Coastal model validation – DMI experiences and some general issues

Jun She, Kristine Madsen, Lars Jonasson, Zhenwen Wan

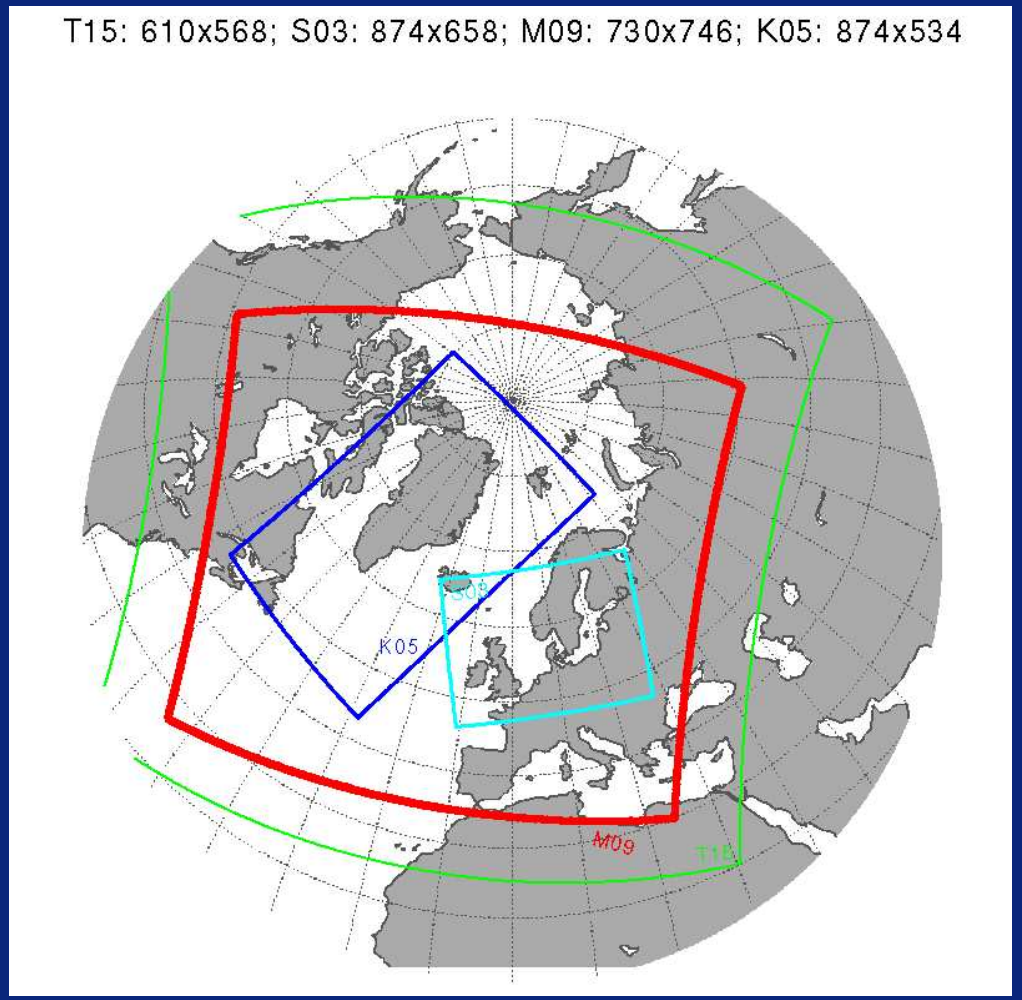
Danish Meteorological Institute

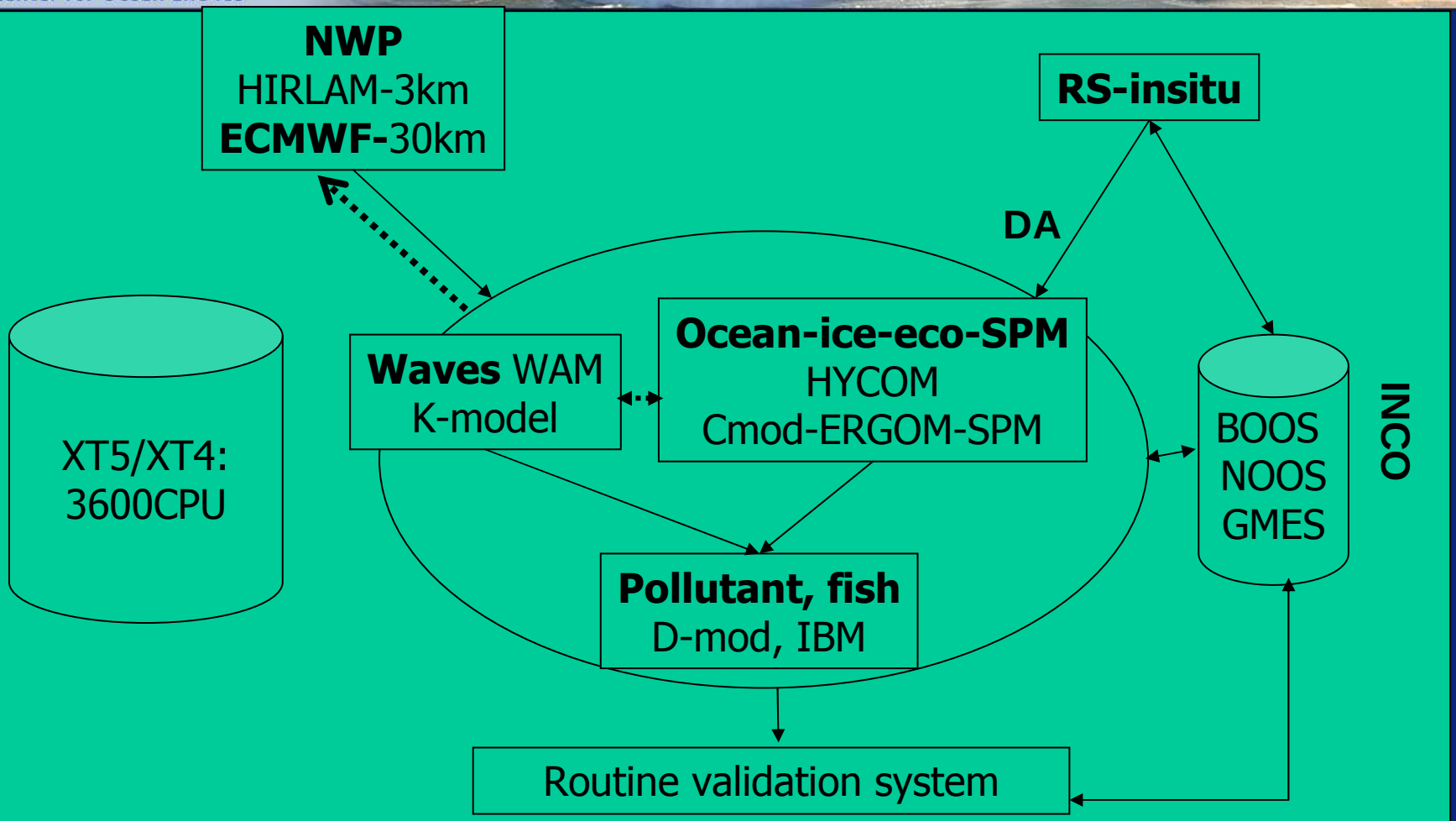
Centre for Ocean and Ice

Agenda

- What applications can coastal sea models be used for? – some examples
- General remarks

DMI NWP model HIRLAM Baltic-North Sea in 3km reso. 60h forecast





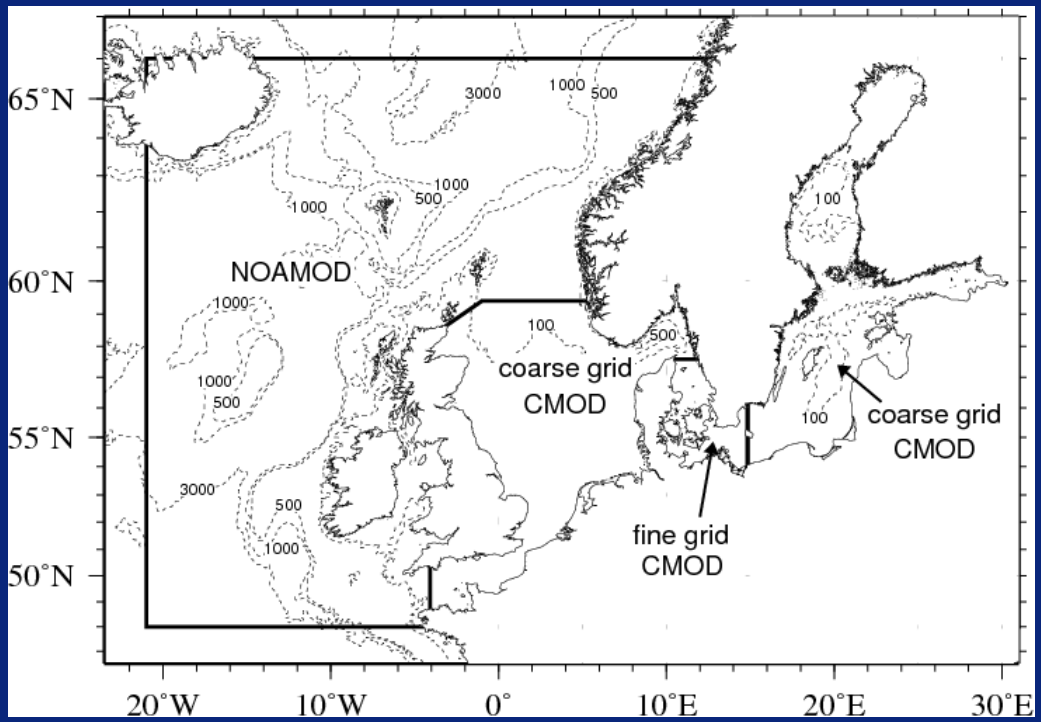
DMI modelling system

Critical mass to back up DMI coastal model system

- DMI Centre for Ocean and Ice: 13 modellers
- Marine Ecological Modelling Centre Common model framework (DMI, NERI, DTU-AQUA): 20-25 modellers
- MyOcean Baltic Sea Common model framework (DMI, BSH, SMHI, FMI, IMS): 10-15modellers

Coupled Cmod-ERGOM-SPM-WAM for the Baltic and North Sea

- 6-1/3-0.5 nm grid, 50 z-levels,
- 2 way nested
- 4 turbulence mixing scheme (K-omega etc)
- Flooding-drying
- Data assimilation: SST, T/S profiles

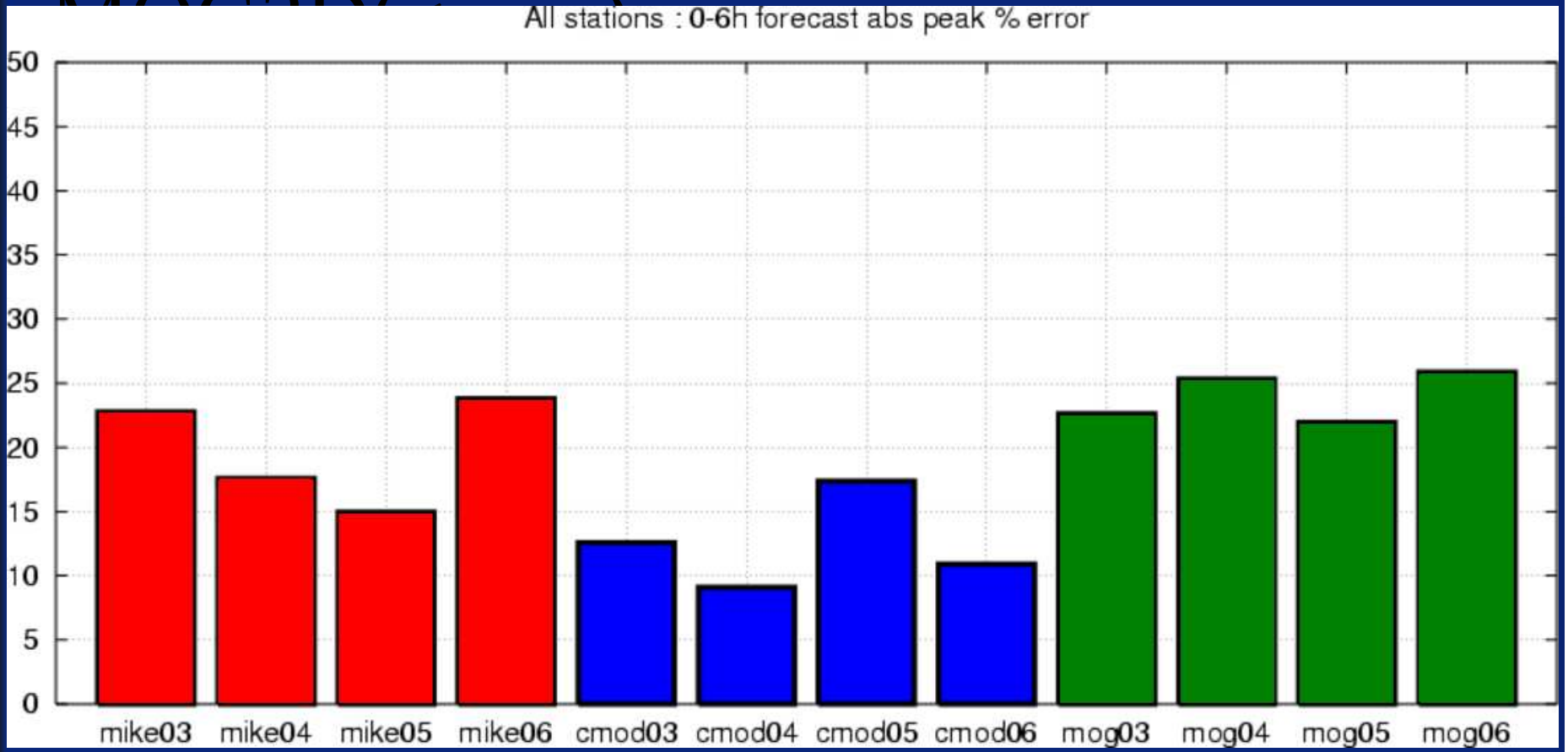


Surface applications

- Synoptic scale application of waves, surge, ice, inflow events, currents with high skill and can perform routine verifications (ship-routine, offshore oil&gas, wind mill, sailing sports etc)
- Oil spill forecast warning
- National climate change adaptation service for water level, ice, currents, T, S
- No biogeochemical service application yet

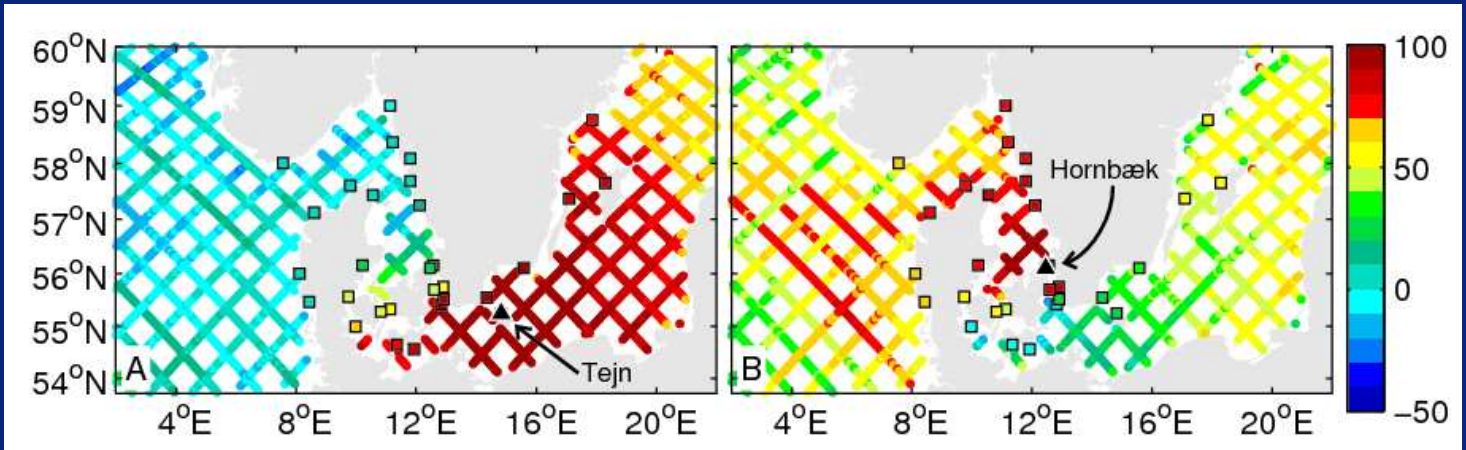
Model error inter-comparison: storm surge

mike21(red) + Cmod(blue) + MOG2D(green)

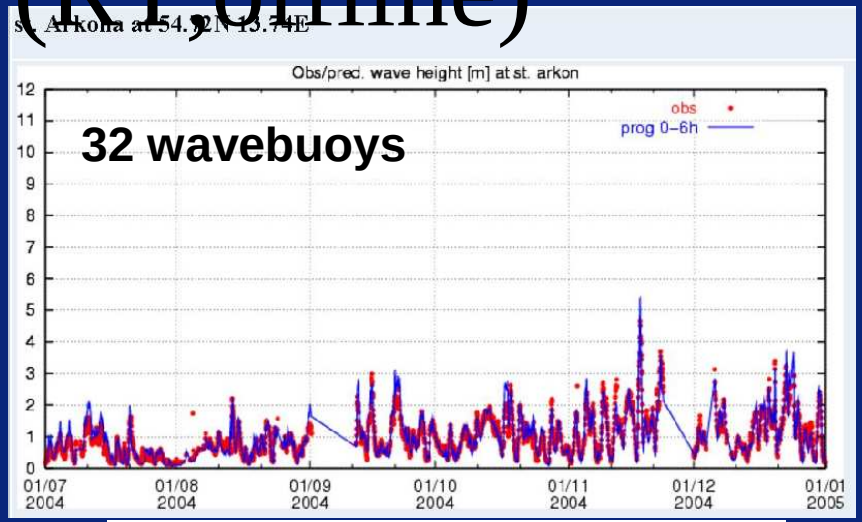


Merging tidal gauge and altimetry data for coastal model validation using a statistical model

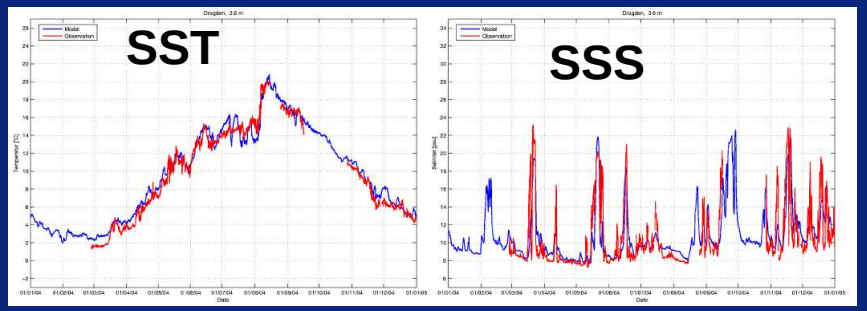
- Multivariate regression where data from 14 tide gauge stations are regressed onto the satellite altimetry observations
- Tide gauges selected based on the correlation with satellite observations
- Allows real-time sea level estimation in points where satellite data are available

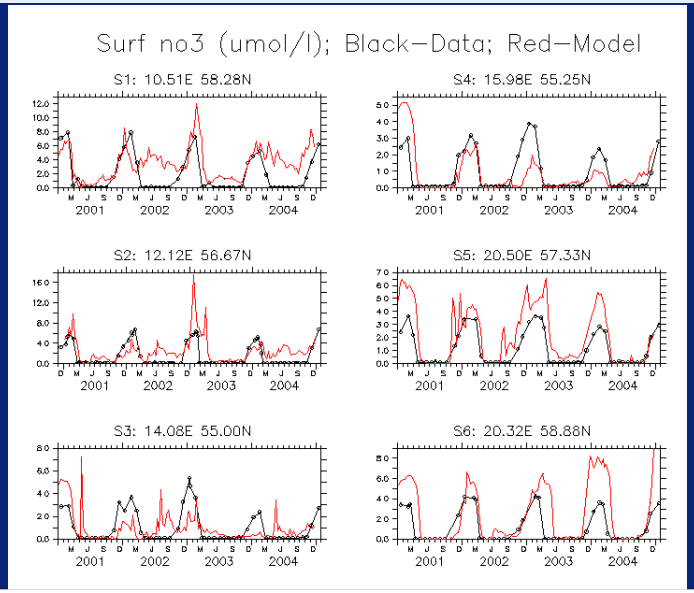


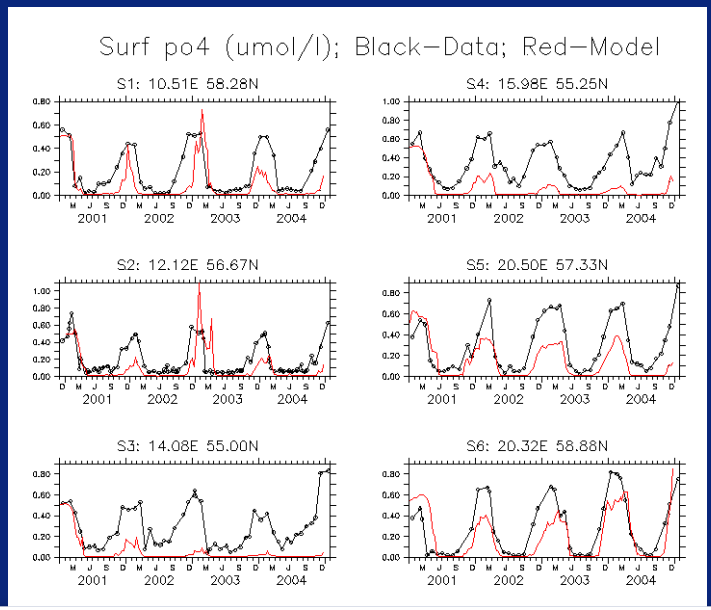
Validation/verification in surface (RT,offline)



Danish Straits

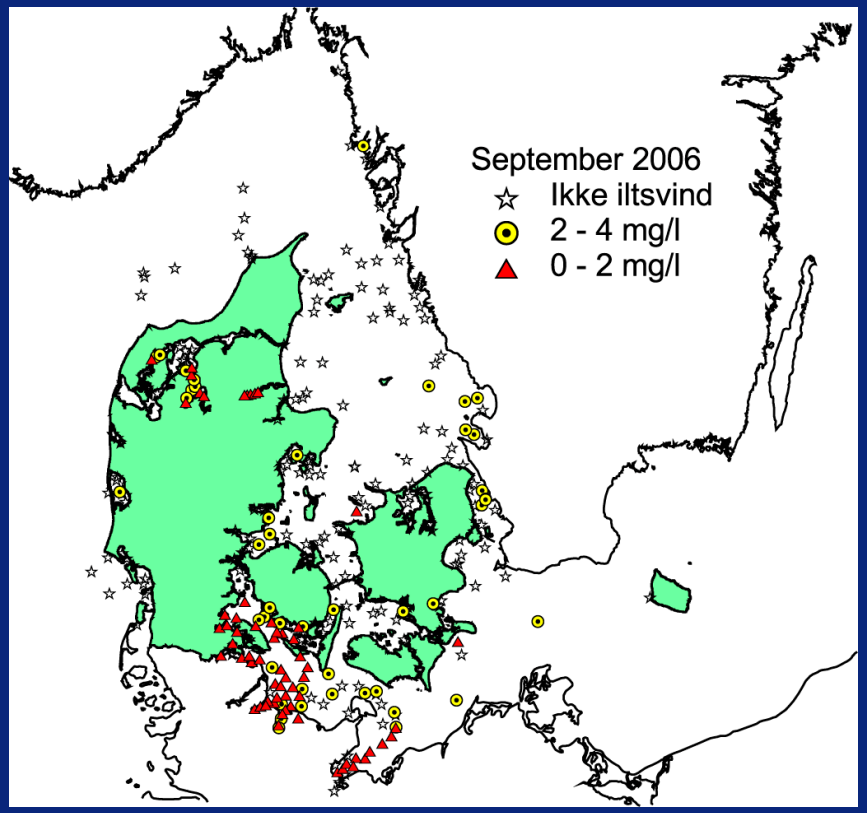


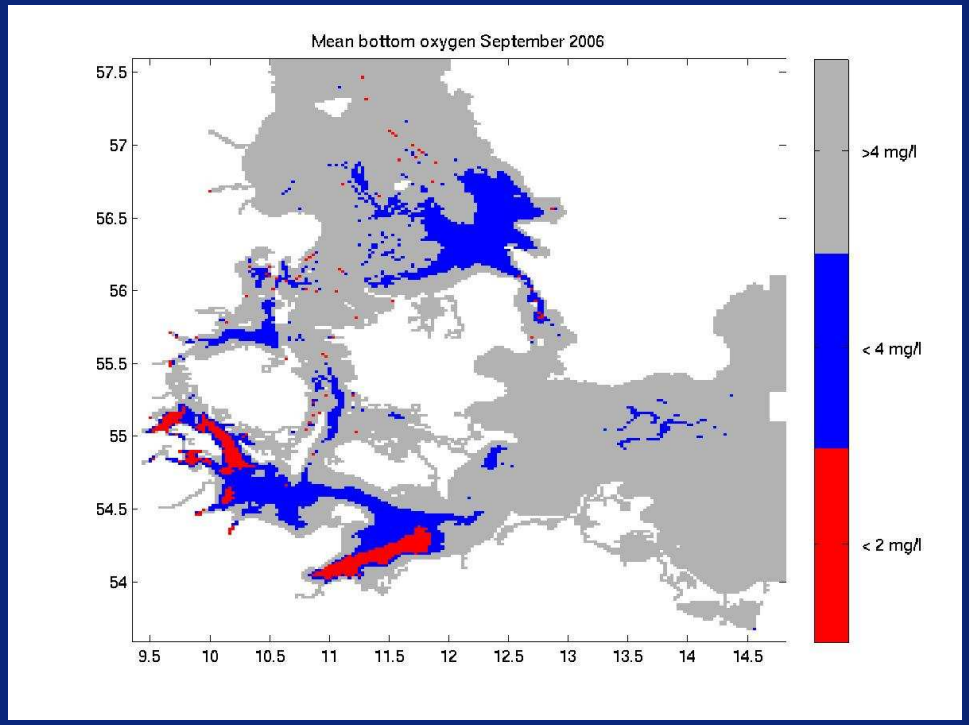




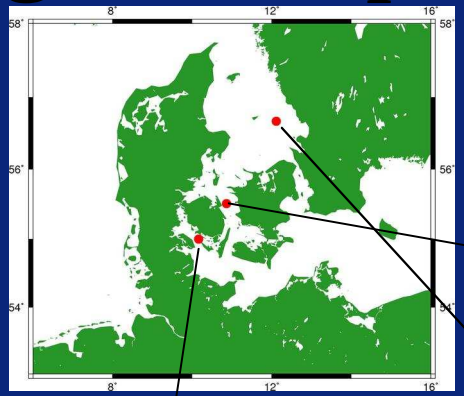
Potential subsurface applications

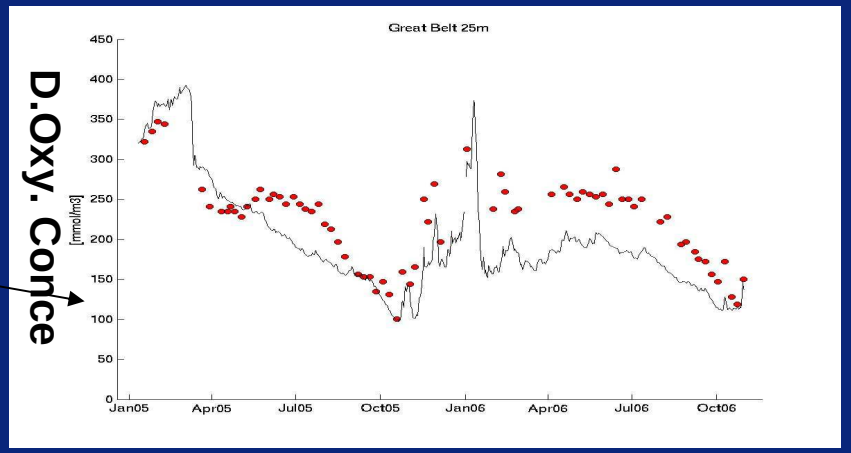
Oxygen depletion: an example of model validation processes

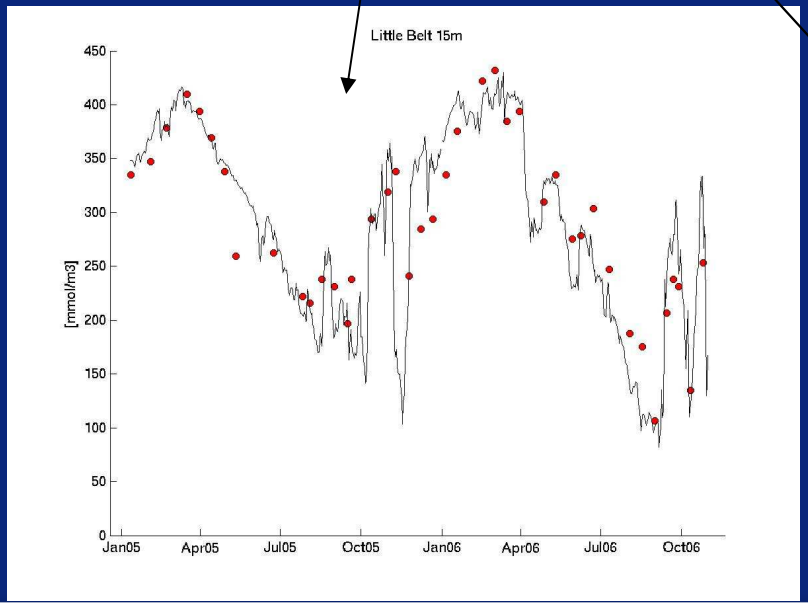


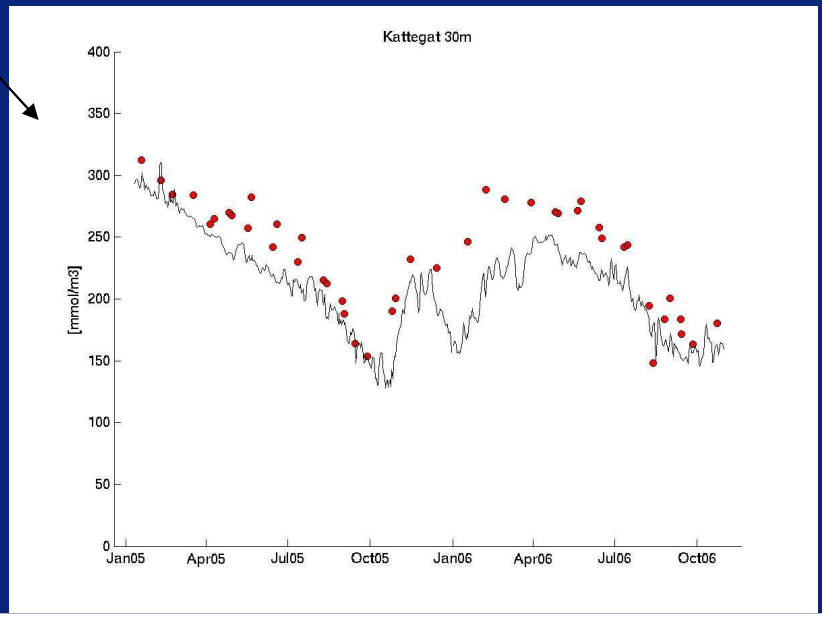


Stations and model-data bottom Oxygen comparison



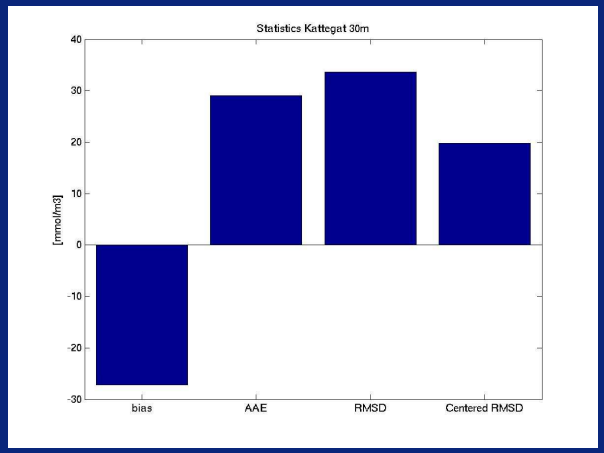


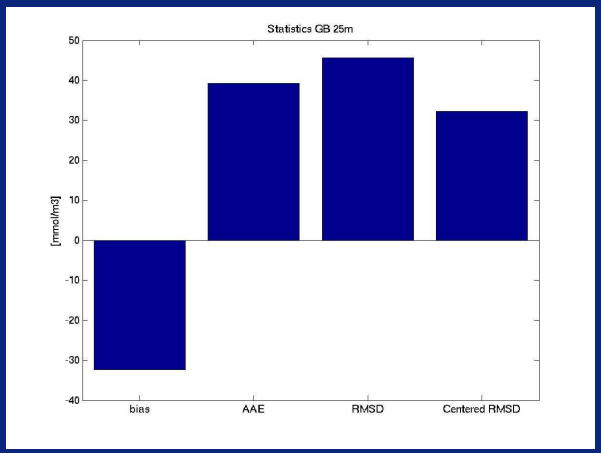


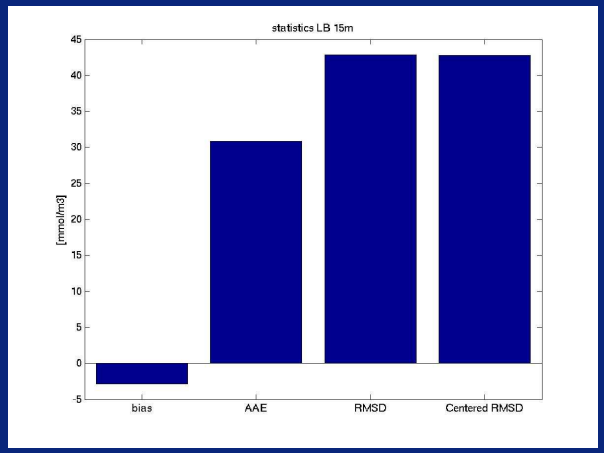


Good? How good?

- The RMS error <1.5mg/l
- Good spatial pattern
- Conclusion: the model has a usable skill for oxygen depletion prediction

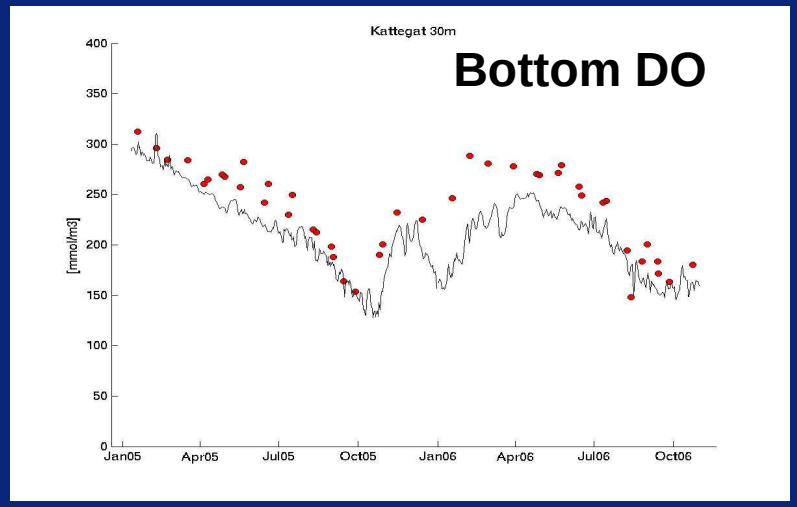


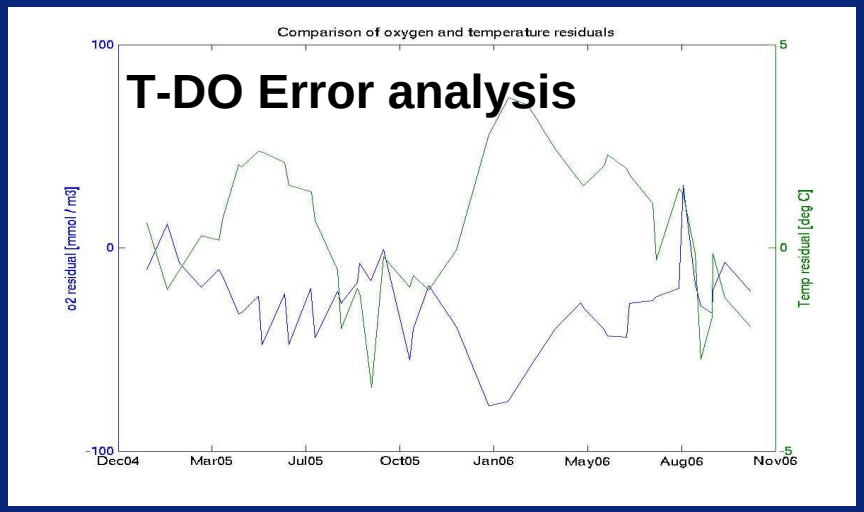


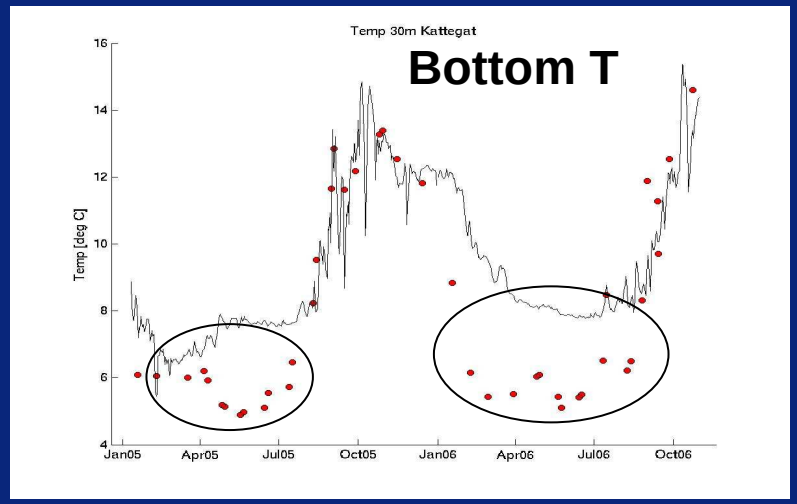


Sometime not good, why? What to improve?

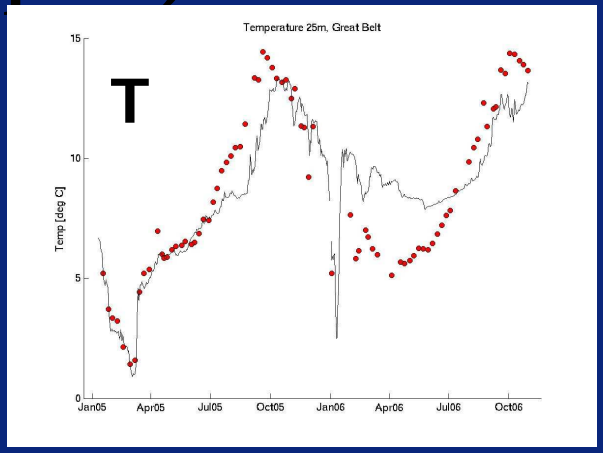
- Bottom temperature error highly correlated with bottom oxygen error
- Definition of bottom: fixed depth? Or bottom as it is?
- What to improve: Tb, mixing..

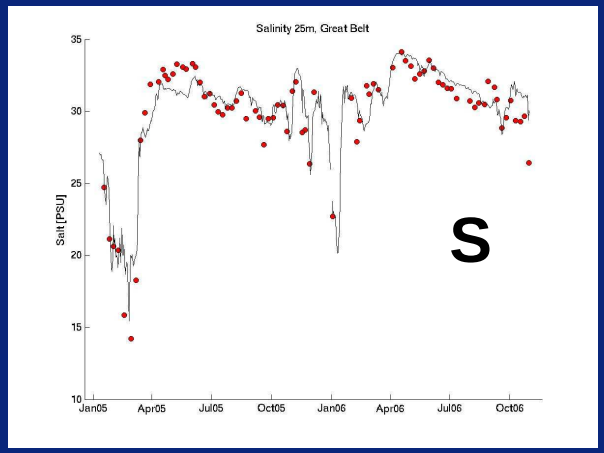


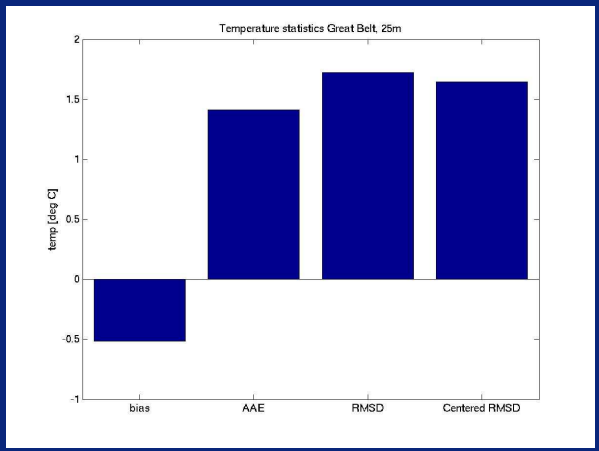


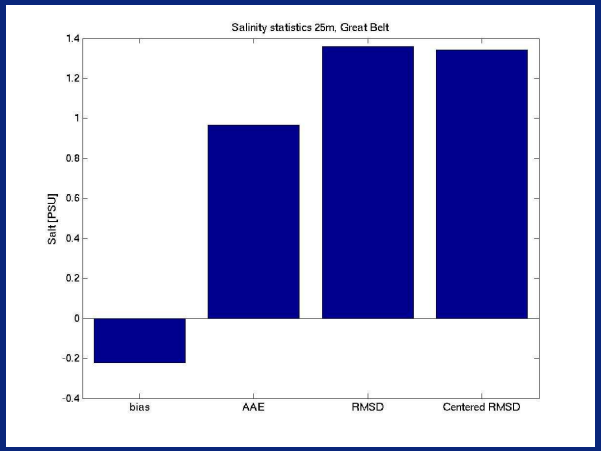


Bottom T/S (Great Belt, 25m depth)

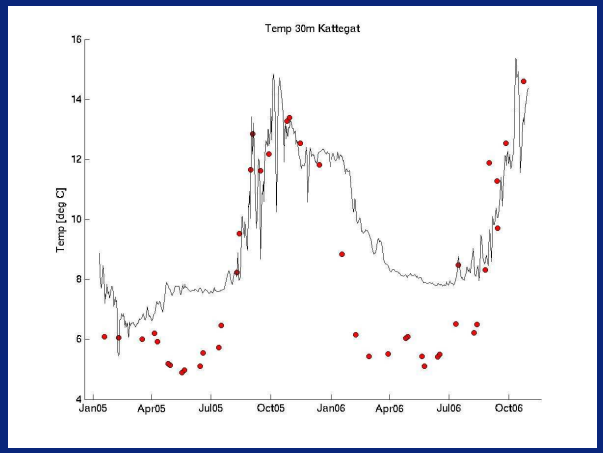


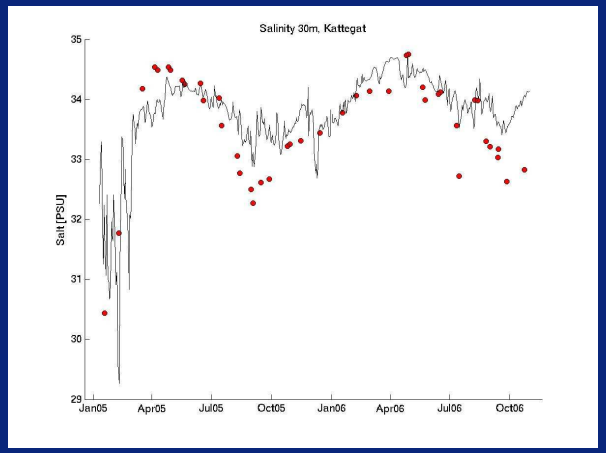


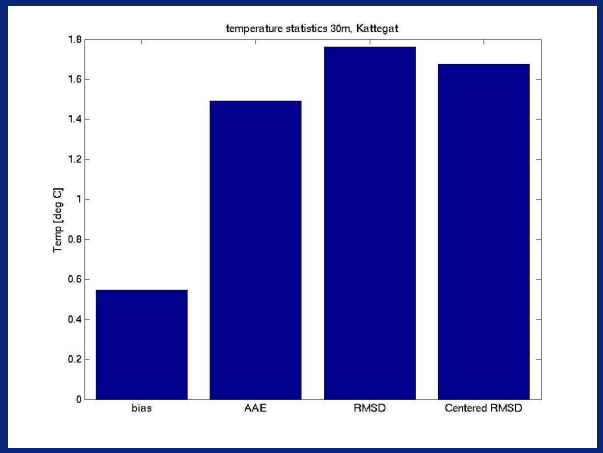


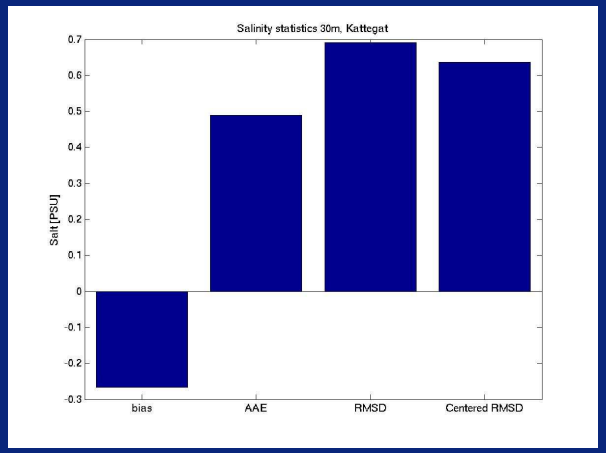


Bottom T/S (Kattegat, 30m depth)



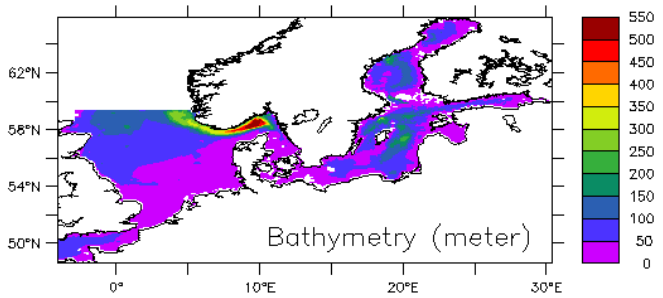


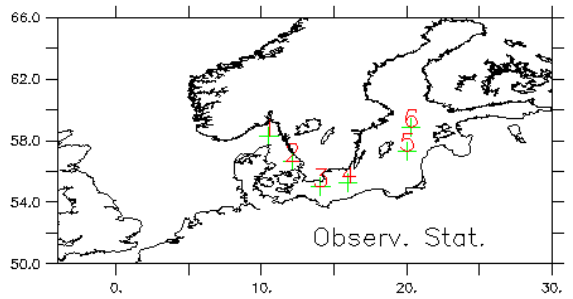




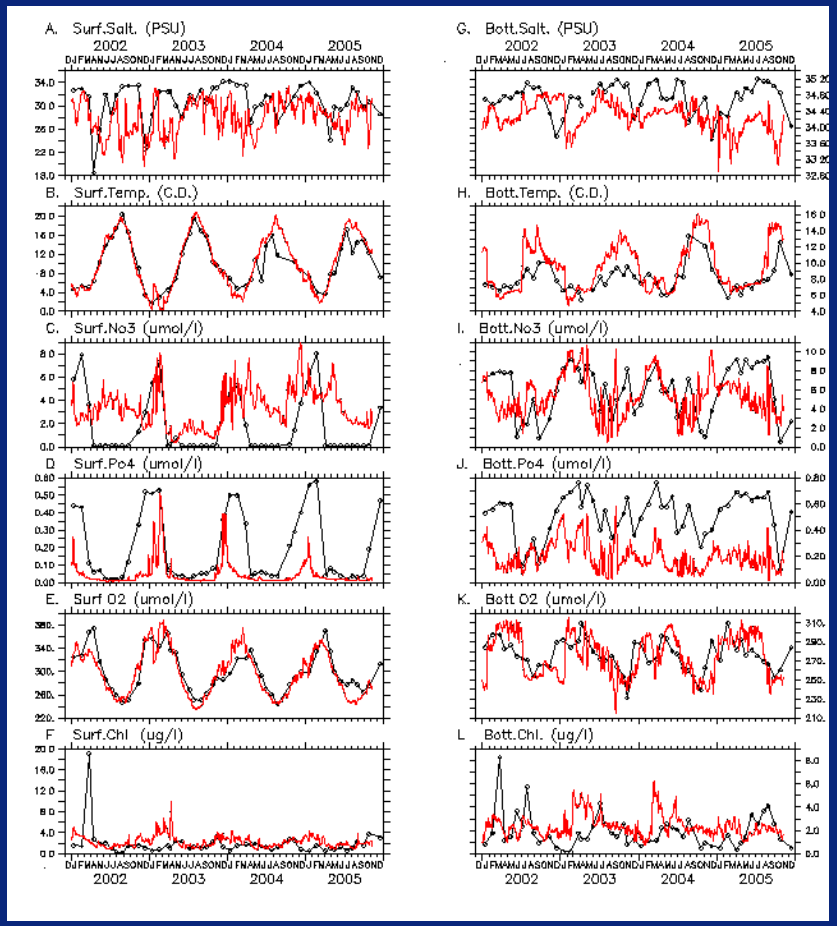
Ecosystem model calibration-DMI ERGOM

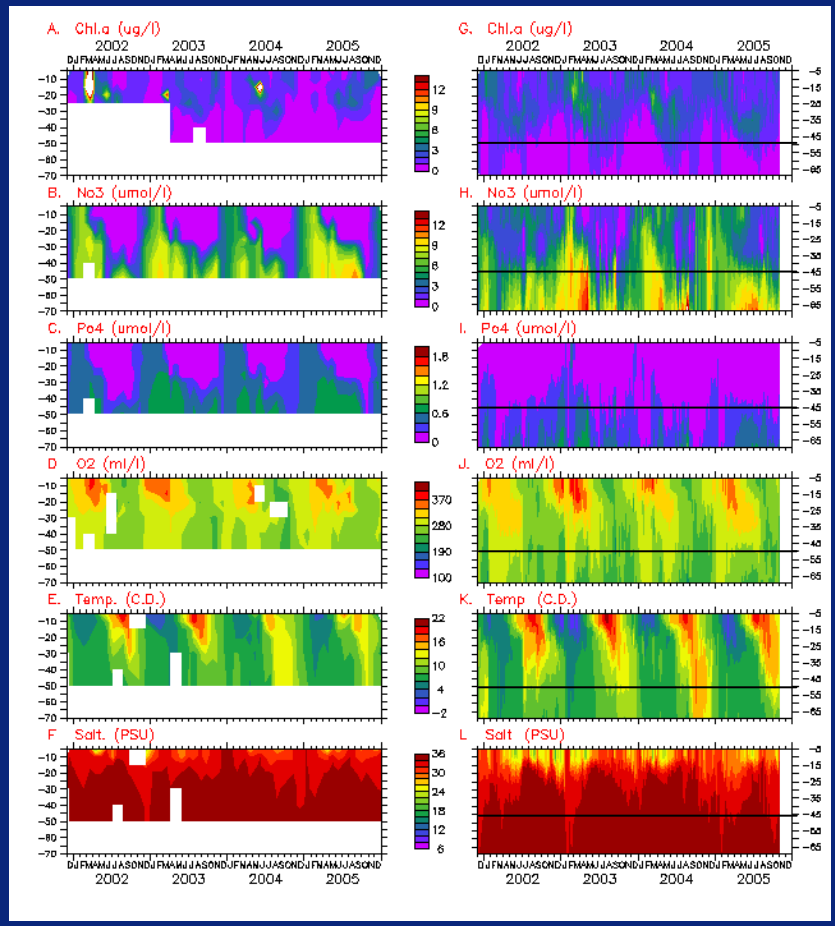
- Purpose: to improve model quality on basic biochemical paramters (e.g DIN, DO, Phosphate, chla) in
  - Surface, subsurface, bottom,
  - Seasonal, interannual, synoptic scales
  - Basin-sub-basin structure
- Station selection: certain rules applied



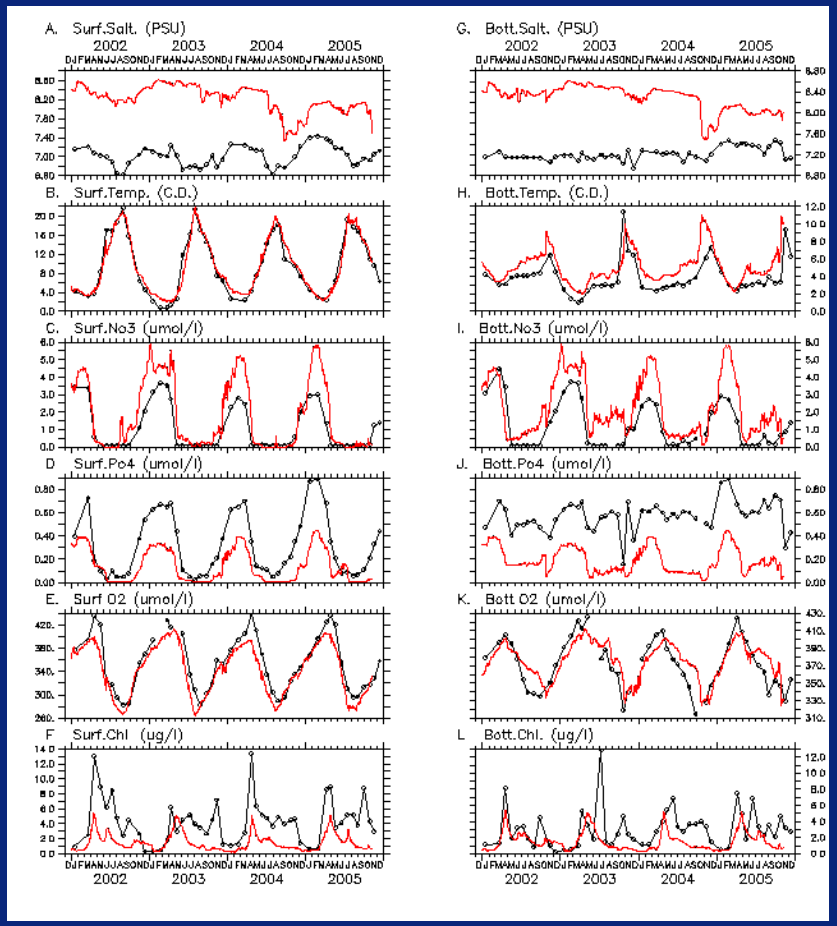


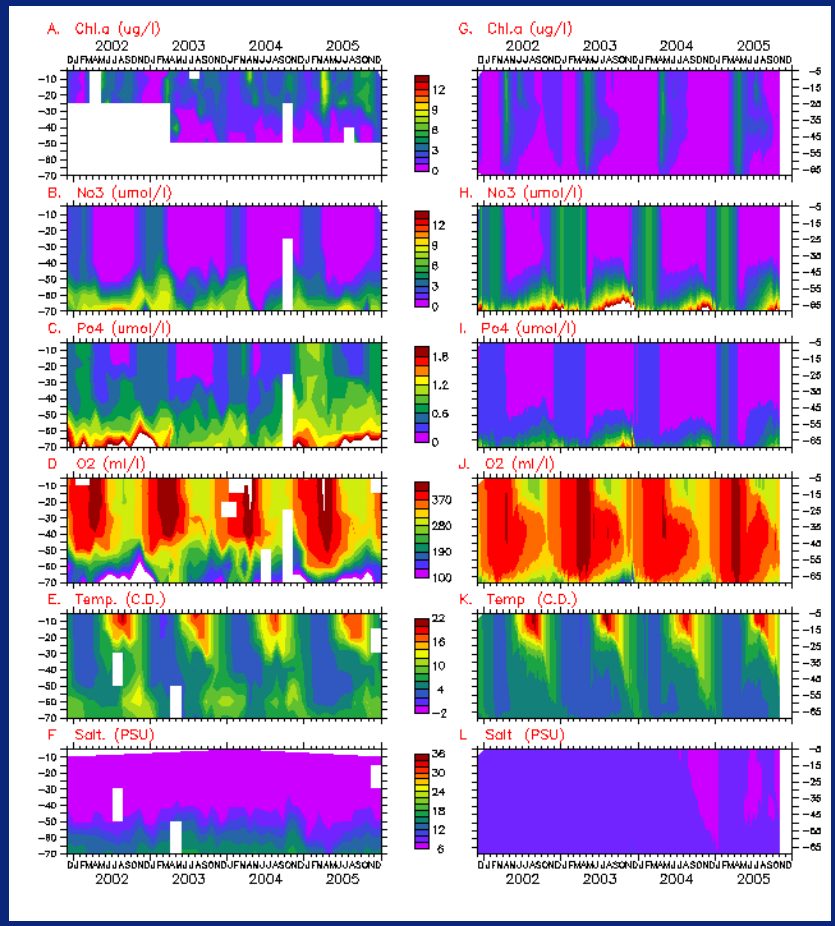
Station 1: Kattegat entrance



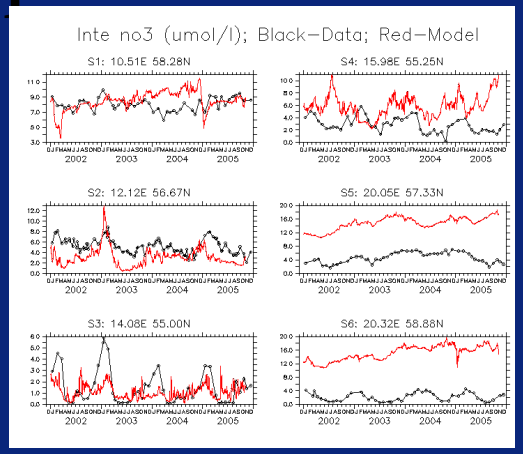


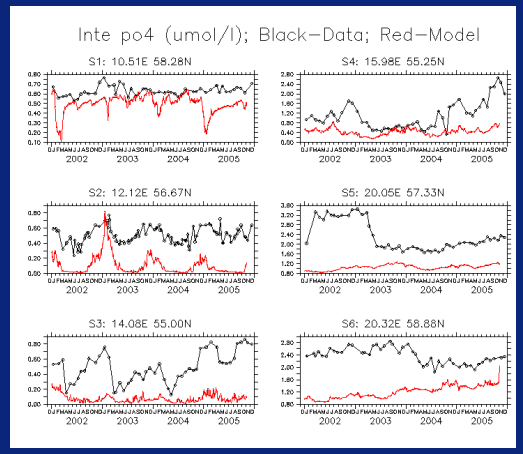
Station 5: Gotland Deep

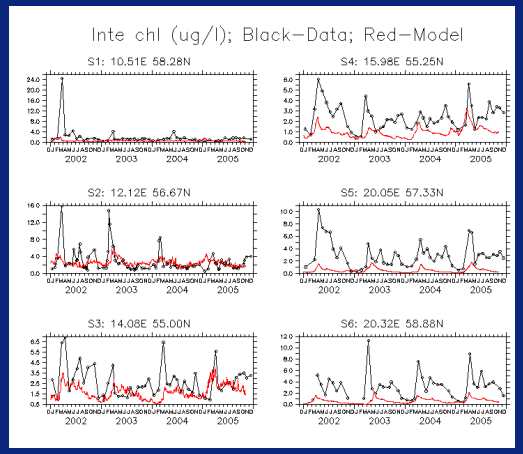


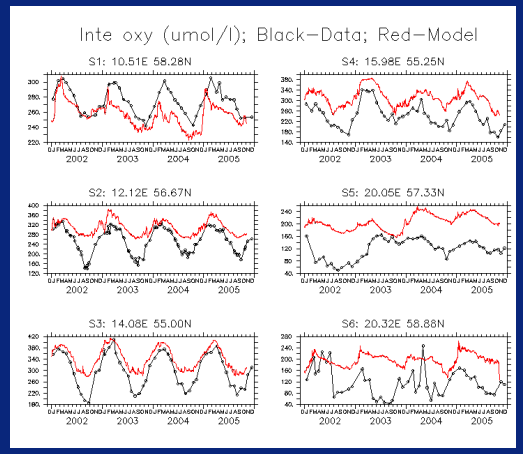


Calibration of vertically integrated properties









Identified areas for improvement

- What
  - Bottom temperature
  - Bottom oxygen too high
  - Too low phosphate, esp. in Baltic Proper
  - Two high nitrate in deep water
- How
  - Spin up, data assimilation, increase mixing
  - Spin up, improving T
  - Adding phosphate source term; spin-up; improving O2
  - Improving O2-Nitrate relationship, debug

General remarks

- Purpose of validation
- Design validation experiment
- Quantify validation matrices for specific application purposes
- Unified validation protcols (tech.)
- Link error statistics with ocean & model processes
- Common S&T concerns
- Evaluate model and data on phenomenon and applications
- Data needs

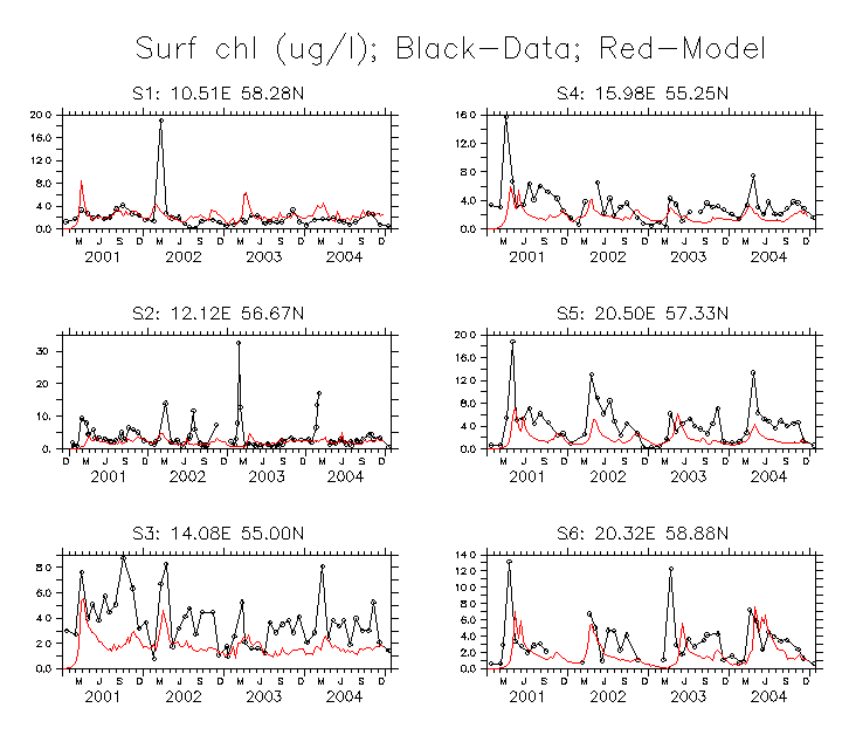
Common S&T issues for model validation

- Software standard validation
- Benchmark test strucure: properties vs quality indecis
- Data uncertainties
- Error cross-correlation analysis, in
  - Identify error sources
  - Data assimilation
  - Assessment and optimal design of observation networks

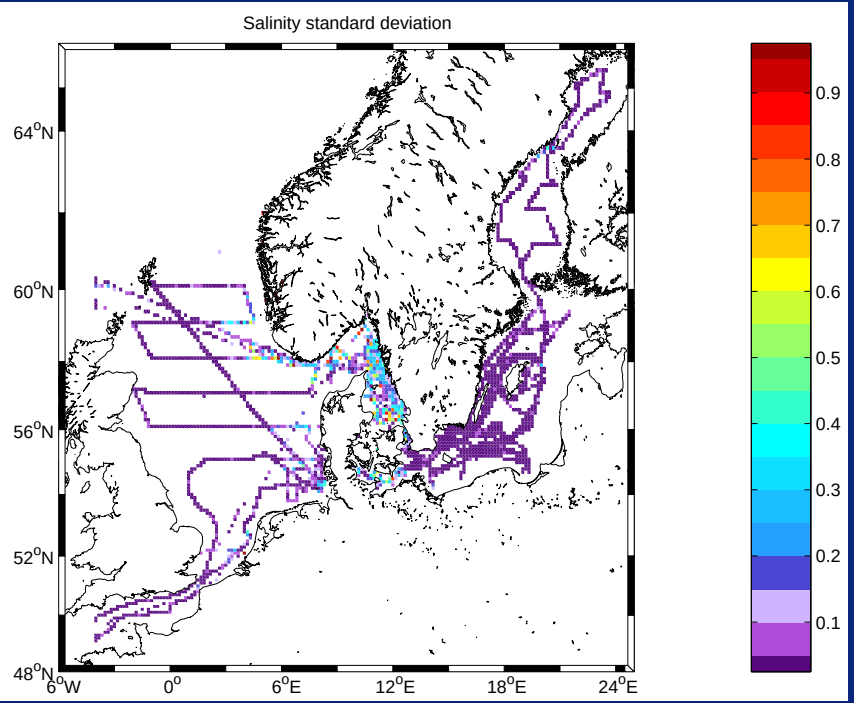
General remarks

- Purpose of model validation
  - To which extent, for which applications we can trust the model?
  - To find where and how to improve the model?
- What to validate?
  - Variables: absolute values, spatial-temporal variation
  - Processes: mixing, friction, transport etc
  - Phenomenon:
    - Synoptic scale: front, inflow, algae bloom, oxygen depletion
    - Seasonal change
    - Interannual change
- To understand data
  - Data uncertainty:
    - sampling error
    - Instrument error (multi-sensor)
  - Can the data represent the phenomenon?
- How?
  - Budget balance: no drift
  - Vertically integrated properties
  - Spatial patterns
  - Single point time series
  - Peak events
  - Vertical structure
- Error cross-correlation analysis

About observations



The monthly data may not represent interannual change and synoptic scale signals

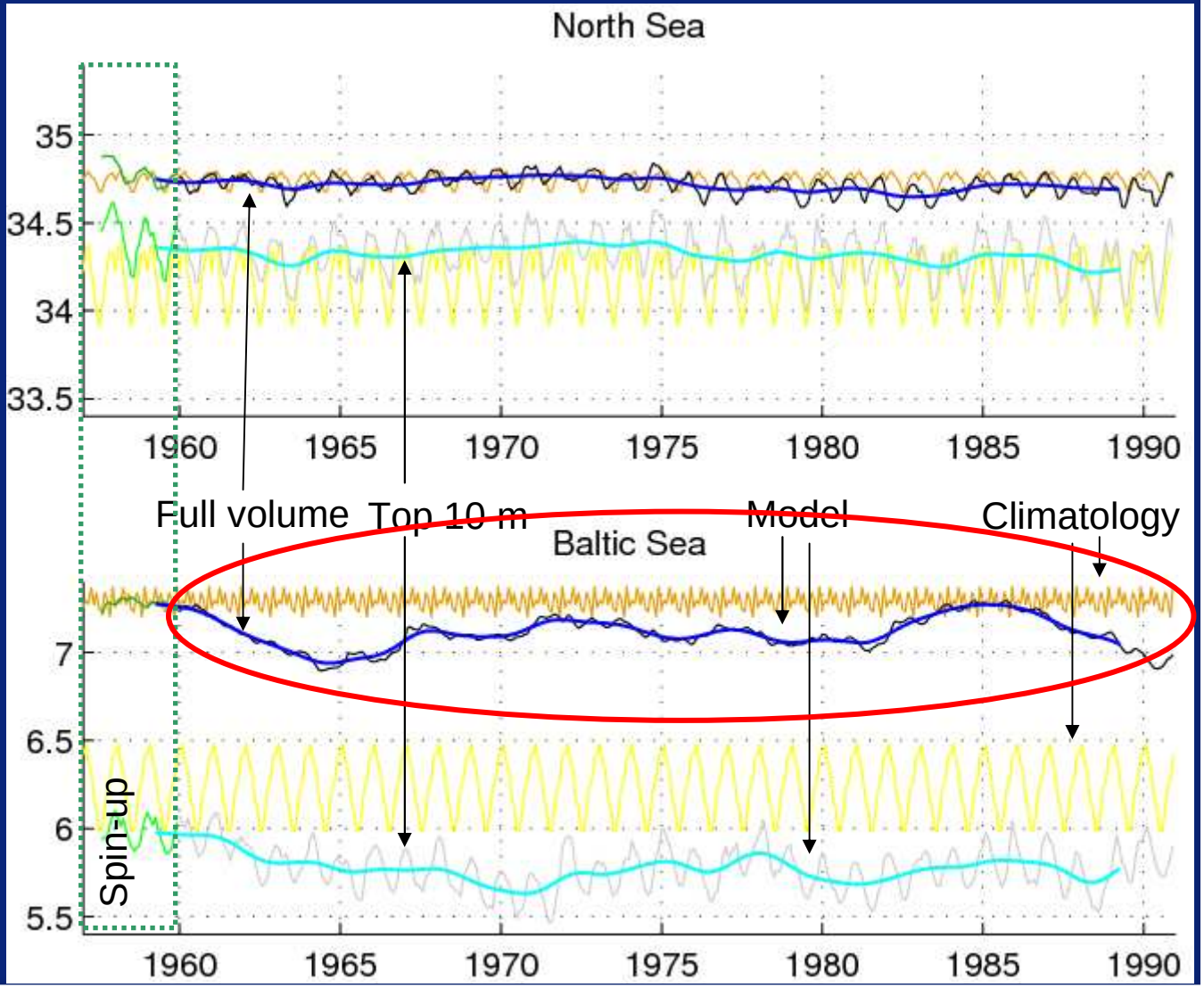


Horizontal sampling error of SSS (psu) in a 6nm by 6nm box

Volume averaged salinity – validation

Application in regional climate change simulation

- Overall, the salinity is stable and close to climatology (Janssen et al. 1999).
- Baltic sea surface water about 0.4 psu too fresh, and the seasonal cycle is smaller than in the climatology.
- Baltic Sea interannual variability of same magnitude as Gotland Deep observations for non-stagnant periods (Feistel et al. 2008).



Status of coastal model quality and applications based on DMI models

- T/S:
  - Surface: synoptic-seasonal-interannual scale applications
  - Subsurface: less predictability comparing to surface but useful; biggest error in bottom
- Oxygen: usable for oxygen depletion prediction applications (simplified models)
- Chl/Nitrate/Phosphate
  - Surface/shallow water: seasonal change signal useful, synopic and interannual change signal to be improved.
  - Deep water: seasonal change signal weak and less useful
  - Deep bottom water: no real applications can be made before further improvements

DMI
Center for Ocean and Ice

Status of coastal model quality and applications based on DMI models (cont.)

- 3D Coastal ocean model can be applied in marine climate change studies
- Coastal Sea biochemical model is not ready to make useful operational forecast yet.
- Coastal Sea biochemical model may be used for reanalysis applications
- Coastal Sea biochemical models may not be ready to make quality assured climate scenario runs

Thank you!