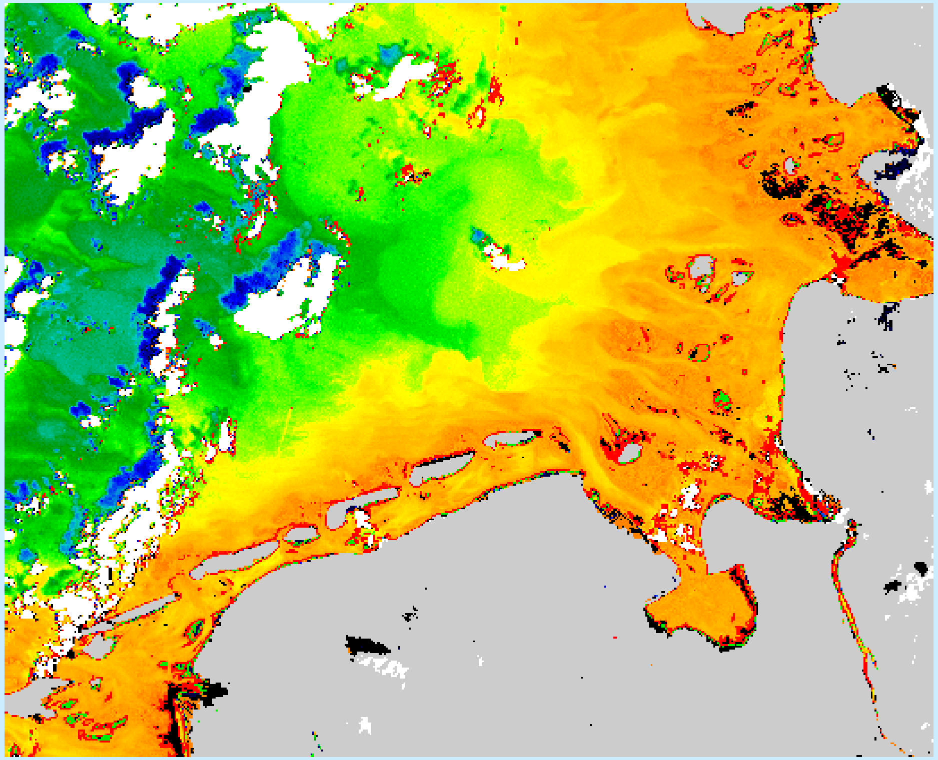


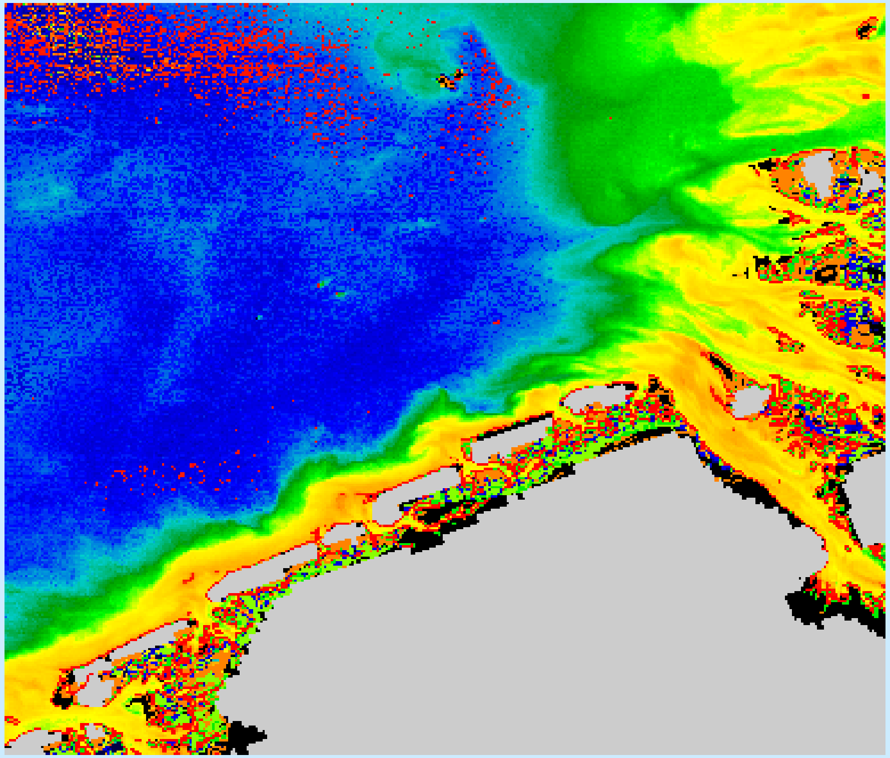
Use New Data:
MERIS TSM-300 m Data and numerical model simulations

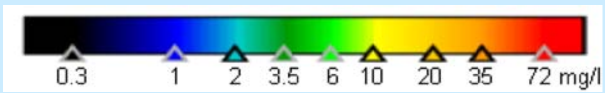


9 Sep 2004

19 Feb 2005



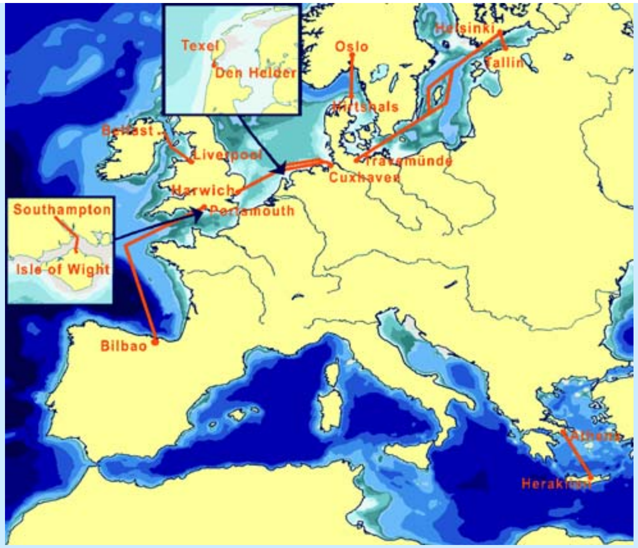


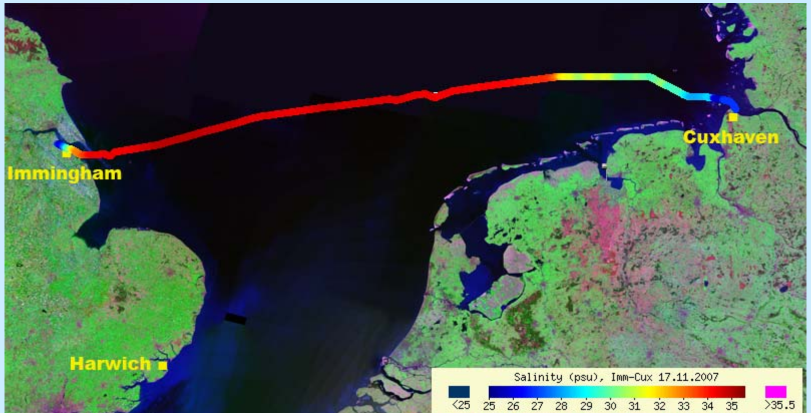


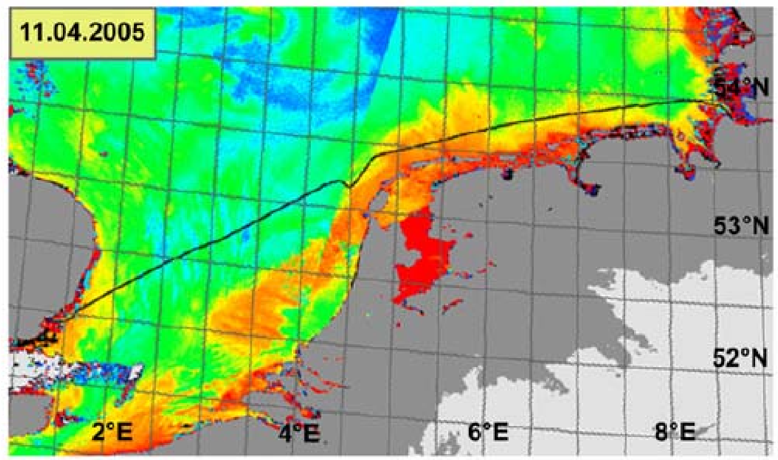
Gemein et al. (2006)

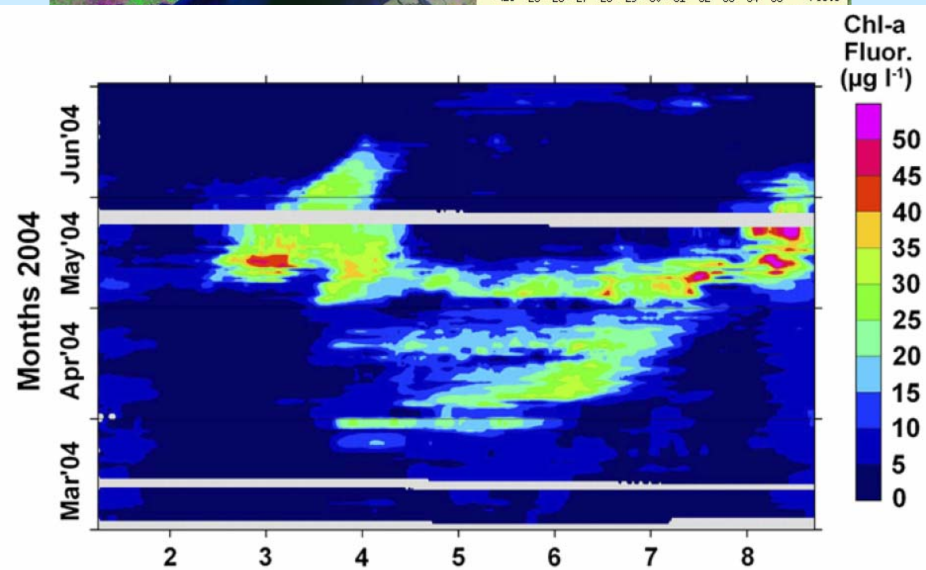
Ships of Opportunity (FerryBoxes)

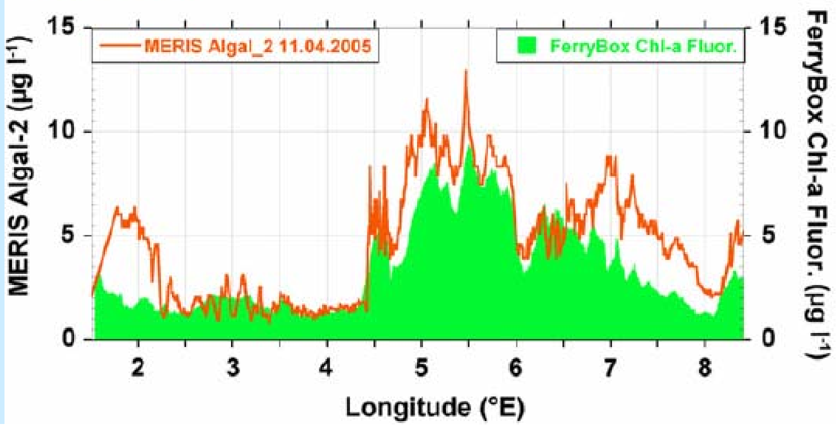
Data-Data, but also Data-Model Calibration is Needed





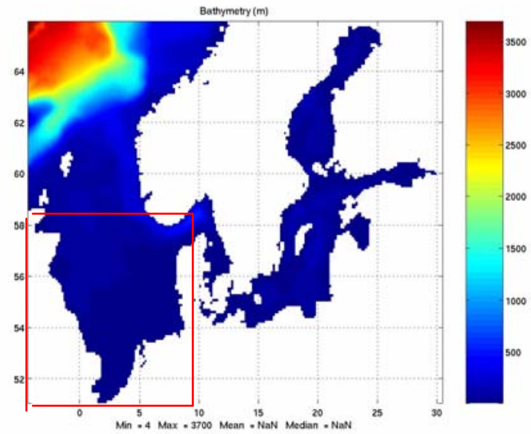




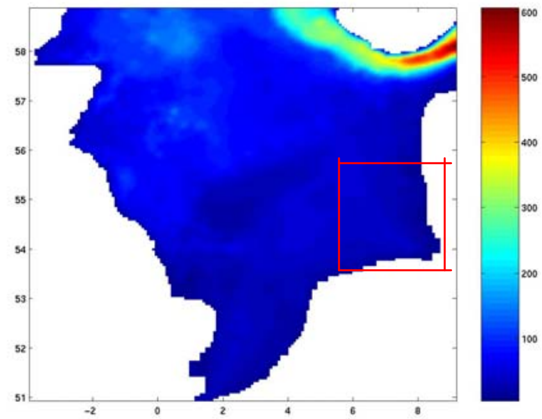


Numerical Modelling Can Help a Lot in the Regional Studies.

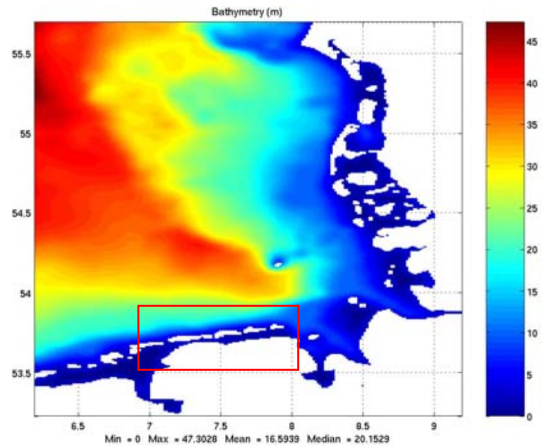
One-way Nested Modelling System



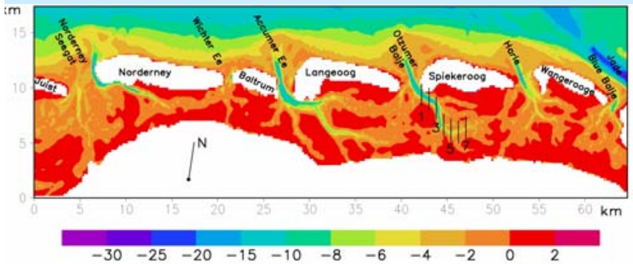
6 nm



3 nm



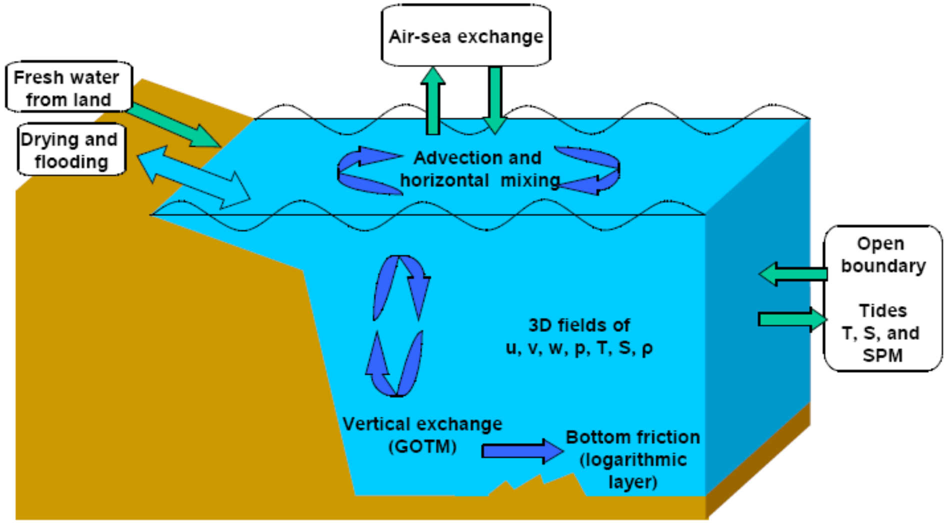
1 km



200 m

East Frisian Wadden Sea

GETM: flooding and drying



... Coupled with Sediment Transport Model

$$\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} + w\frac{\partial c}{\partial z} = \frac{\partial}{\partial z}\left(A_V\frac{\partial c}{\partial z}\right) + \frac{\partial}{\partial z}(w_s c) + D - E$$

$$D = v_s c_b \left(1 - \frac{\tau_b}{\tau_d}\right)$$

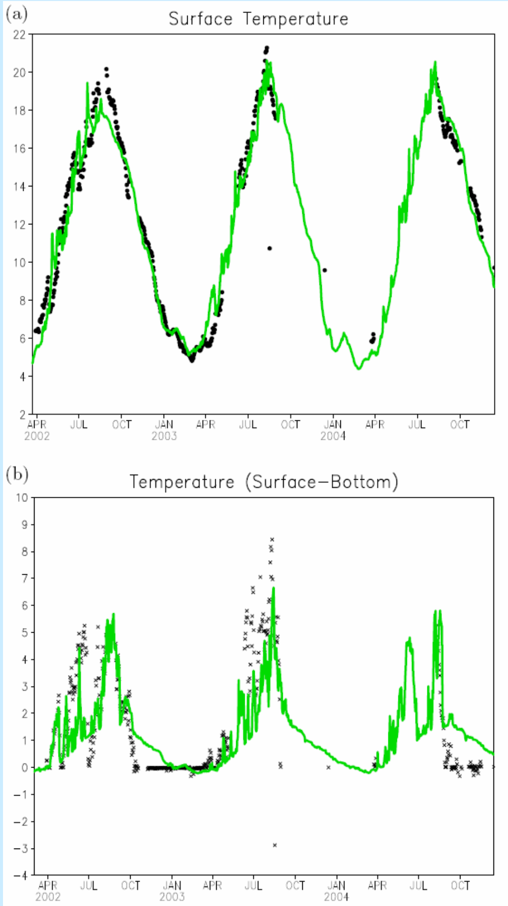
$$E = \alpha M_e \left(\frac{\tau_b}{\tau_e} - 1\right)$$

- 3D equations
- Two classes of sediment (mud and sand)
- Complex physical parameterizations
- Calibrated to present day observations
- Hydrodynamic model forced by waves and tides

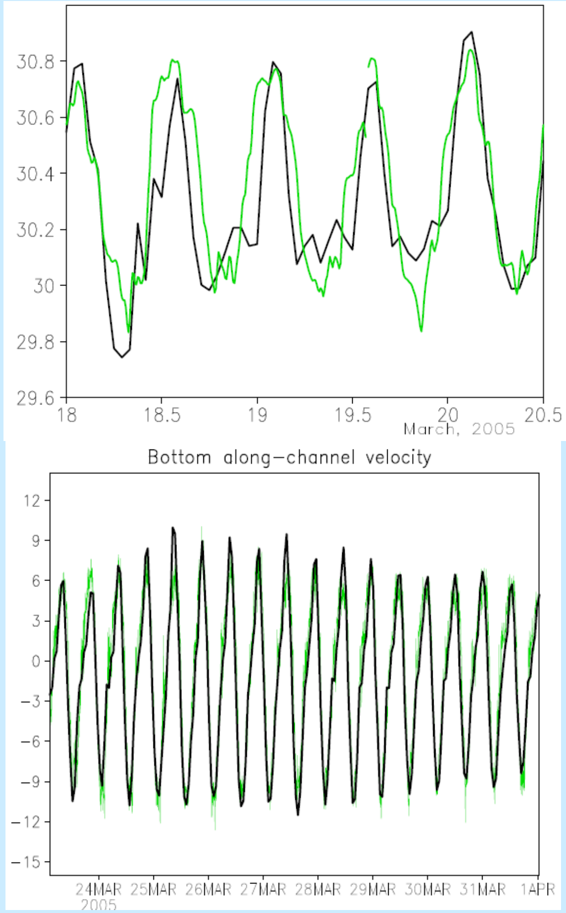
Areas of Application:

- North Sea (in cooperation with BSH)
- German Bight (HAMSOM-based)
- East Frisian Wadden Sea
- Hörnum Bay (North Frisian Wadden Sea)

Are Models Enough Mature and Validated in Order to be Used in Pre-operational Activities?

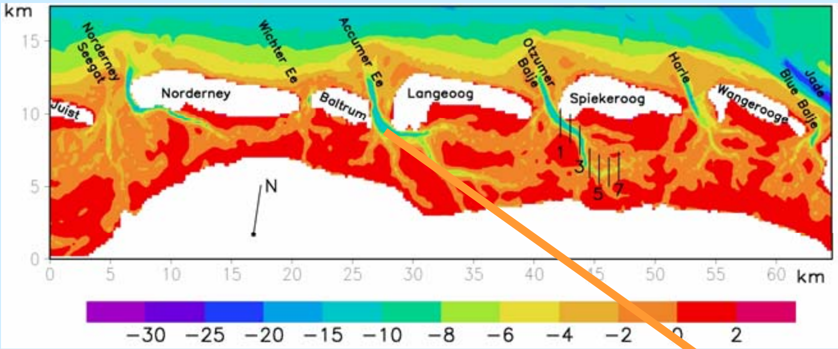


German Bight
(BSH data)

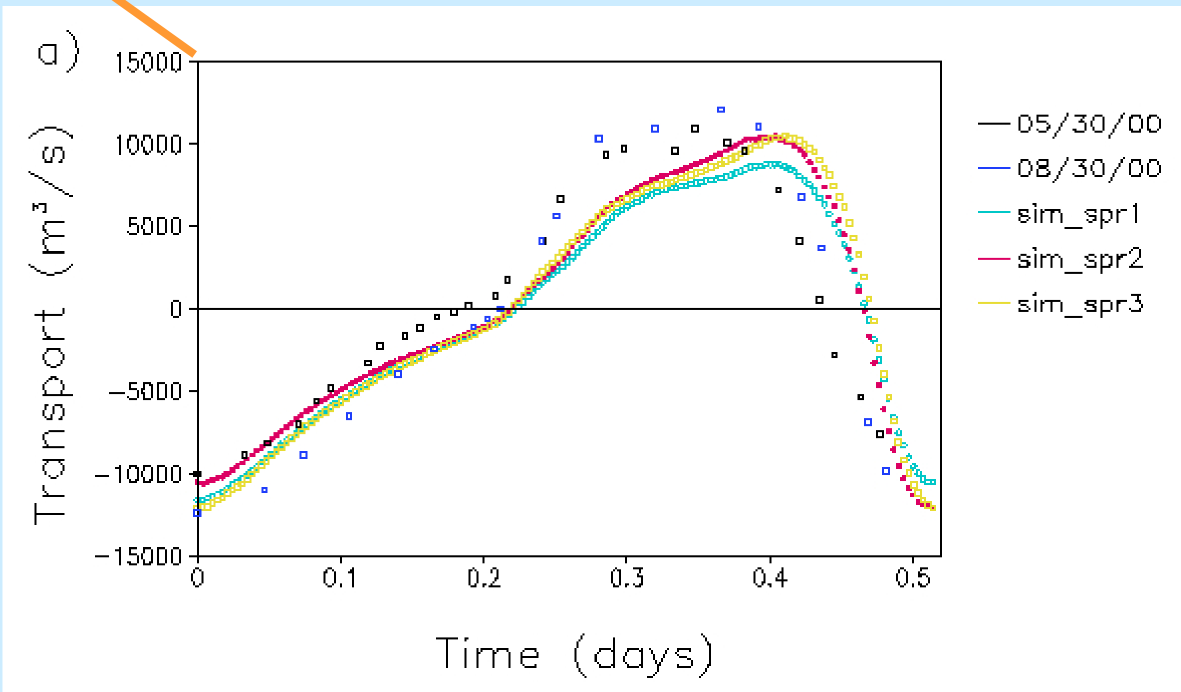


Wadden Sea
(U_Ol data)

Validation of the Wadden Sea model

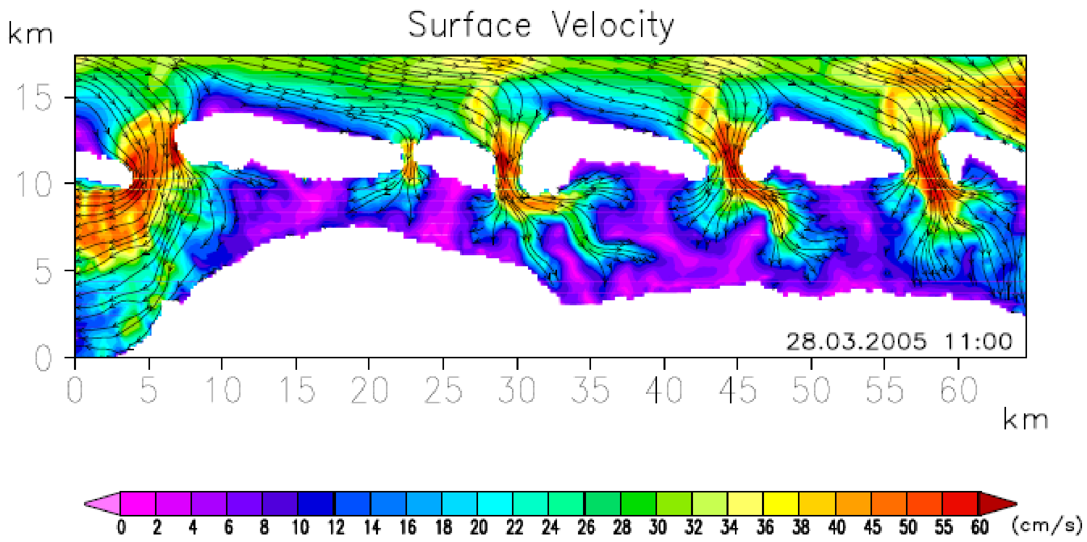


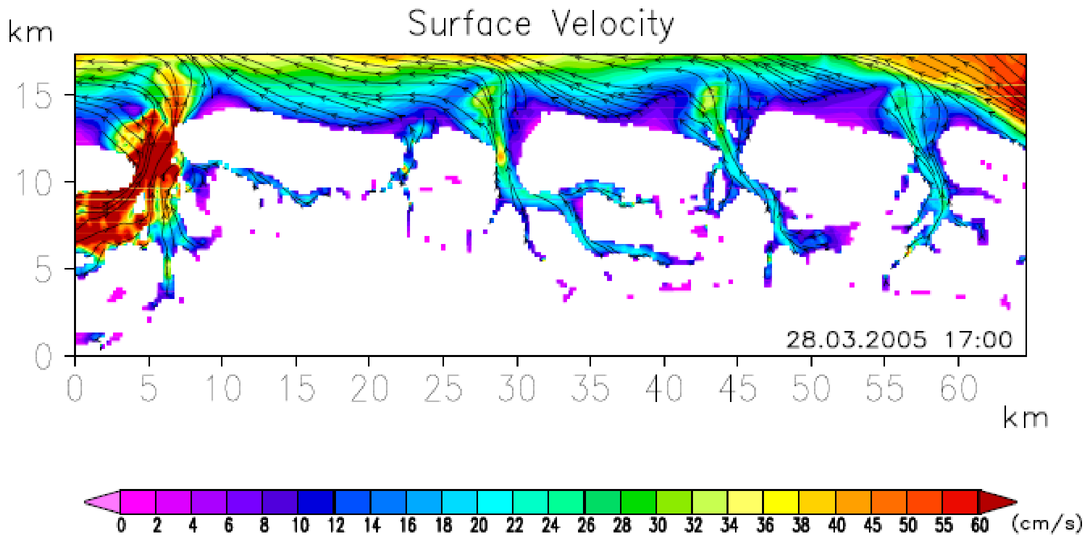
GKSS-ADCP data versus simulated data



Stanev et al. (2003a, OD)

Circulation





Conceptual Models and Process Studies

Tidal asymmetry due to superposition of M2 and M4 tide

$$U = \sin(\omega t) + \frac{1}{2}\sin(2\omega t)$$

Inward transport

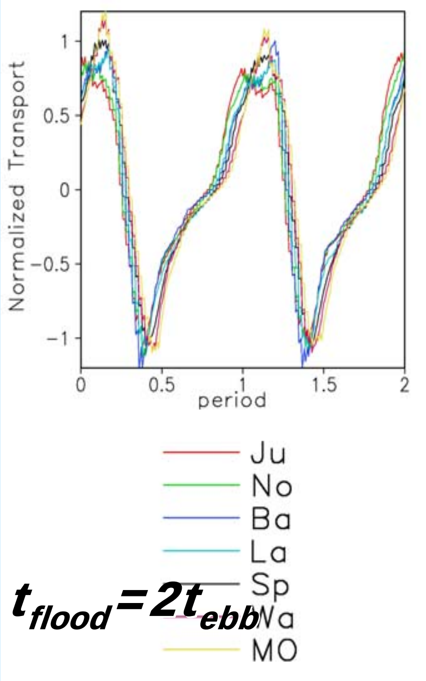
Tidal asymmetry due to topograpgy control

$$\zeta' = \sin(2\pi t / T) = \sin(\omega t)$$

$$\frac{dV'}{dt} = \varepsilon\omega\cos(\omega t) + \varepsilon^2\omega\frac{1}{2}\sin(2\omega t)$$

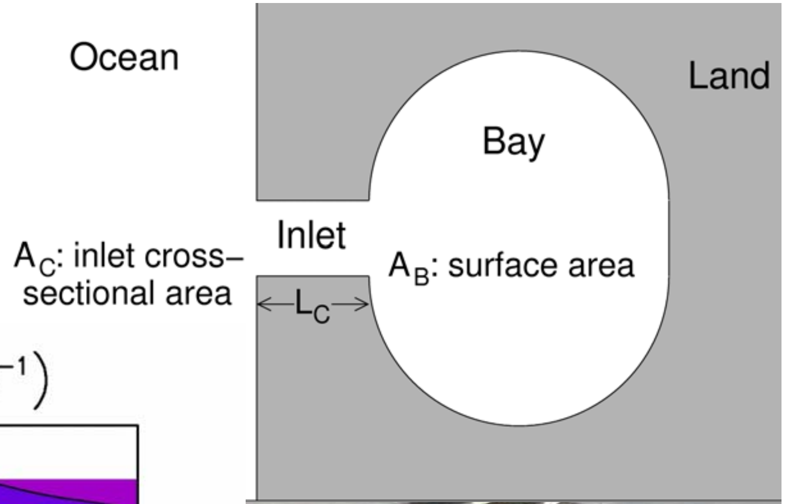
Outward transport

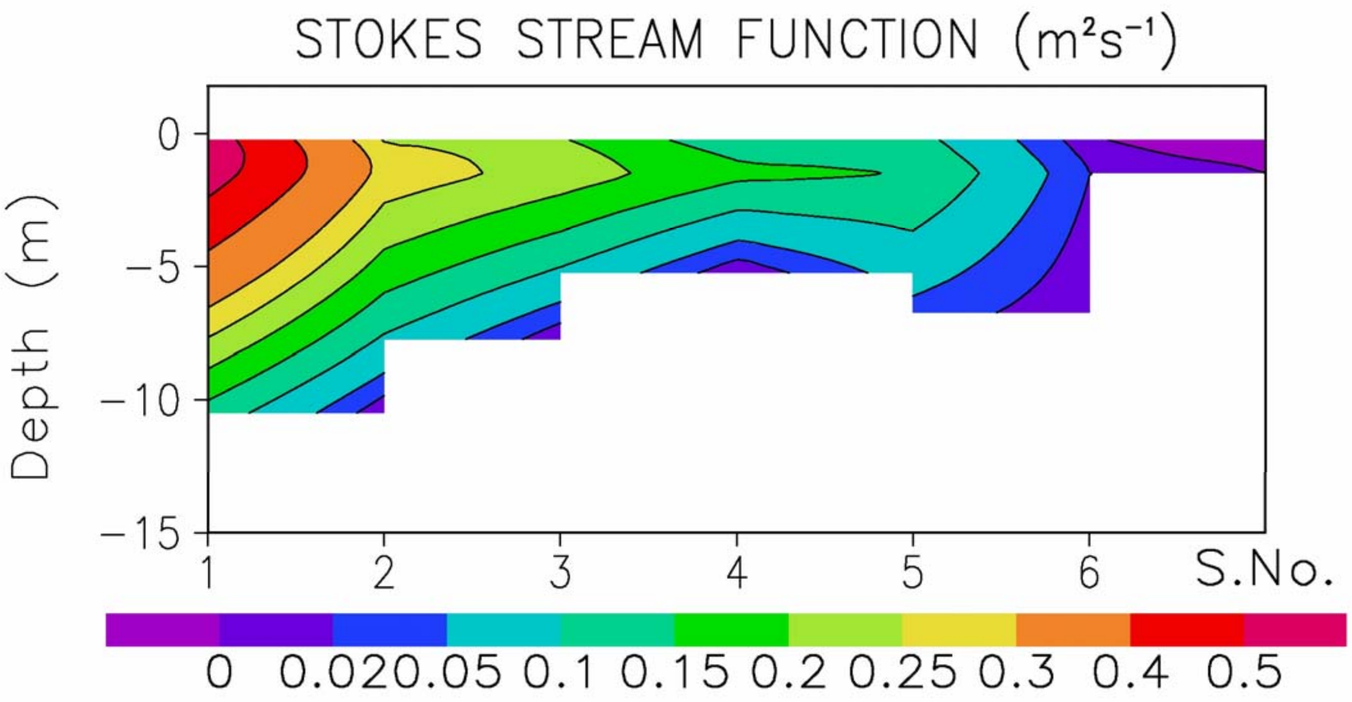
Can tidal asymmerties cause net transport of sediment? GROEN (Neth. J. S. Res, 1967): YES!

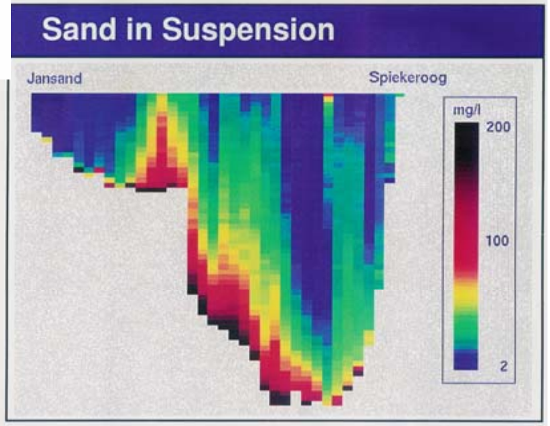


$t_{flood} = 2t_{ebb}$

Asymmetric transport in the vertical plane (Stanev et al., 2007, CSR) could be another candidate to explain the landward transport of sediment.







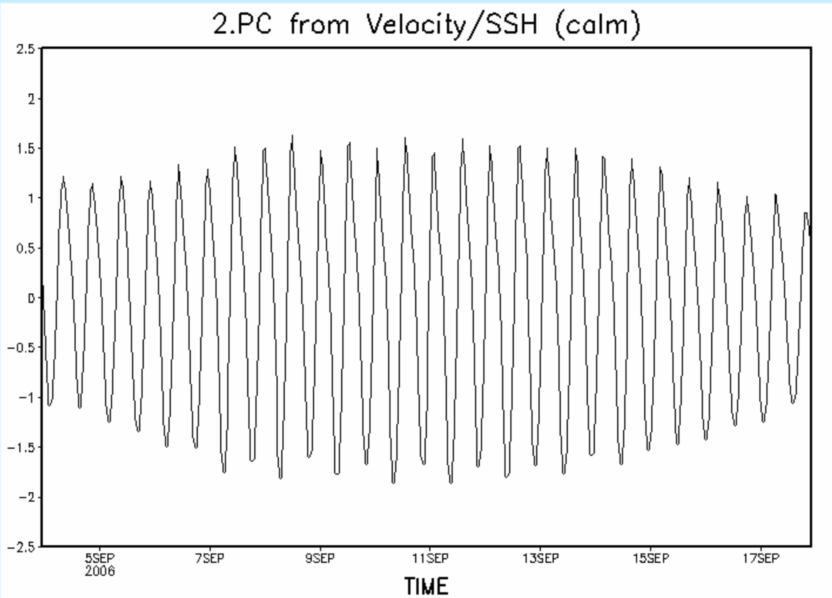
Courtesy B. Flemming

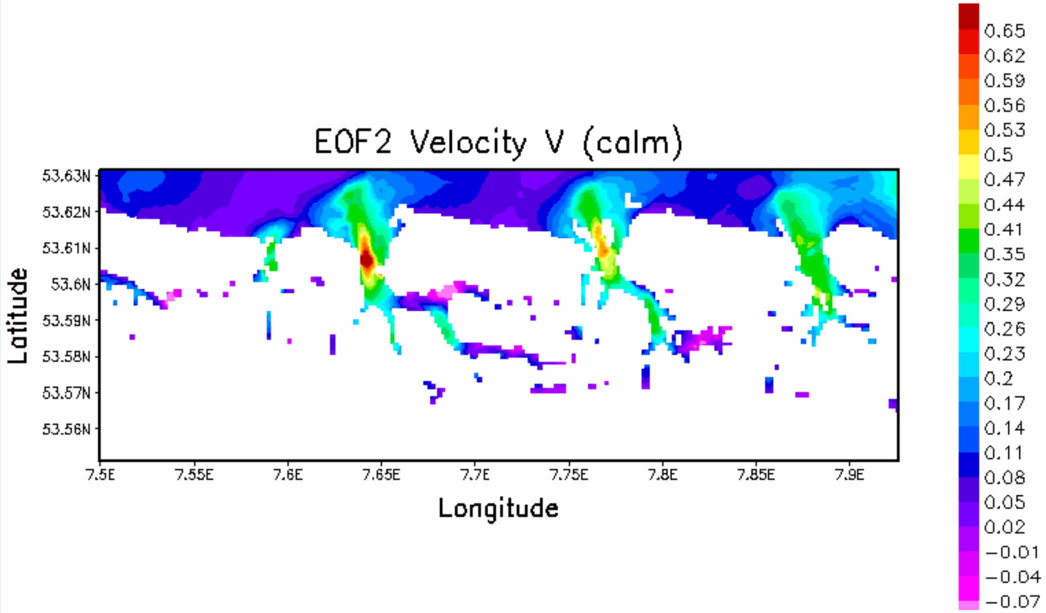
Transport of vertically non-uniform sediment concentrations is another level of complication. Stanev et al. (2007, JGR): Without shear diffusion, the sediment dynamics are largely governed by the "displacement mechanism"

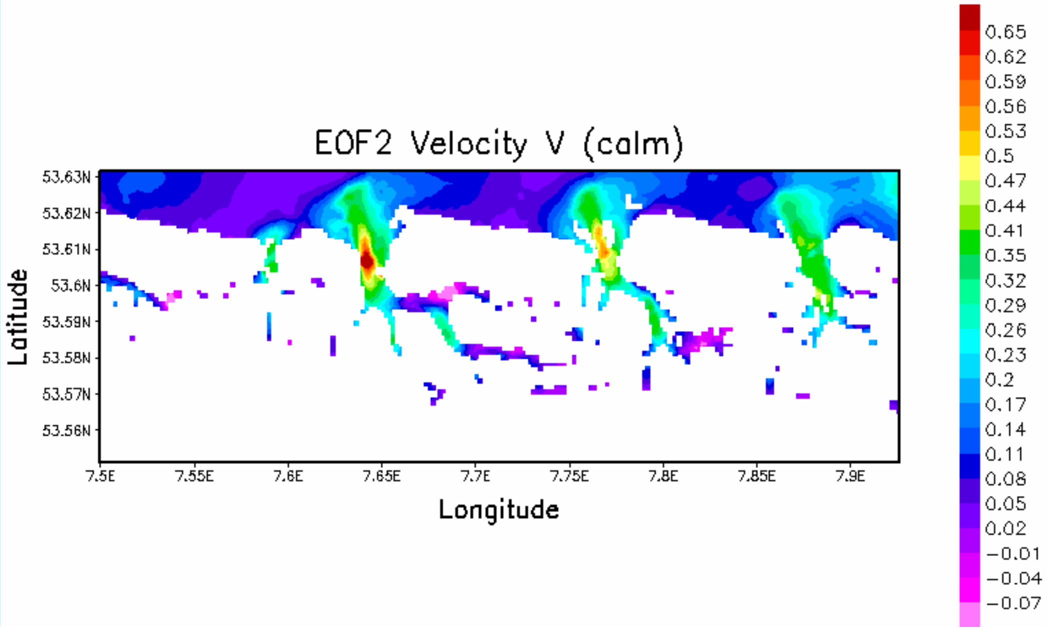
Along Channel Change of Correlation Patterns:

Are Tidal Basins Only Ebb-Dominated?

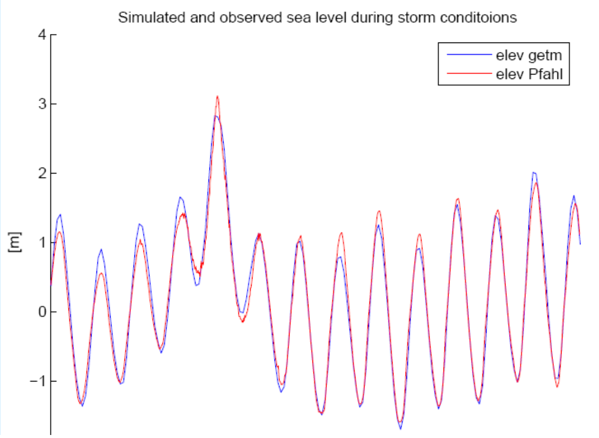
Asymmetries along the channels would contribute to accumulating sediments enabling feedback between circulation, basin hypsometry and sediment transport

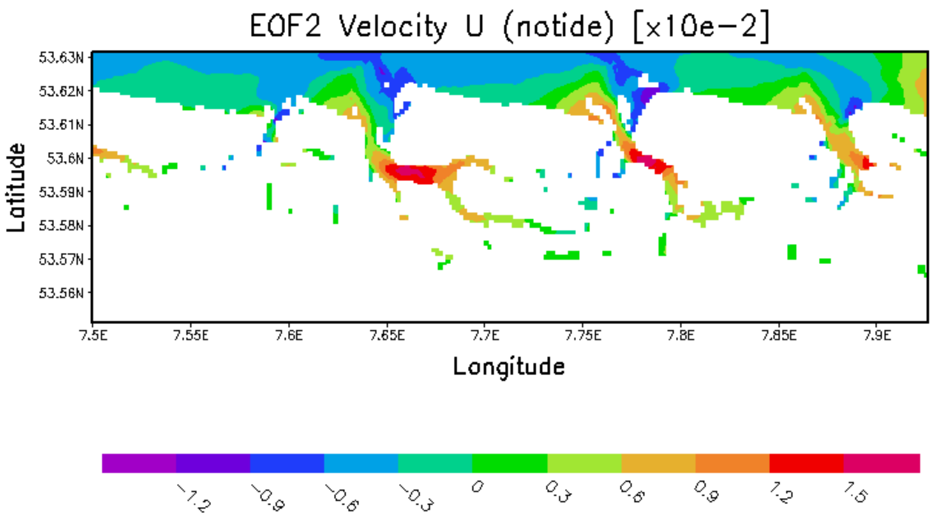


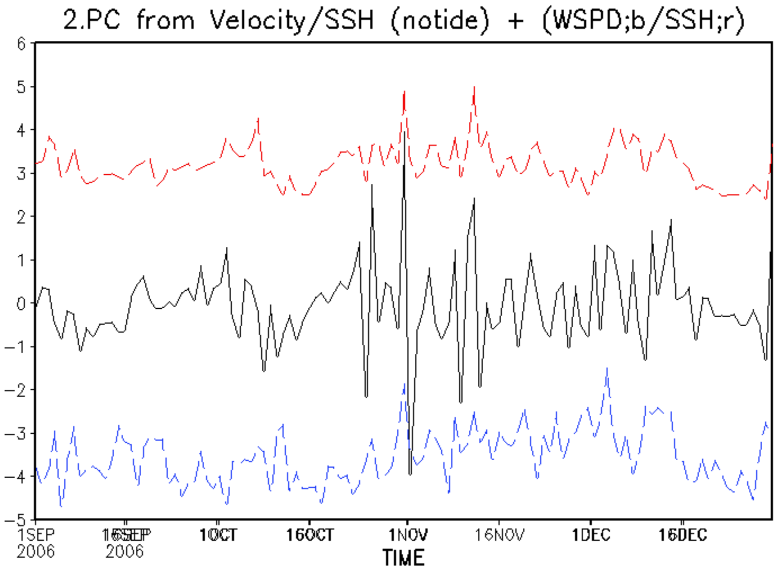


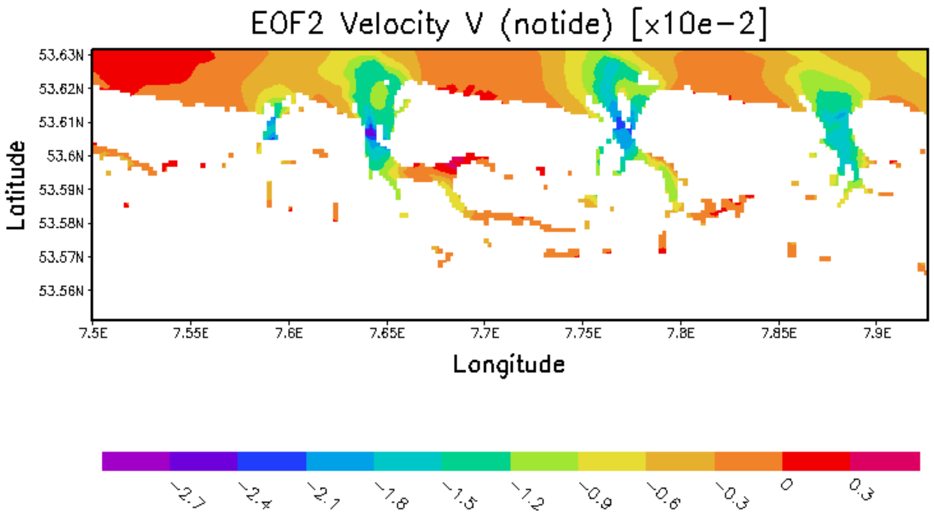


The Response to Extreme Events (Storm Surge Brita) is Different From the One to Tides.

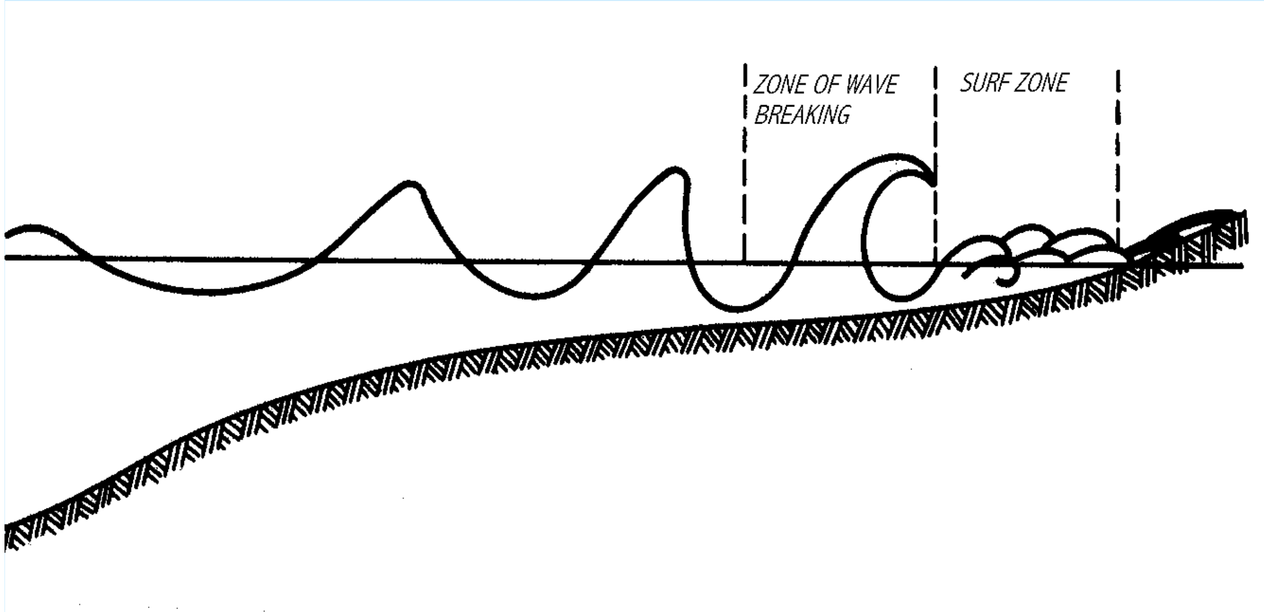


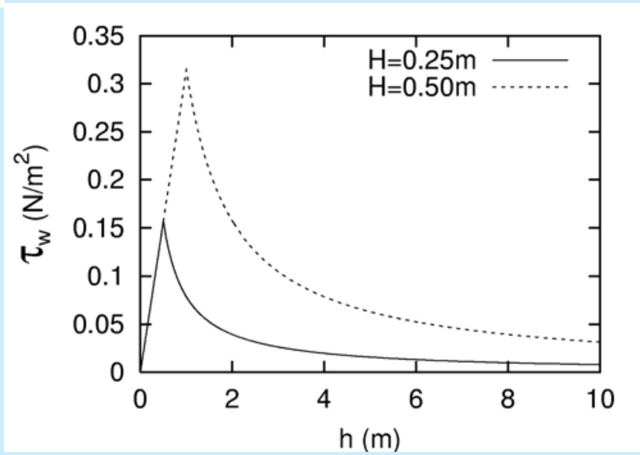




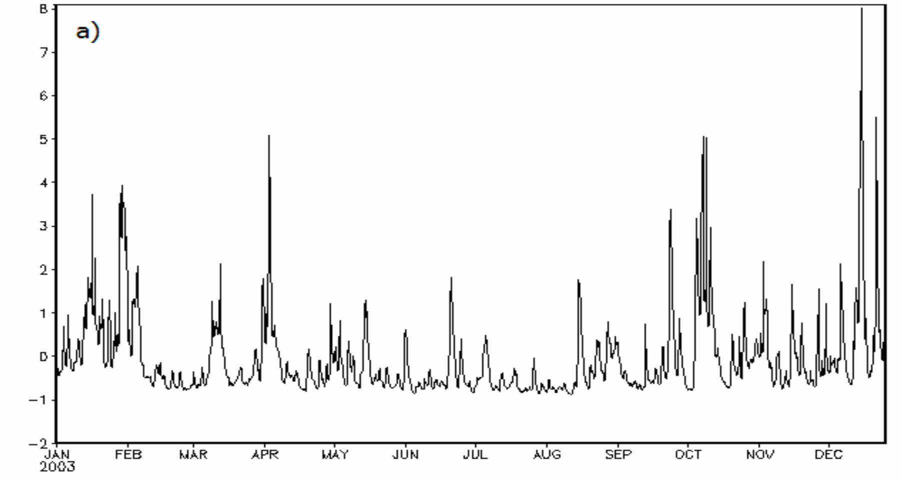


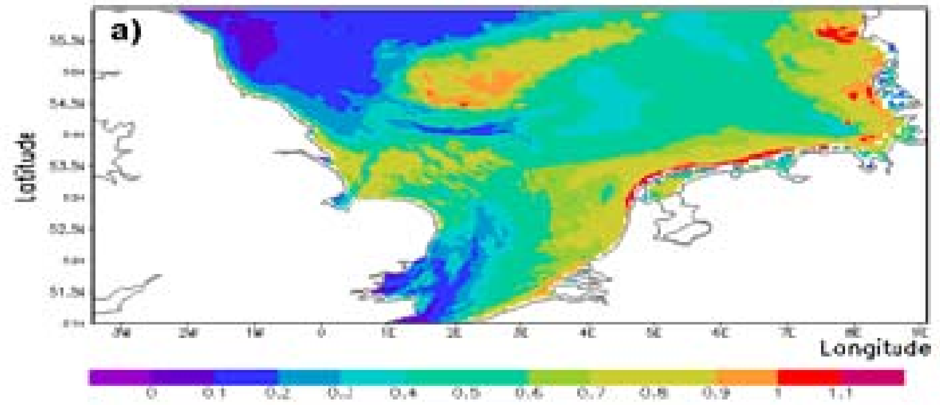
The Impact of Wind Waves on the Sediment Transport

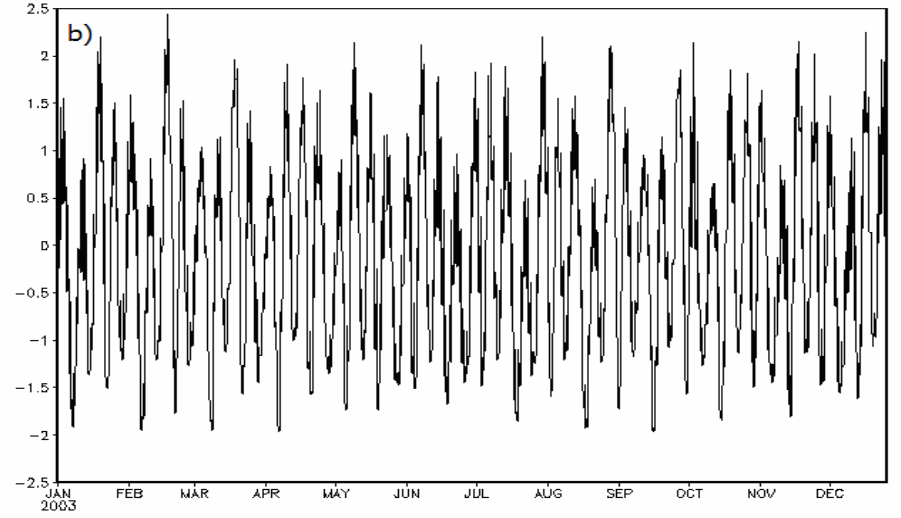


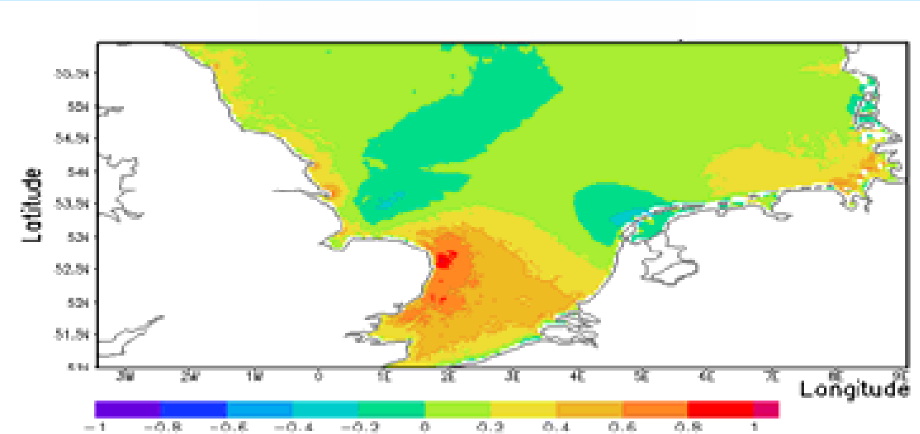


EOF Analysis of Forcing: Bed Shear Stress due to Surface Waves and Tides (Currents)





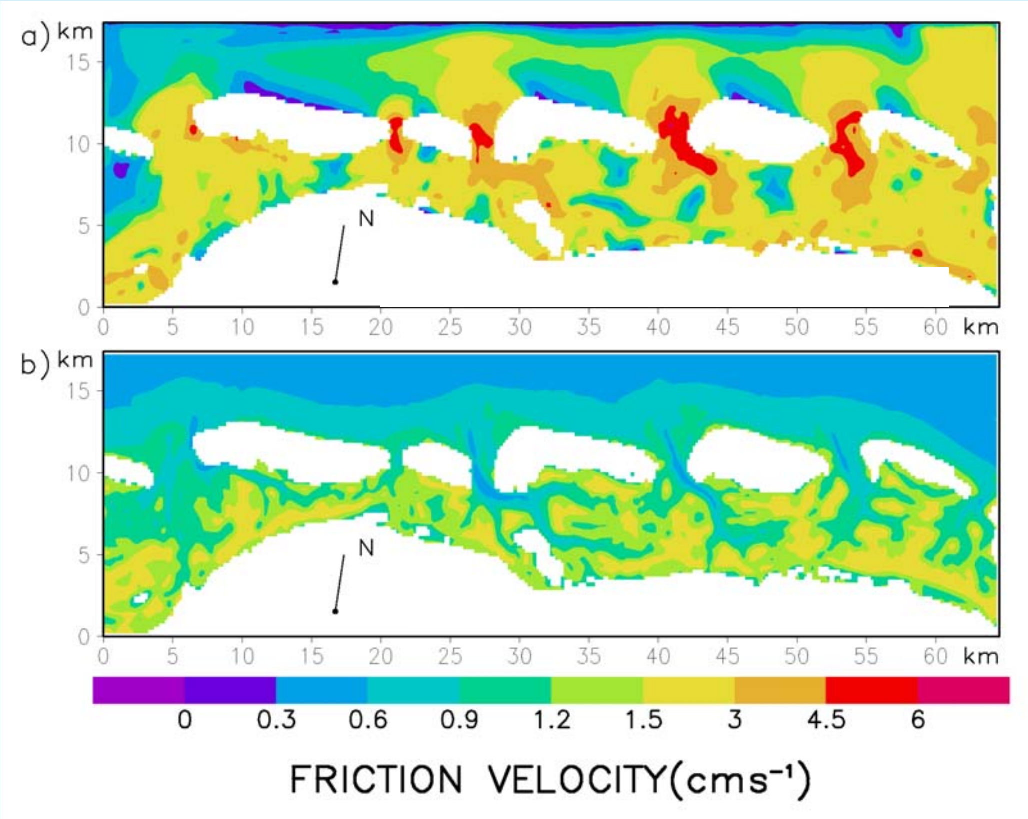




Bed Shear Stress Due to Tides and Wind Display Different Patterns Also in the Wadden Sea

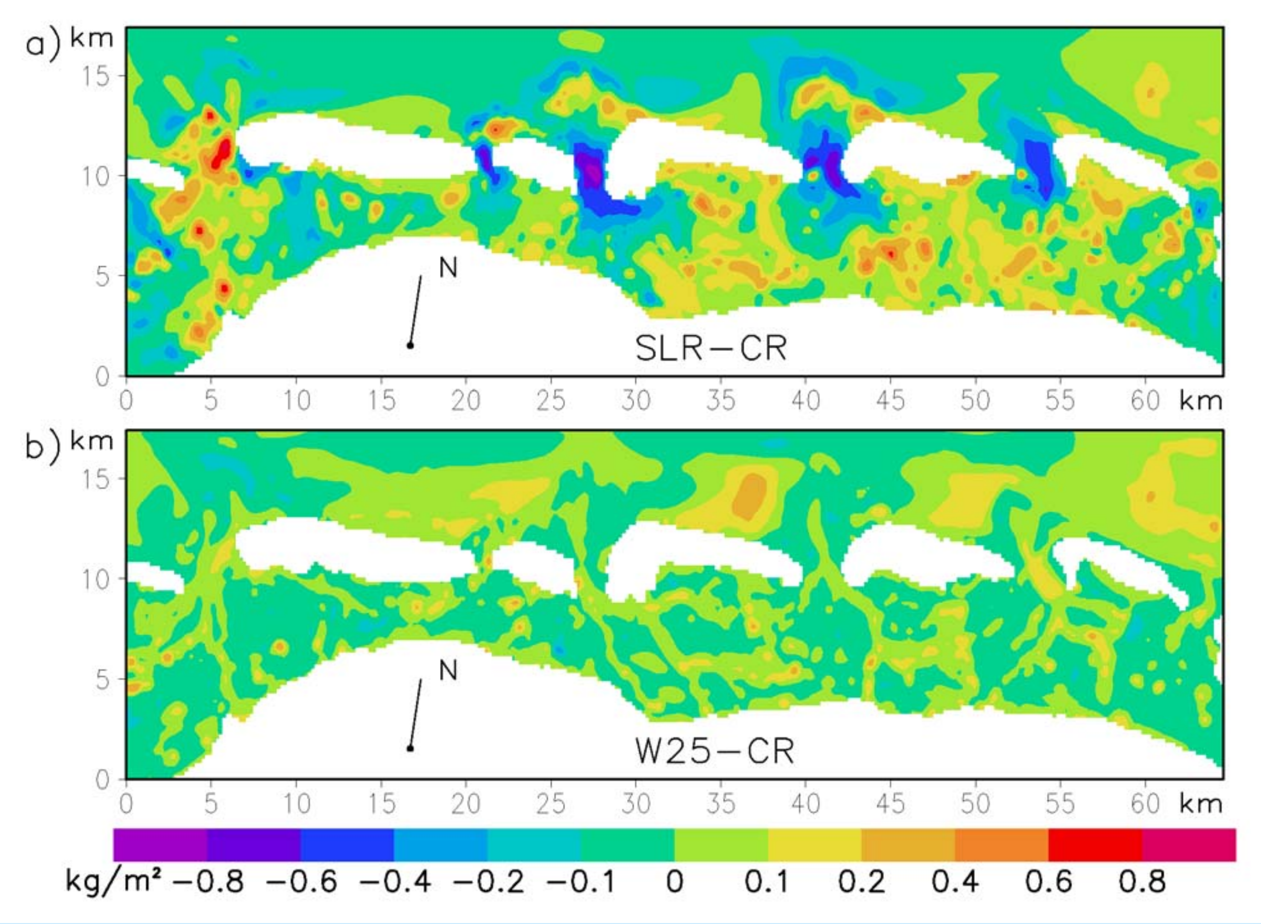
Tides

Waves



Stanev et al. (2006, OD)

The Response to Climate Change Affects in a Non-Trivial Way Spatial and Temporal Variability Patterns.

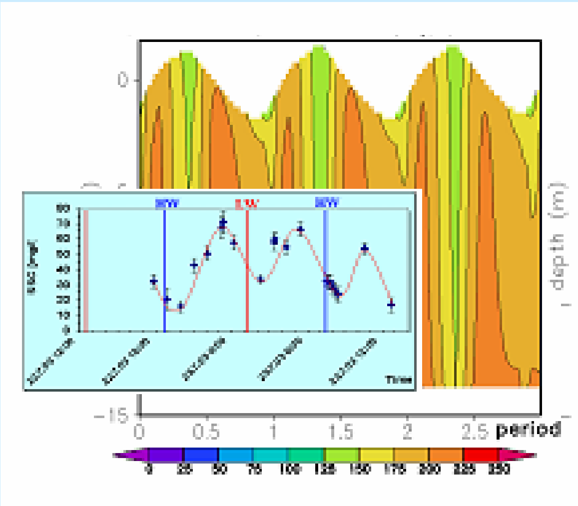


Deposition Minus Erosion

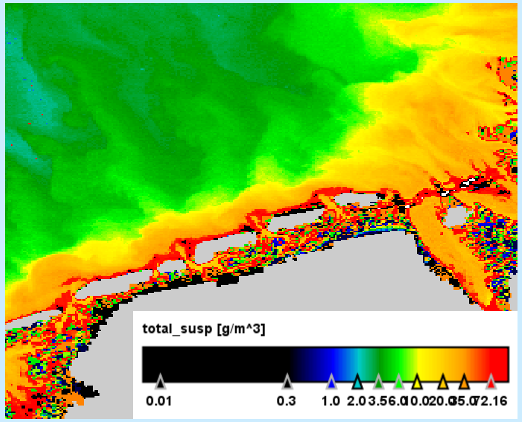
Stanev et al. (2006, OD)

Suspended Sediment

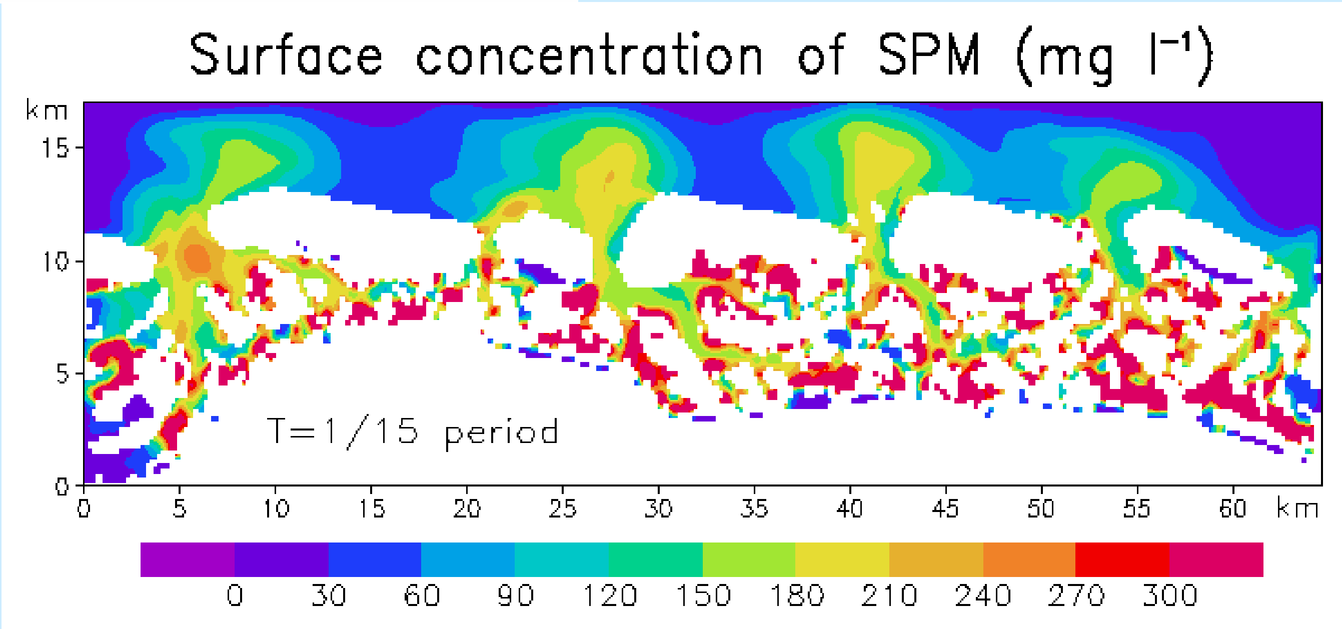
(GETM, 200m Resolution)



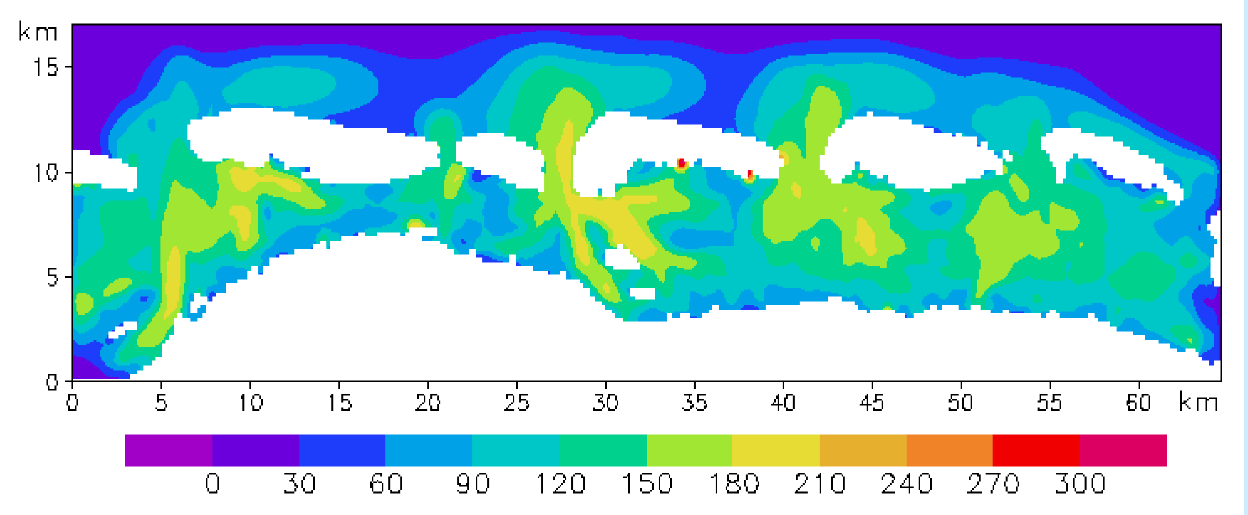
The importance of exchange between tidal flats and open ocean



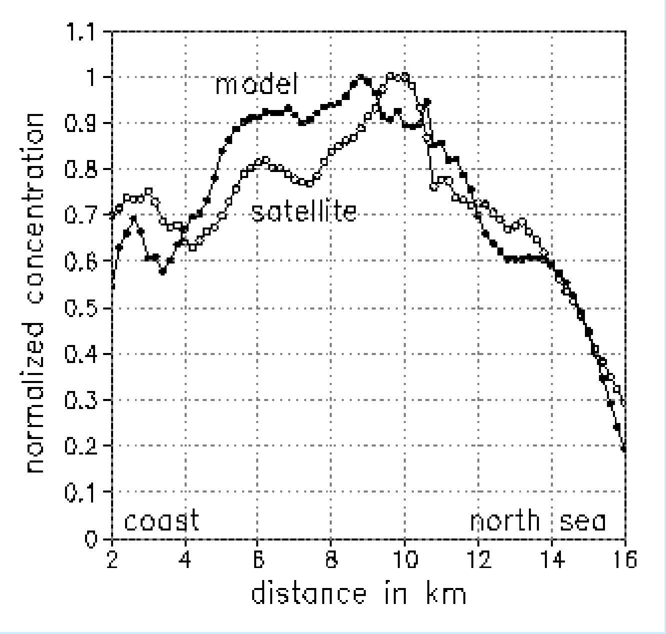
MERIS/ENVISAT, 03/29/04, 9:50, 300m, Gemein et al. (2006)



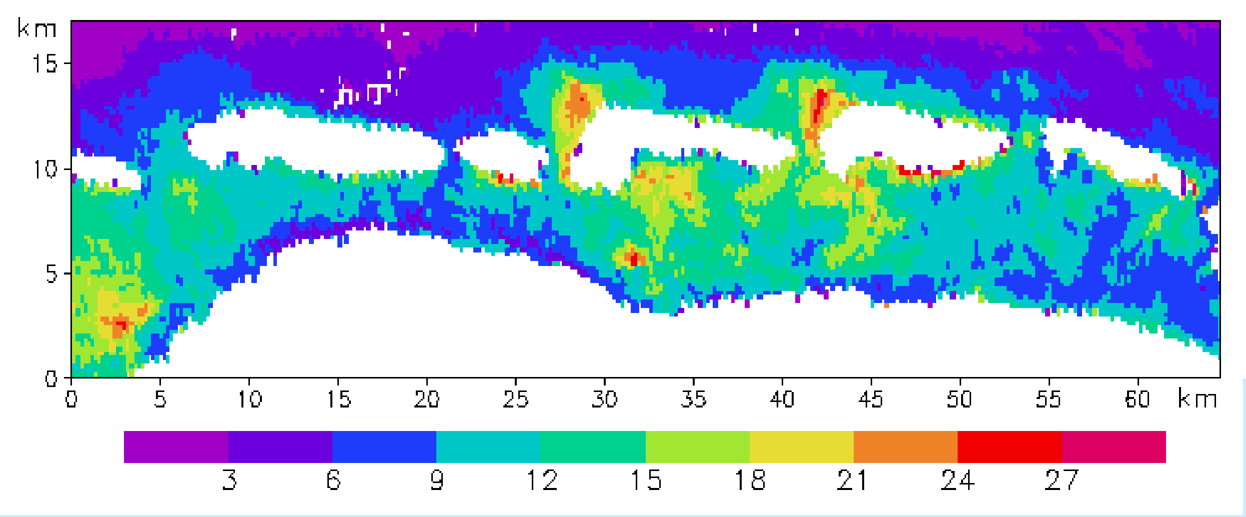
Validation Against MERIS Data



Numerical simulations



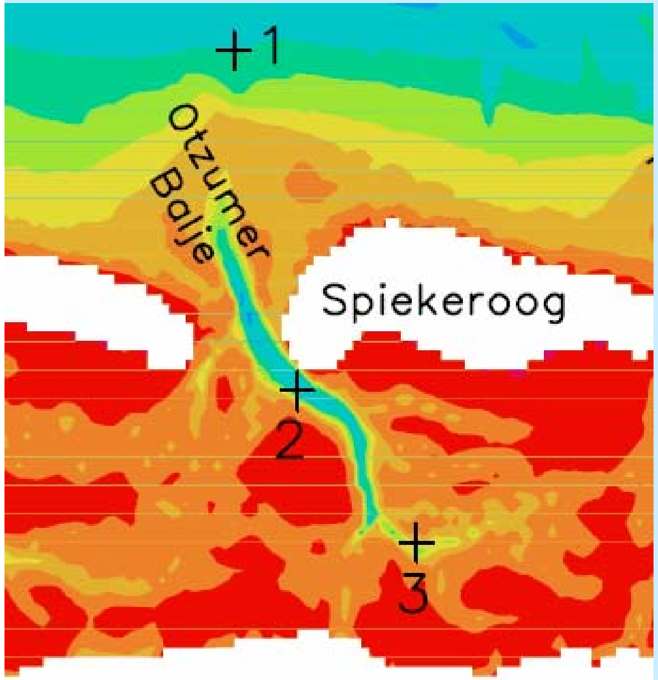
MERIS Image

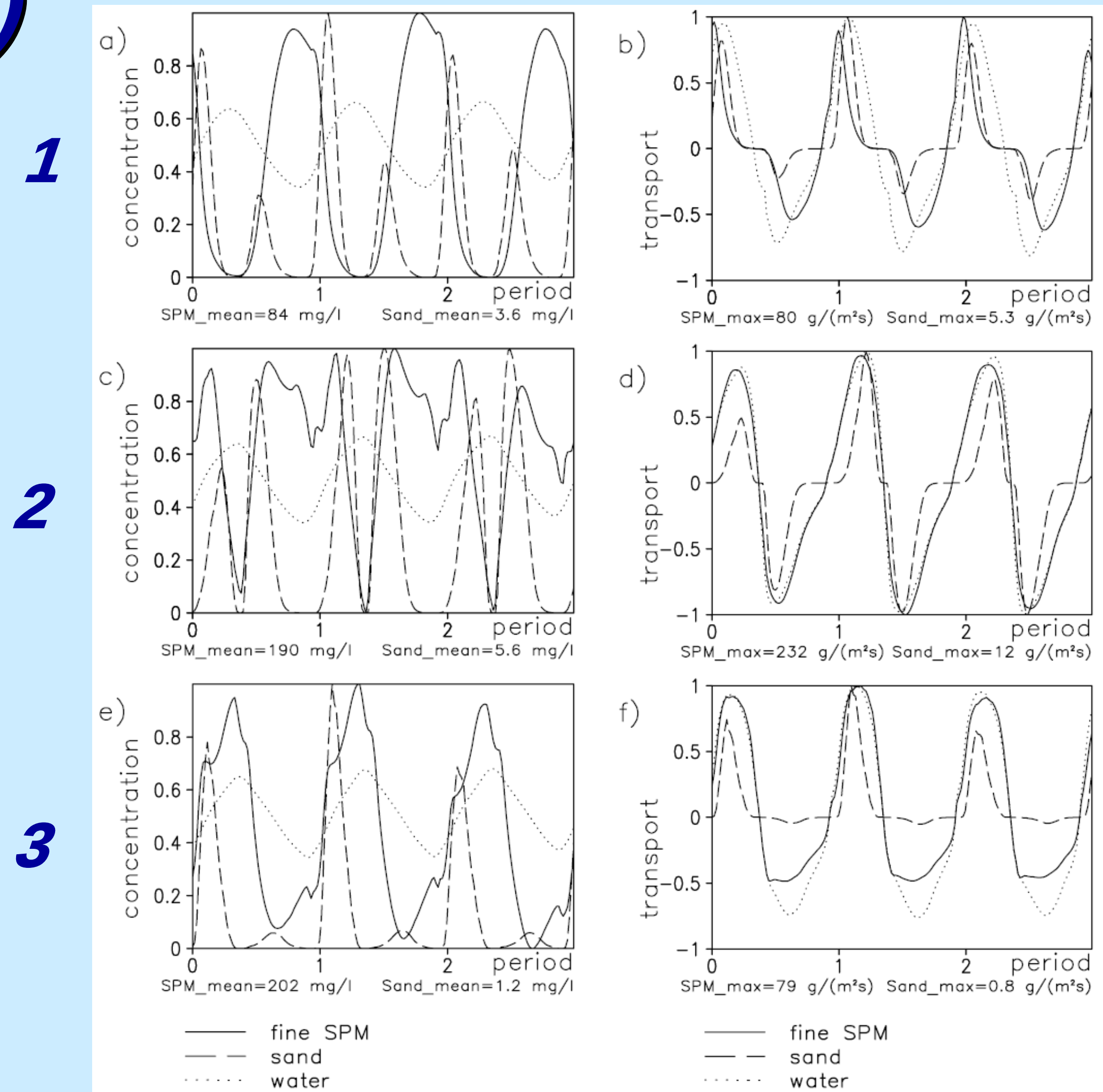


Gemein et al. (2006)

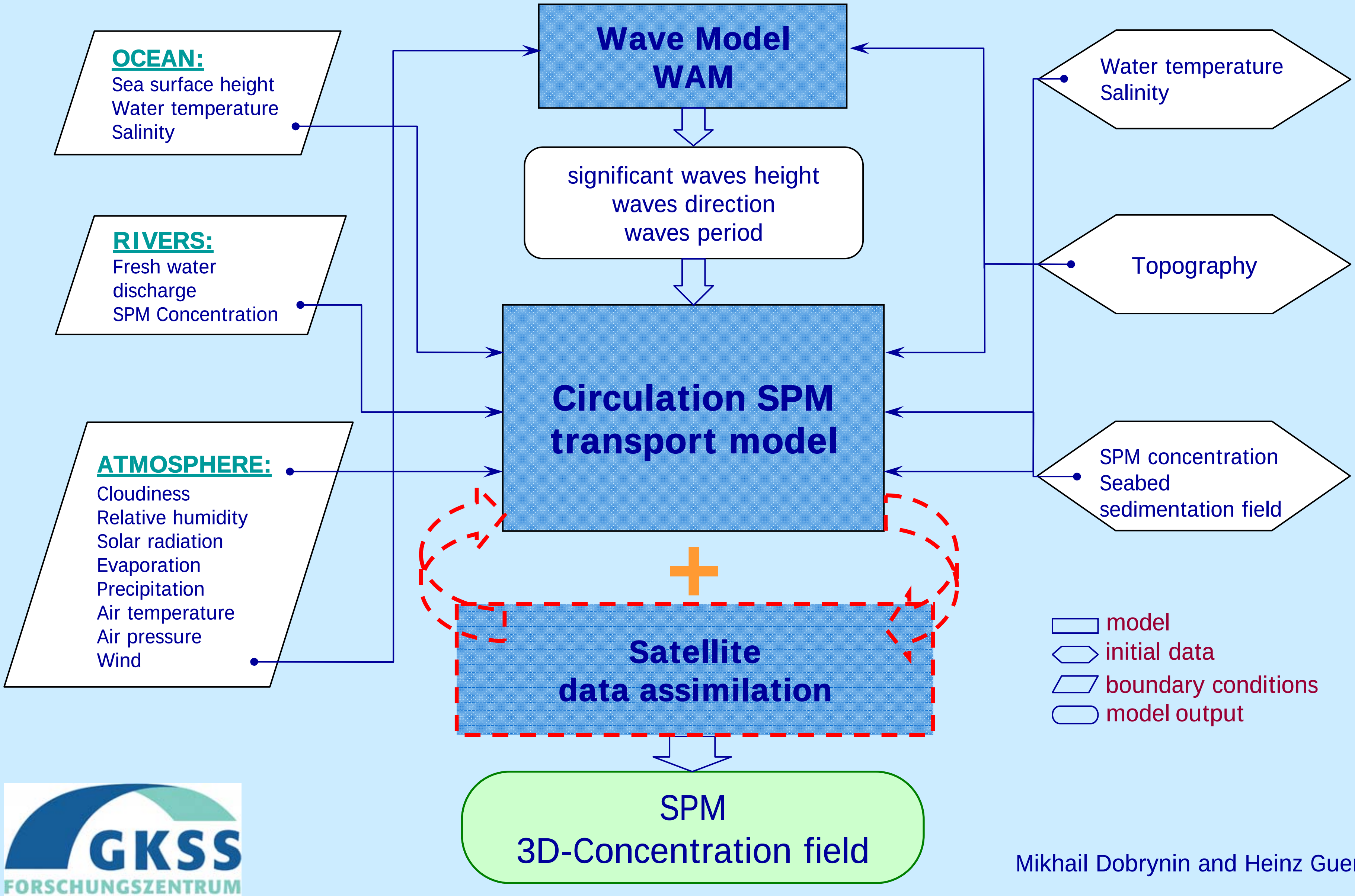
Sediment Sorting (Different Transport of Water, Suspended Matter and Sand)

Sediment is advected on average more slowly than fluid mass.



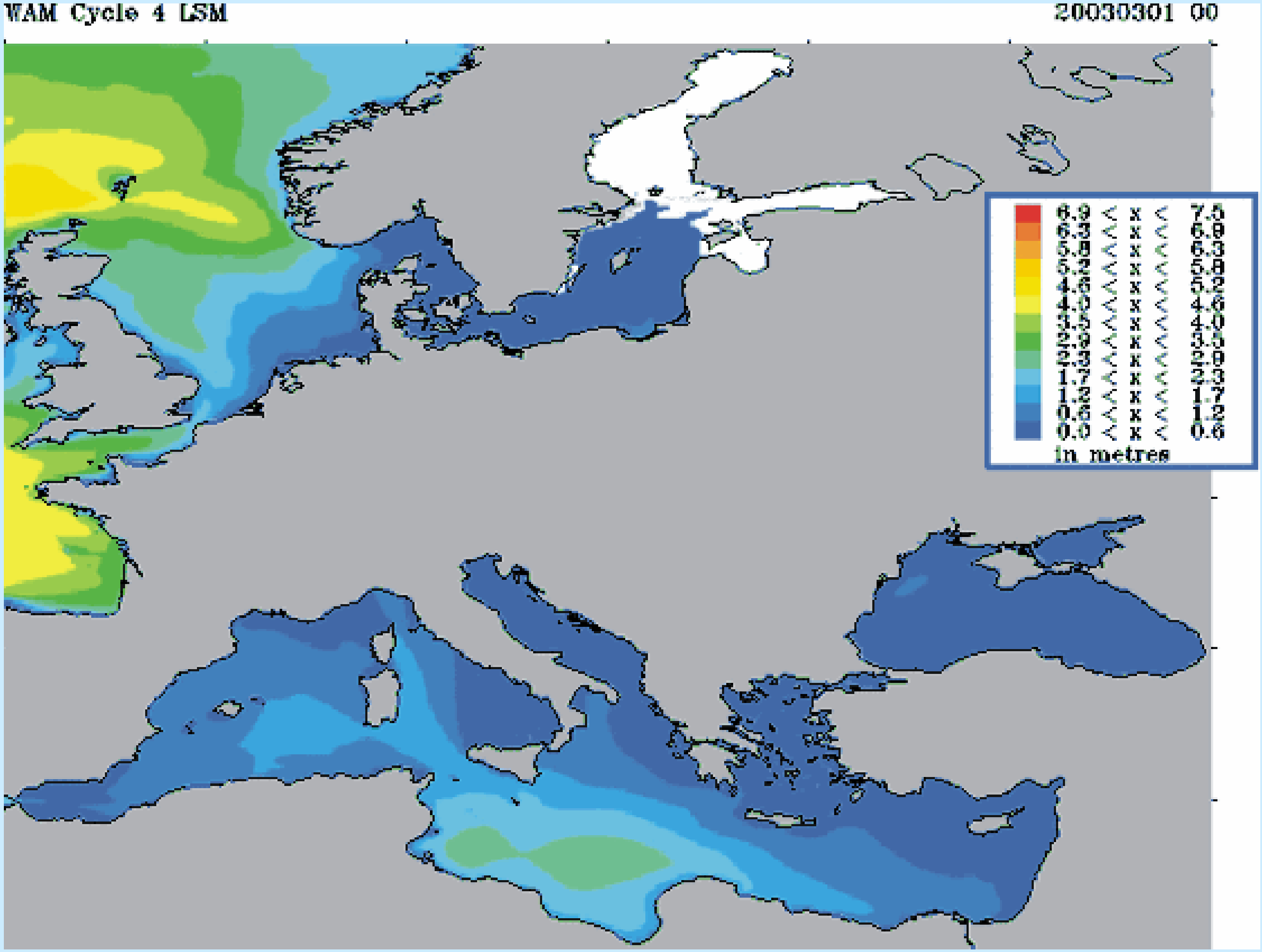


Towards Data Assimilation: Optimal Intrrpolation of MERIS Data



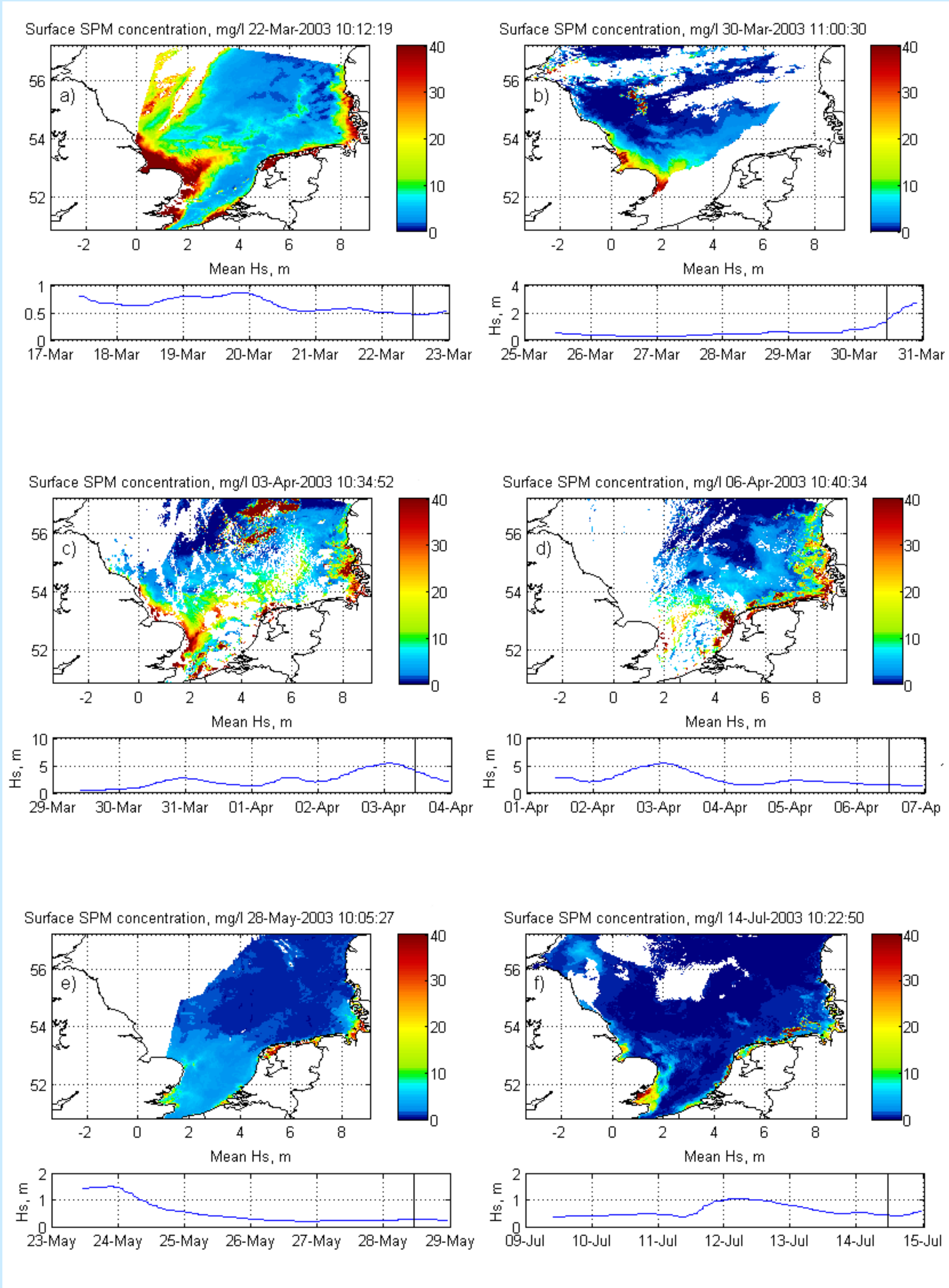
Mikhail Dobrynin and Heinz Guenther

WAM



WAM Cycle 4 LSM
20030301 00
6.9 < x < 7.5
6.3 < x < 6.9
5.8 < x < 6.3
5.2 < x < 5.8
4.6 < x < 5.2
4.0 < x < 4.6
3.5 < x < 4.0
2.9 < x < 3.5
2.3 < x < 2.9
1.7 < x < 2.3
1.2 < x < 1.7
0.6 < x < 1.2
0.0 < x < 0.6
in metres

MERIS Data

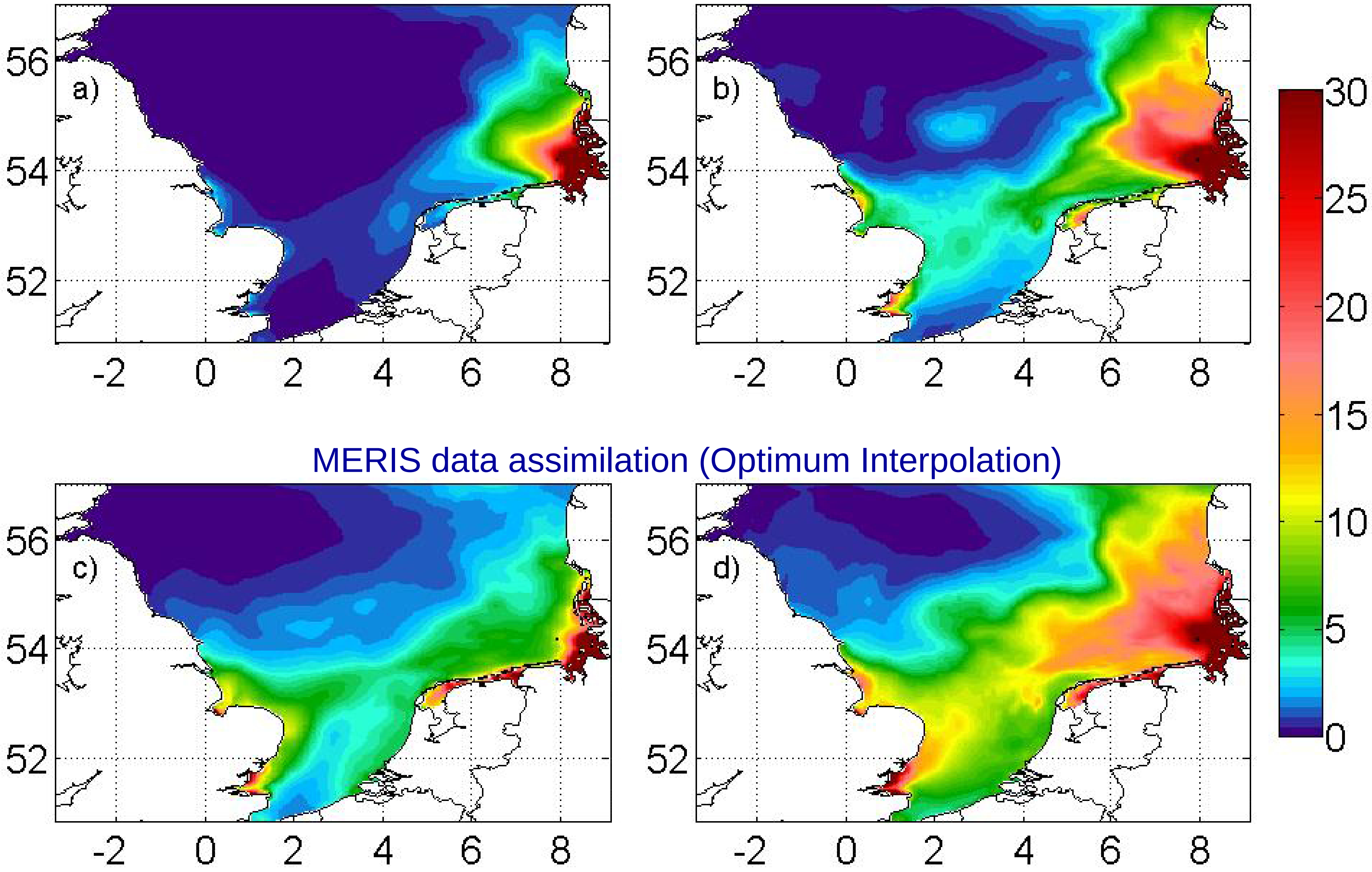

Surface SPM concentration, mg/l 22-Mar-2003 10:12:19
a)
Mean Hs, m
17-Mar 18-Mar 19-Mar 20-Mar 21-Mar 22-Mar 23-Mar
Surface SPM concentration, mg/l 30-Mar-2003 11:00:30
b)
Mean Hs, m
Hs, m
25-Mar 26-Mar 27-Mar 28-Mar 29-Mar 30-Mar 31-Mar
Surface SPM concentration, mg/l 03-Apr-2003 10:34:52
c)
Mean Hs, m
Hs, m
29-Mar 30-Mar 31-Mar 01-Apr 02-Apr 03-Apr 04-Apr
Surface SPM concentration, mg/l 06-Apr-2003 10:40:34
d)
Mean Hs, m
Hs, m
01-Apr 02-Apr 03-Apr 04-Apr 05-Apr 06-Apr 07-Ap
Surface SPM concentration, mg/l 28-May-2003 10:05:27
e)
Mean Hs, m
Hs, m
23-May 24-May 25-May 26-May 27-May 28-May 29-May
Surface SPM concentration, mg/l 14-Jul-2003 10:22:50
f)
Mean Hs, m
Hs, m
09-Jul 10-Jul 11-Jul 12-Jul 13-Jul 14-Jul 15-Jul

Simulated seasonal mean surface SPM concentration, 2003, mg/l

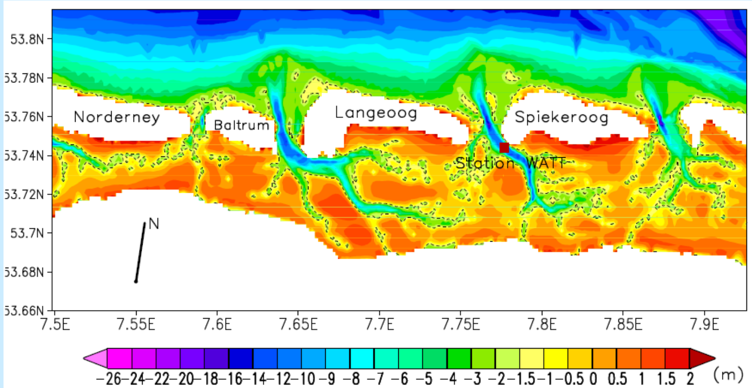
15 April-15 October
calm

16 October – 14 April
storm

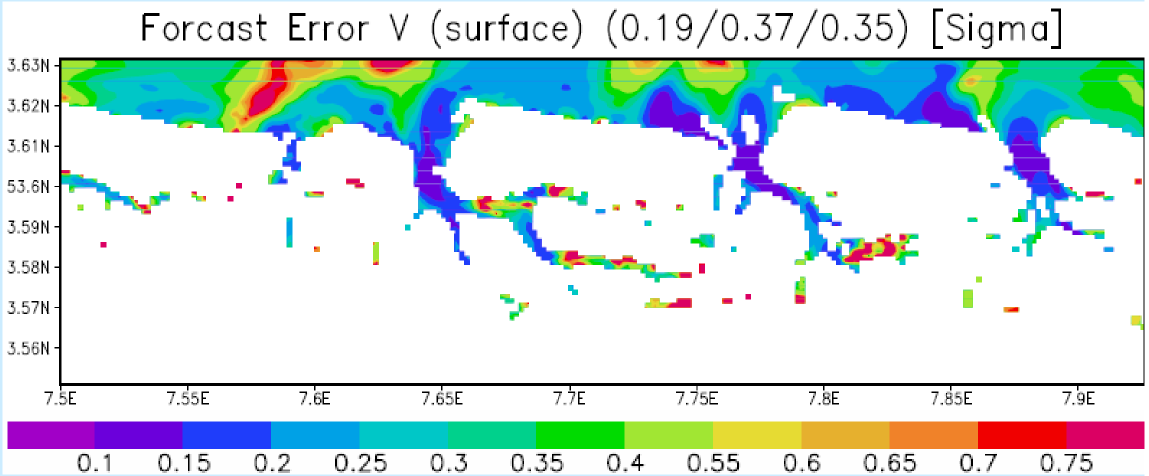
No assimilation

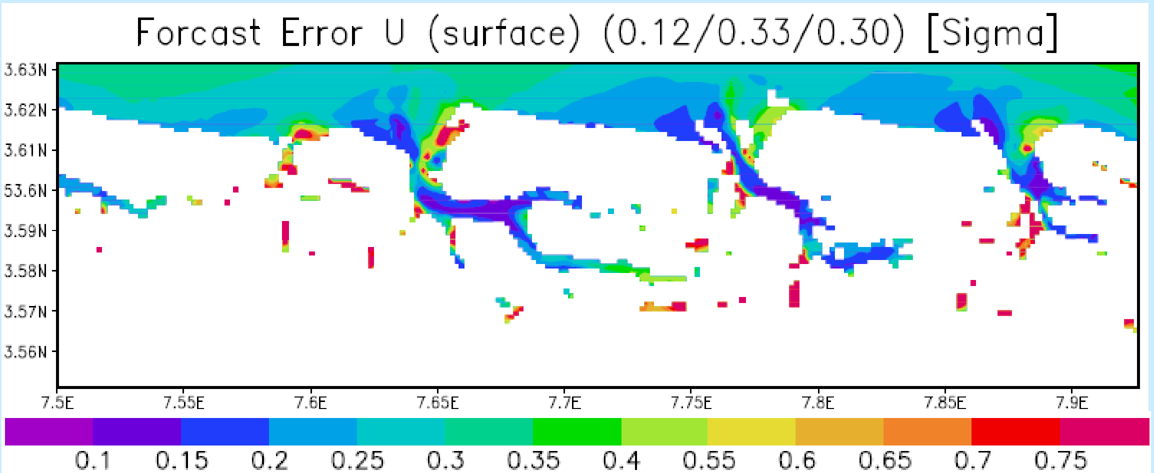


Optimal Interpolation is not the Best Solution for Near-Coastal Regions.



no	dynamics	TKE
1	83.5	85.8
2	15.8	6.9
3	0.2	3.0
sum	99.5	95.1





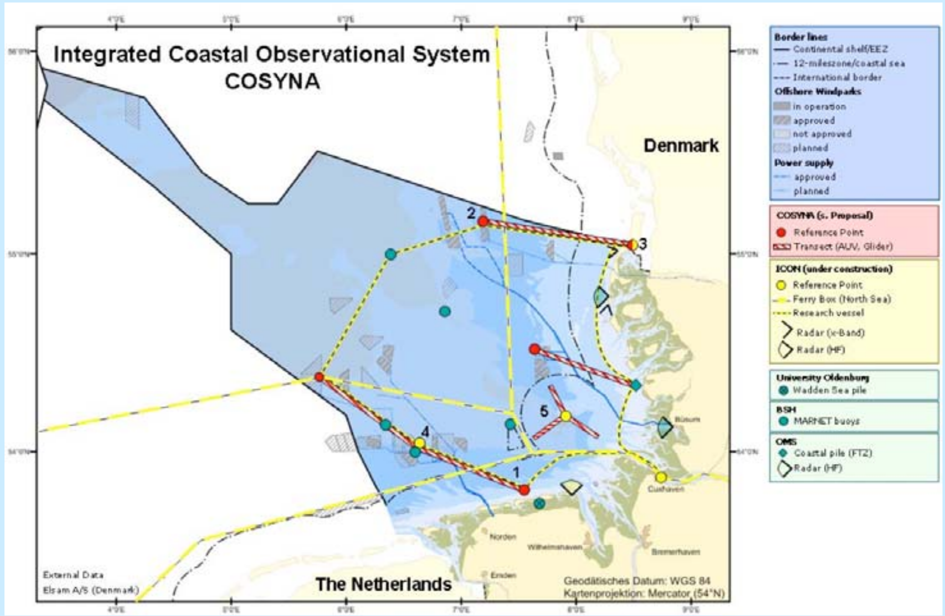
Compressing Data and Statistical Forecasts (Tidal Oscillations)

Further perspectives

COSYNA (Coastal Observation System for Northern and Arctic Seas)

Enable a future long term observational network for the North Sea and Arctic coastal waters

Link to preoperational models for scientific and management purposes



Goals:

consolidate existing systems,

develop new ones,

detect environmental and climate changes in coastal areas,

produce forecasts,

provide products and knowledge.

New enhancements: (AUVs, gliders) offshore wind turbines (WEAs) platforms

However,

- The existing systems are not harmonised.
- Quality assessment is still a problem.
- Real-time data transfer and exchange, as well as availability to modellers is not well solved.
- Assimilation of various sources of near coastal data is still a complex scientific problem.
- No enough coherence between physical, chemical, geological and biological data.

To Summarize: Our Plans

- *Increase synergy between observation and modelling,*
- *Improve observing/forecasting systems*
- *Model supported monitoring*
- *In Longer-term Perspective: Consider Data-Adaptive Sampling*

Thanks for your attention