Norrköping ECOSUPPORT 2010

Uncertainty assessment of state-of-the-art coupled physical-biogeochemical models for the Baltic Sea

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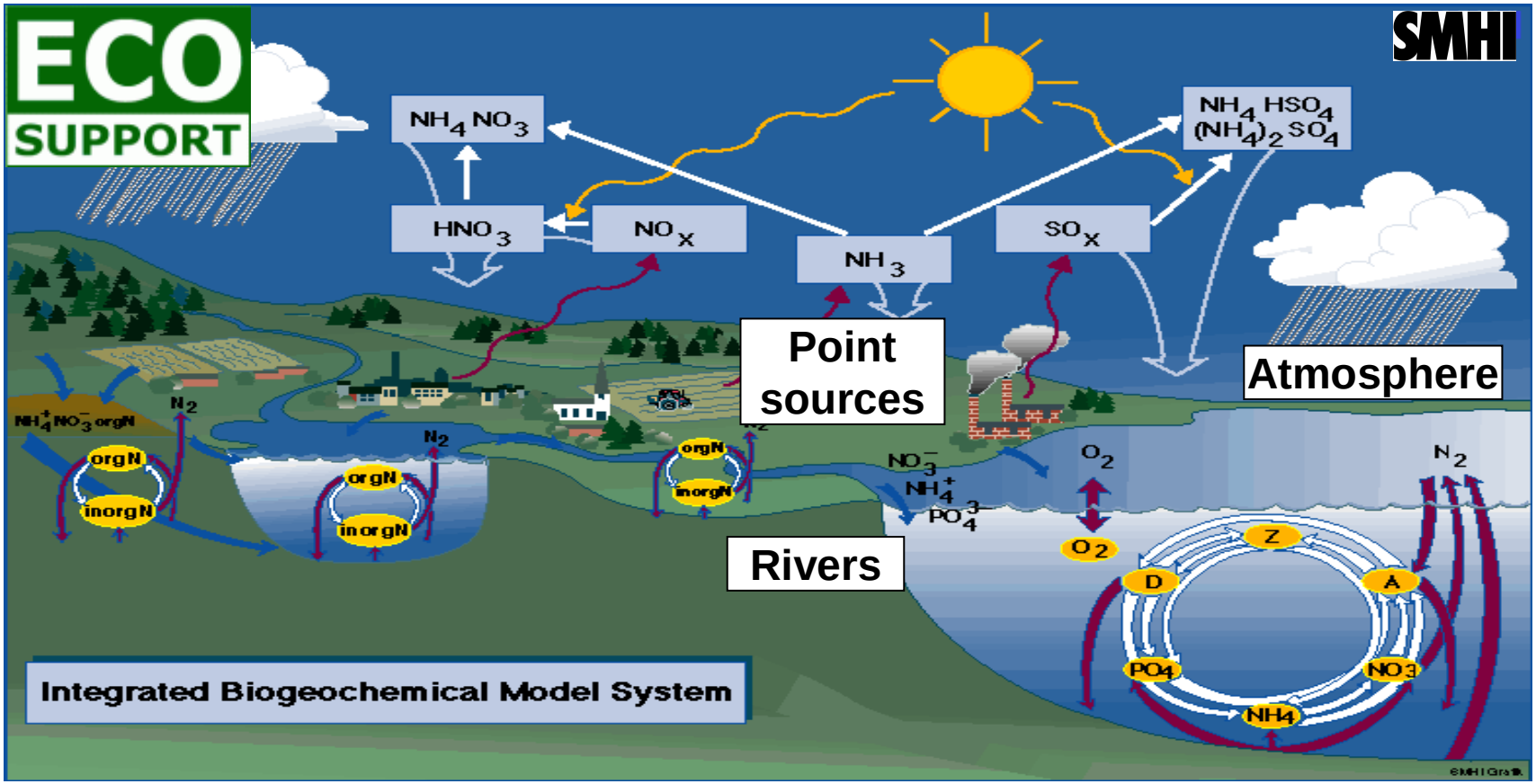
Swedish Meteorological and Hydrological Institute, Sweden

SMHI



1. Three coupled physical-biogeochemical models calculate changing concentrations of nutrients and organic matter in the Baltic Sea

2. Three time periods

- 1850-2006: Hindcast from “pristine” to present conditions
- 1960-2100: Scenarios forced by down scaled climate GCM’s
- 1961-2006: Hindcast/**validation**/control period of scenarios

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Authors:
K. Eilola[1], B. G. Gustafson[2], R. Hordoir[1], A. Höglund[1], I. Kuznetsov[3], H. E. M. Meier[1], T. Neumann[3], O. P. Savchuk[2]

1. Swedish Meteorological and Hydrological Institute, Sweden
2. Baltic Nest Institute, Resilience Centre, Stockholm University, Sweden
3. Baltic Sea Research Institute Warnemünde, Germany

3D Model:	RCO-SCOBI	(2nm)
1D Model:	BALTSEM	(13 basins)
3D Model:	ERGOM	(3nm)

Results in SMHI report (www.smhi.se):
K. Eilola, B. G. Gustafson, R. Hordoir, A. Höglund, I. Kuznetsov, H. E. M. Meier, T. Neumann, O. P. Savchuk, 2009, Quality assessment of state-of-the-art coupled physical-biogeochemical models in hind cast simulations 1970-2005, Rapport Oceanografi No.101, SMHI, Norrköping, Sweden.

Model validation/intercomparison

- State-of-the-art models at the beginning of the project
- Different nutrient loads and initial conditions
- Same physical forcing 1961-2006 (ERA40-RCA)
- Validation data 1970-2005 at standard depths from Baltic Environmental Database (BED)

- First results. Work is in progress. Validation will be repeated with updated forcing and final improvements of models

ECO SUPPORT

Baltic Nest Institute

Leibniz Institute for Baltic Sea Research Warnemünde IOW

SMHI

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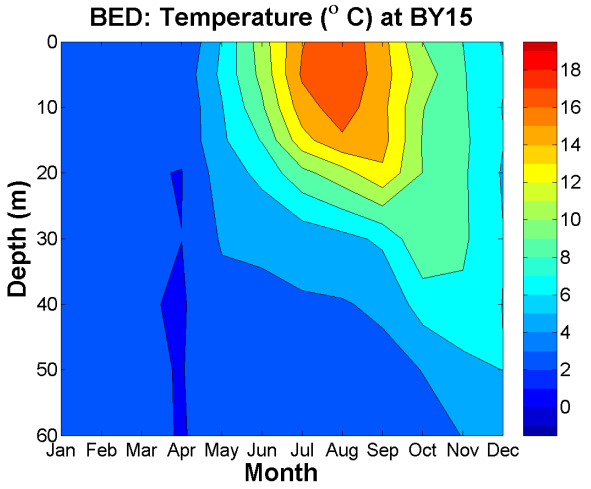
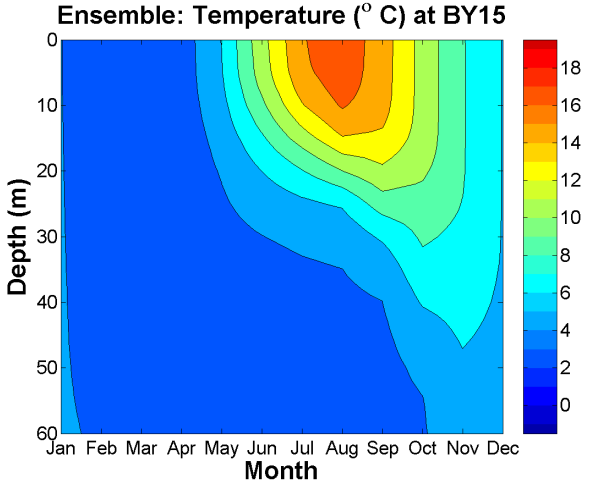
Monthly mean 1970-2005



Observations:

Data at
Standard depths

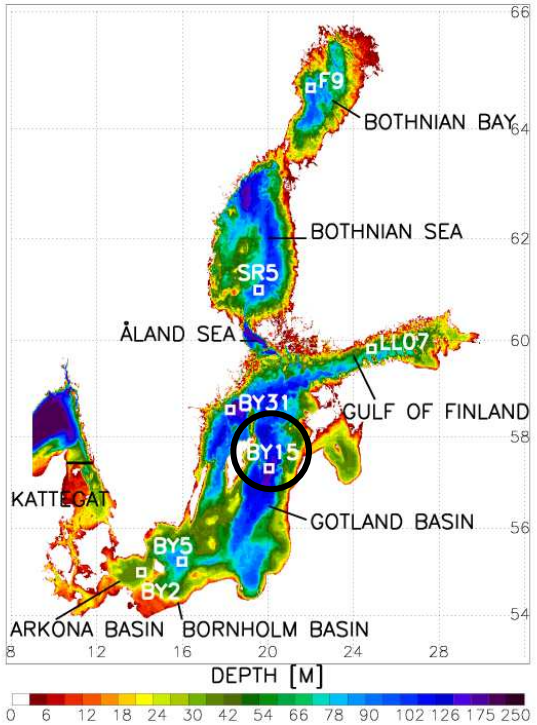


Model ensemble mean*:

Data interval
1 meter

(*average of all models mean values)

Baltic Sea



Station list

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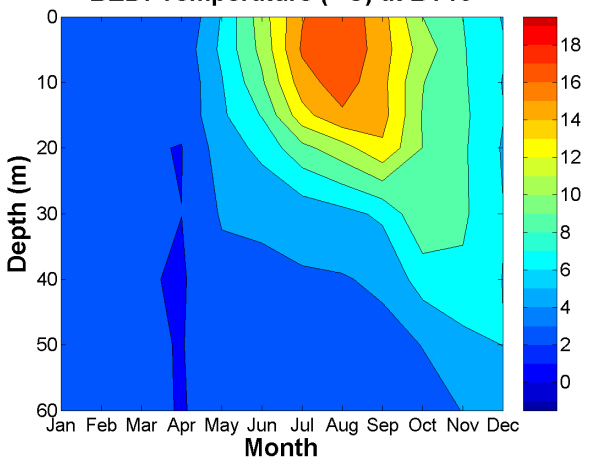
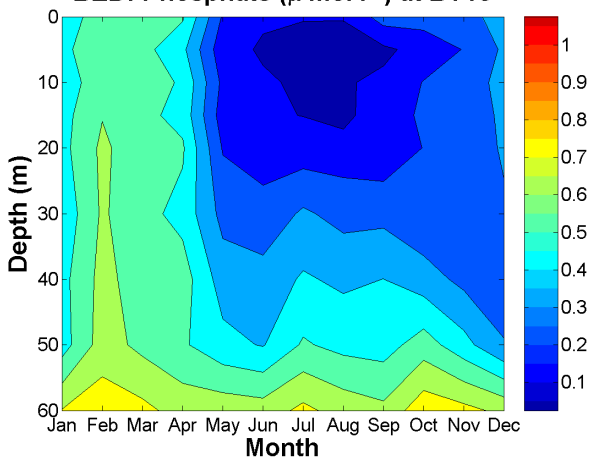
Monthly mean 1970-2005

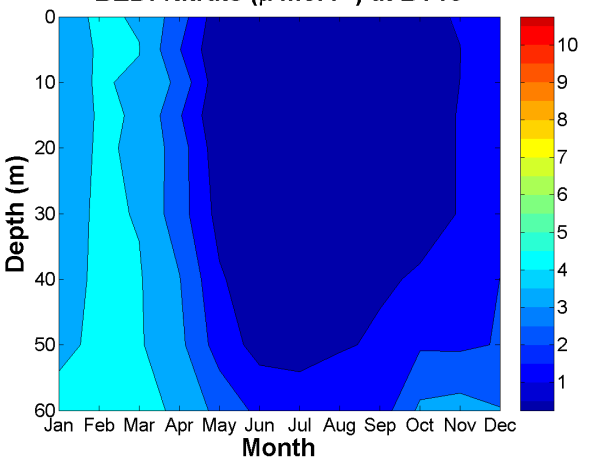
BED: Temperature (^{o} C) at BY15



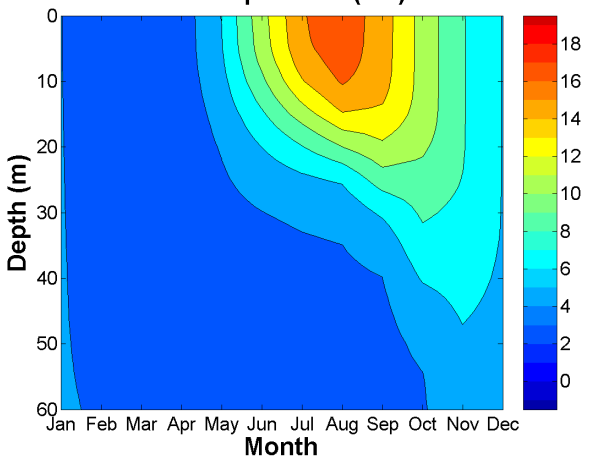
BED: Phosphate (μ mol l^{-1}) at BY15



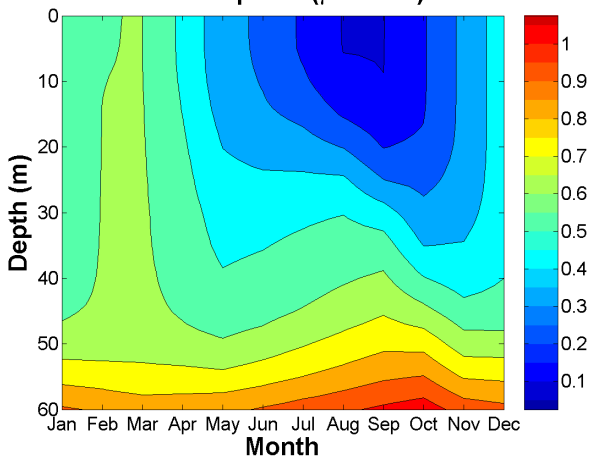
BED: Nitrate (μ mol l^{-1}) at BY15



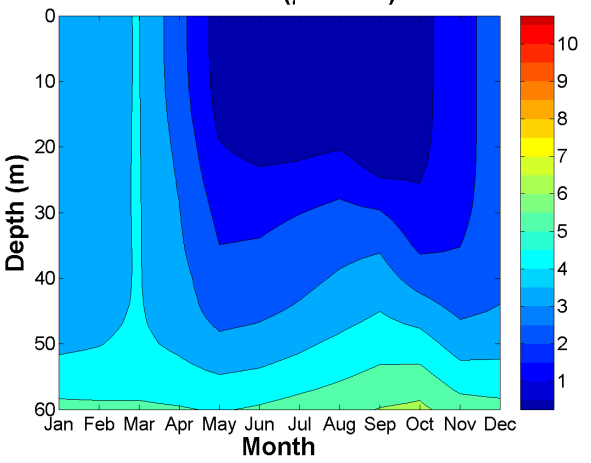
Ensemble: Temperature (^{o} C) at BY15



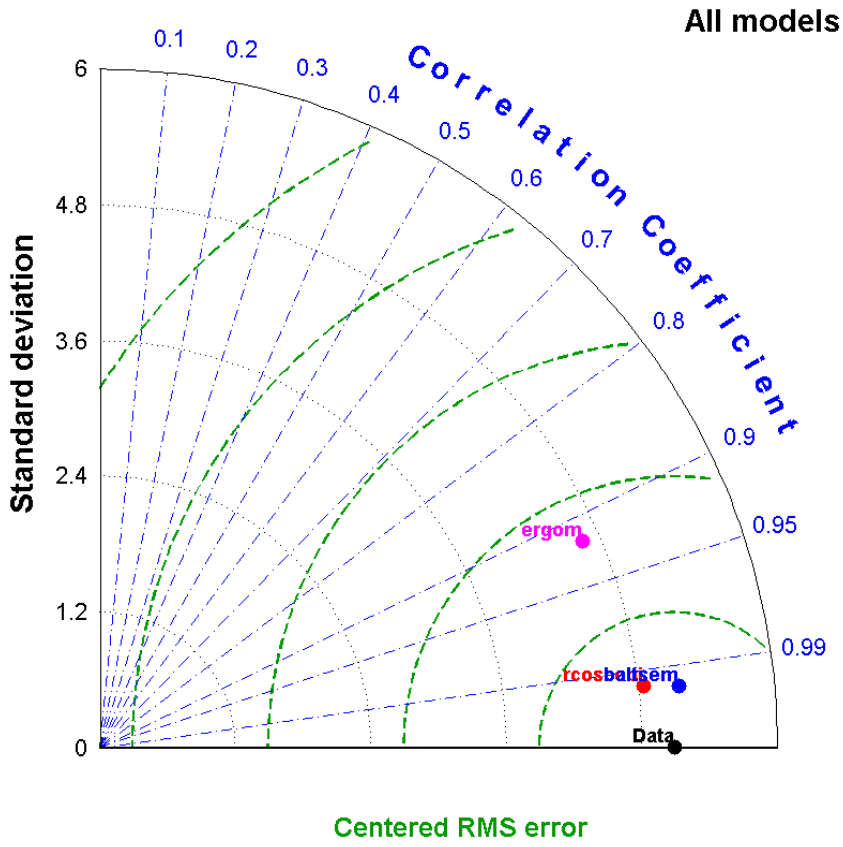
Ensemble: Phosphate (μ mol l^{-1}) at BY15

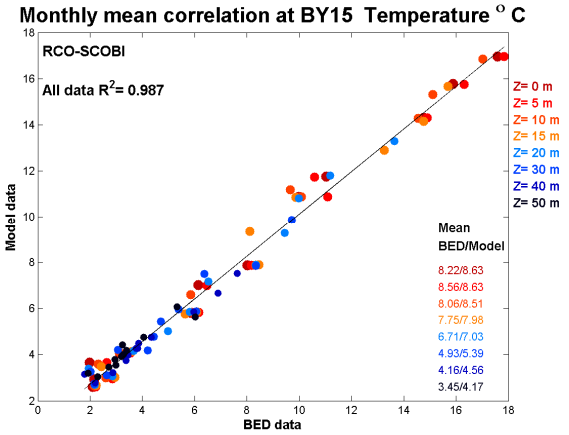


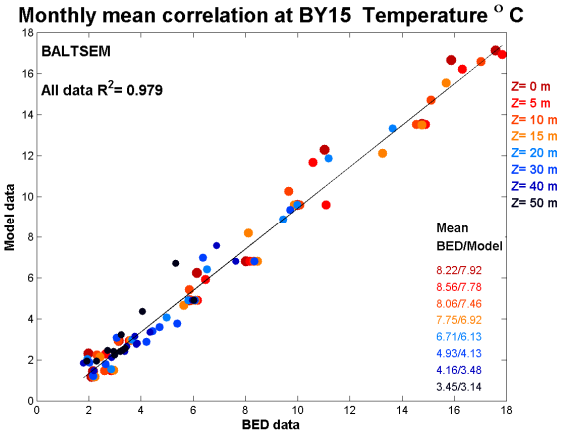
Ensemble: Nitrate (μ mol l^{-1}) at BY15

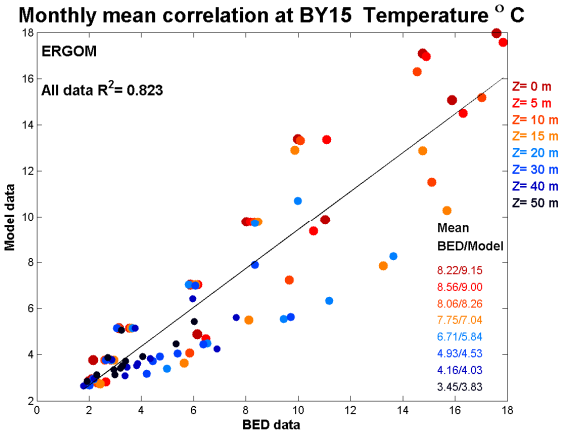


Taylor diagram

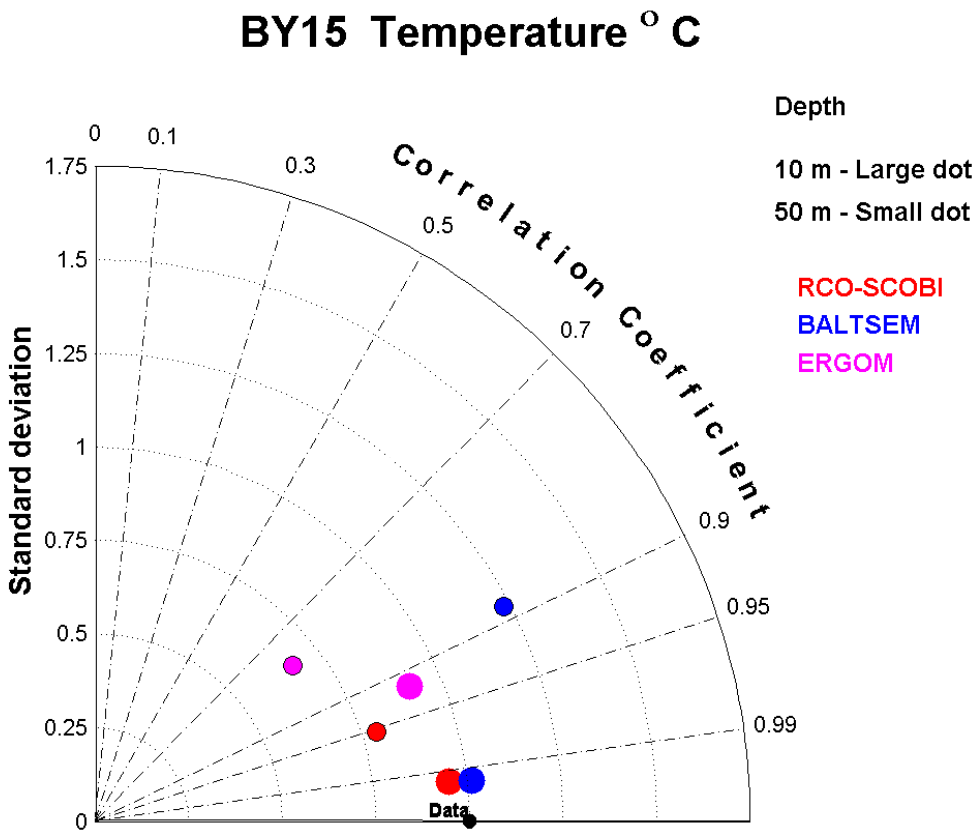








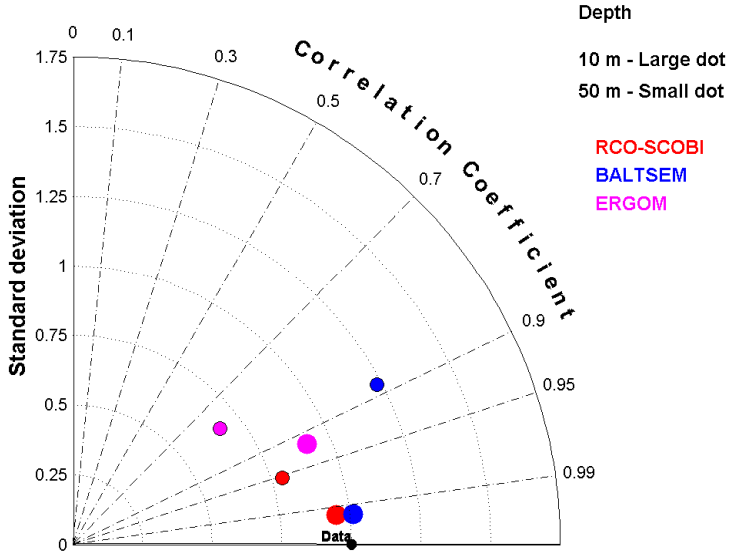
RESULTS SEASONAL



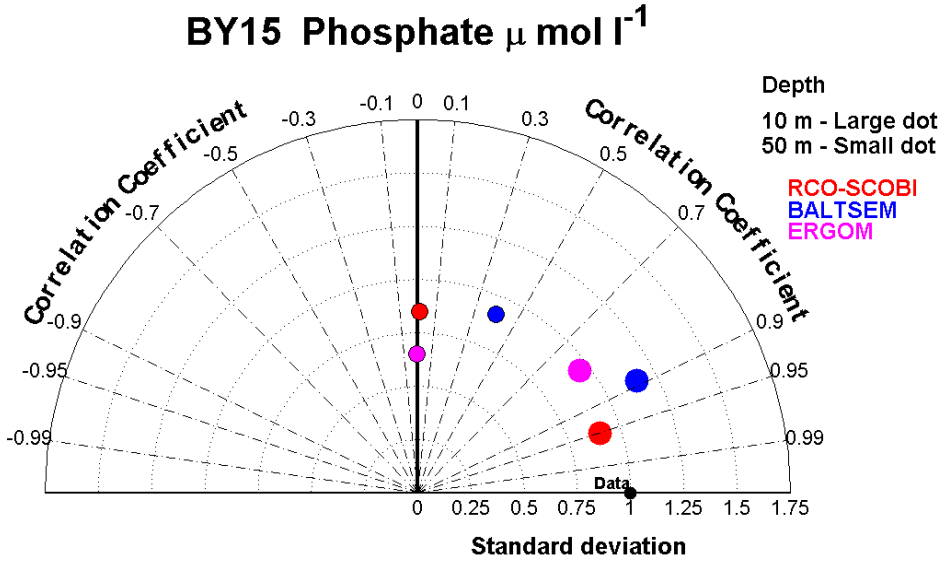
Normalized units to standard deviation
Information from several depths

RESULTS SEASONAL

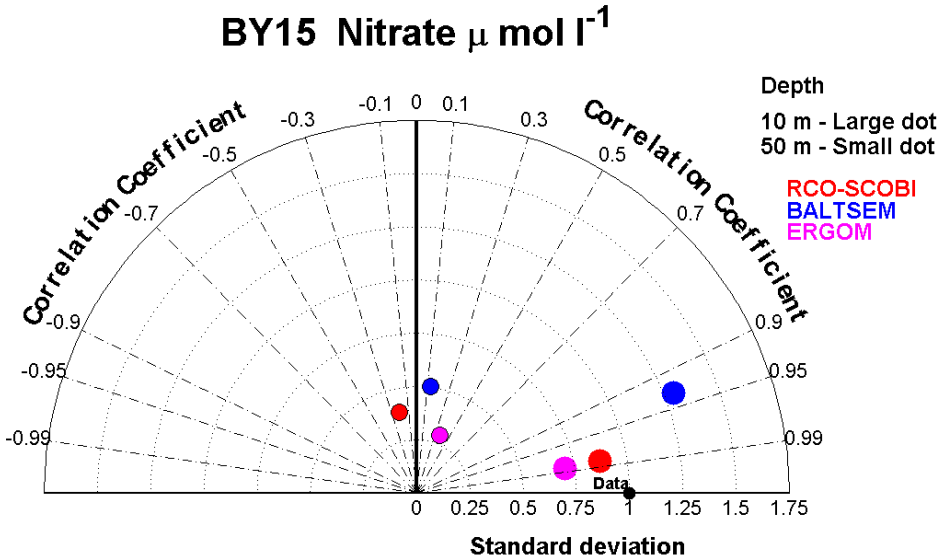
BY15 Temperature ^{o} C



BY15 Phosphate μ mol l^{-1}



BY15 Nitrate μ mol l^{-1}



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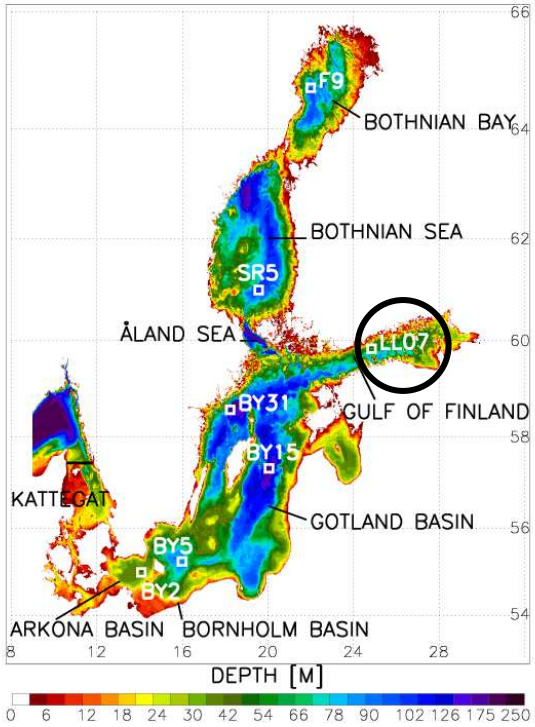
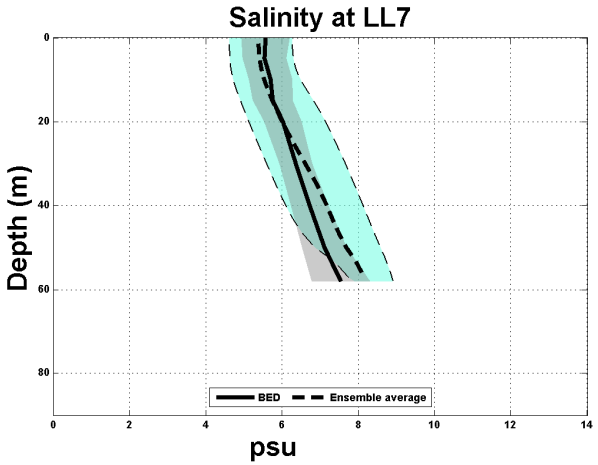
Annual average 1970-2005



Station list

Salinity



Solid line: BED data mean value

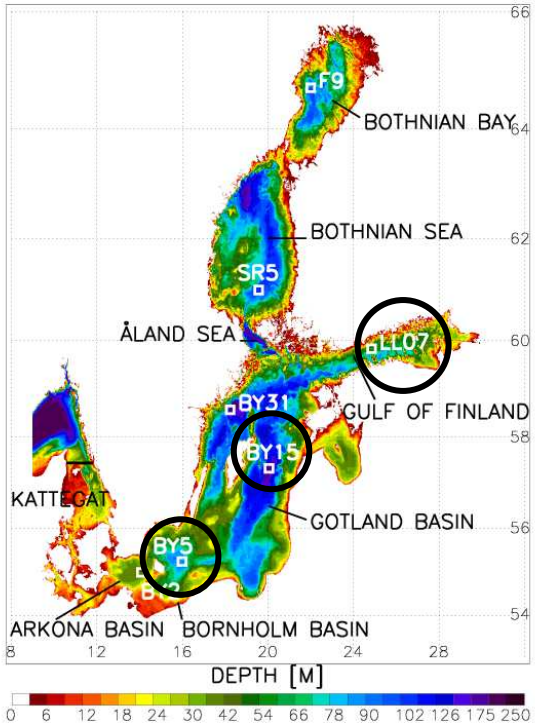
Grey shaded area: ±1 standard deviation

Dashed line: Ensemble mean value

Blue shaded area: Range of ensemble min and max values (ensemble spread)

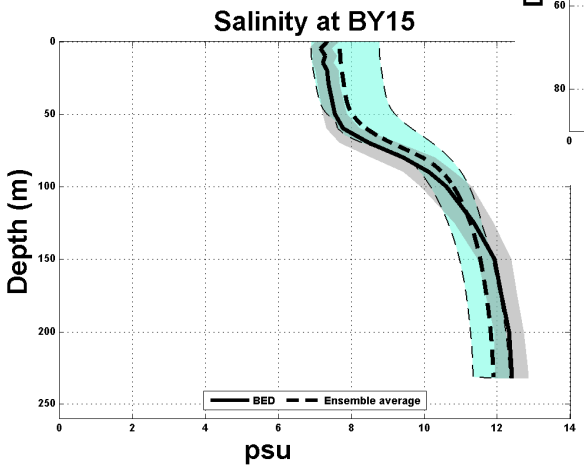
ECOSUPPORT

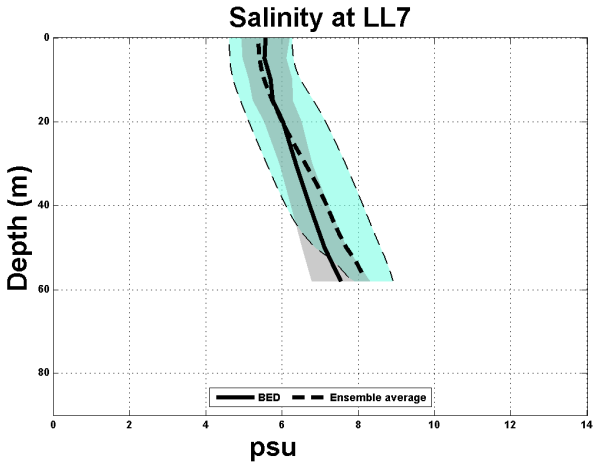
Annual average 1970-2005

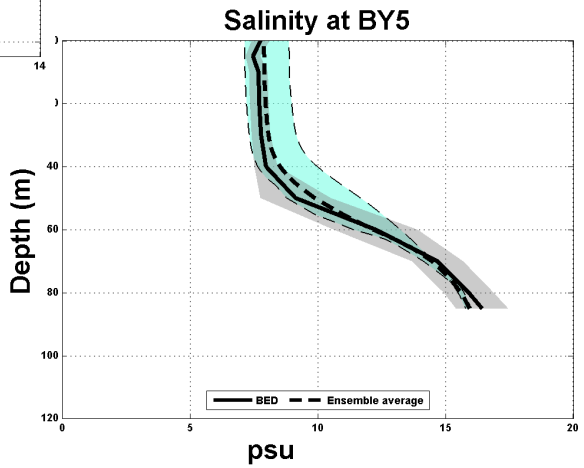


Station list

Salinity

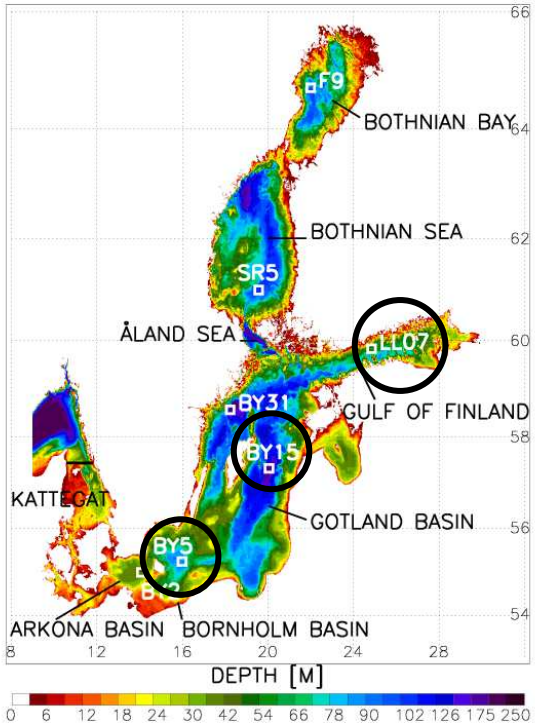






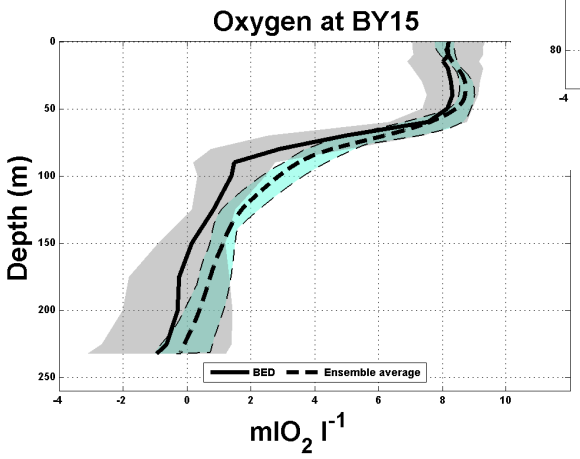
ECOSUPPORT

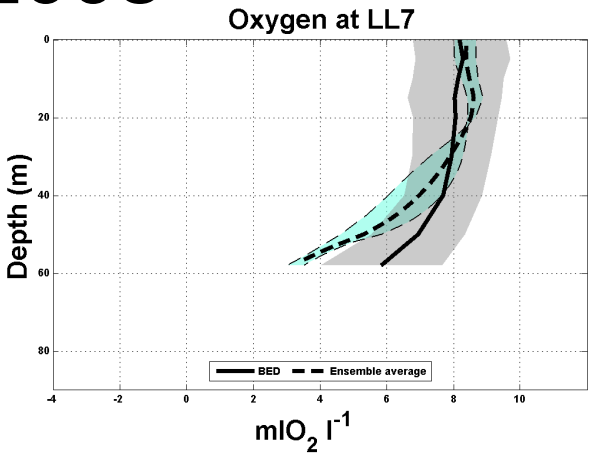
Annual average 1970-2005

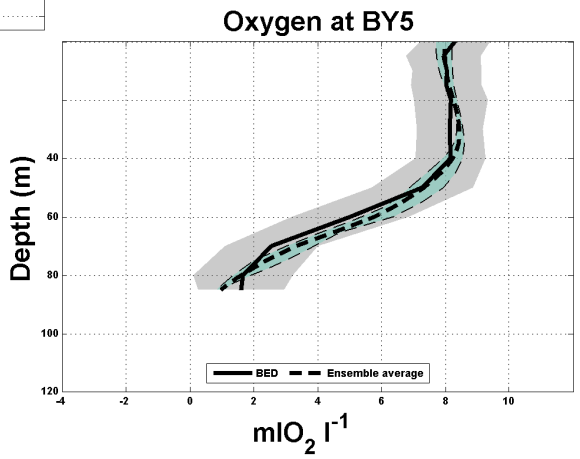


Station list

Oxygen

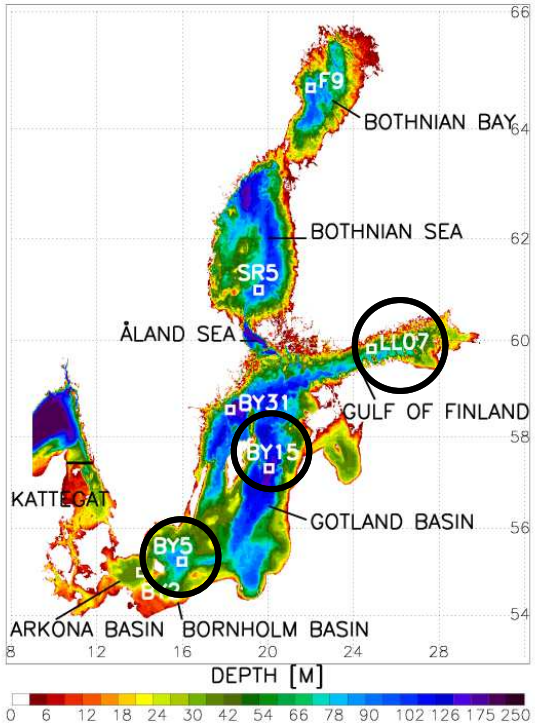






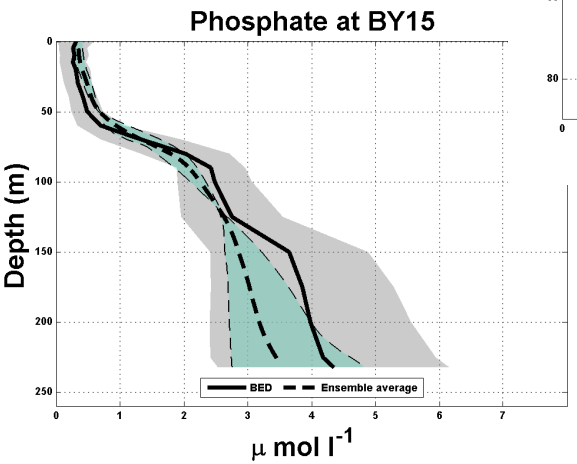
ECOSUPPORT

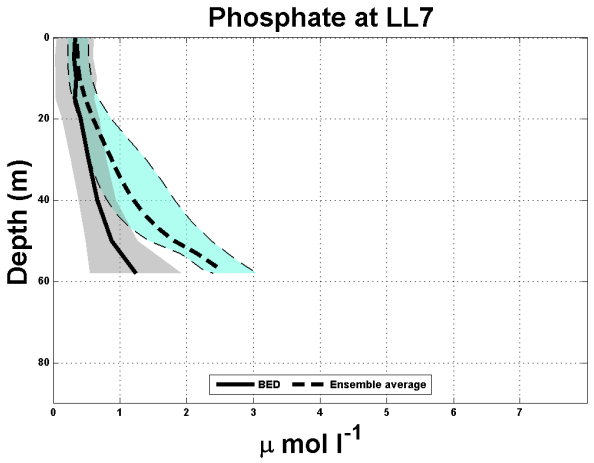
Annual average 1970-2005

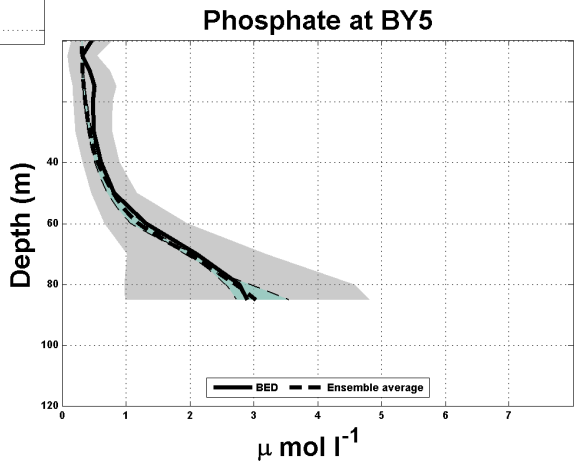


Station list

Phosphate

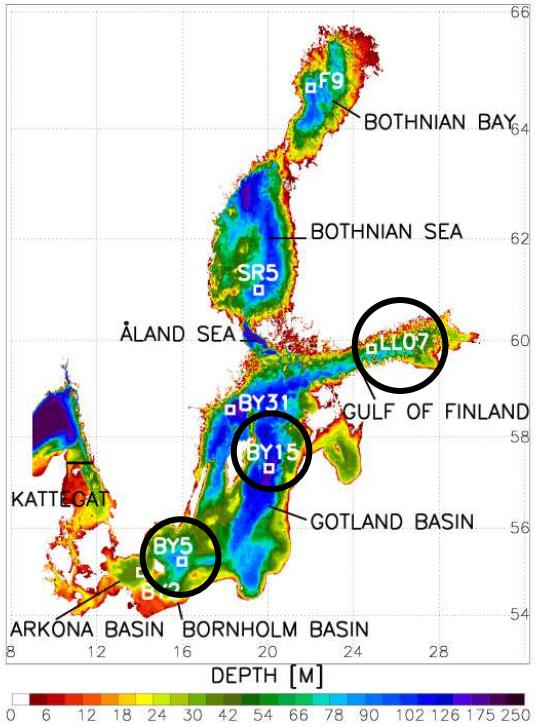






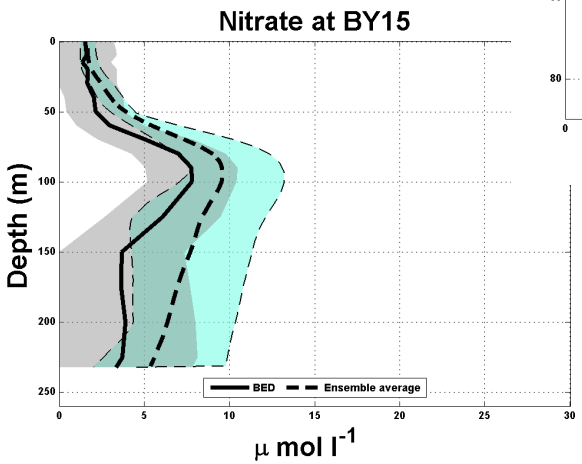
ECOSUPPORT

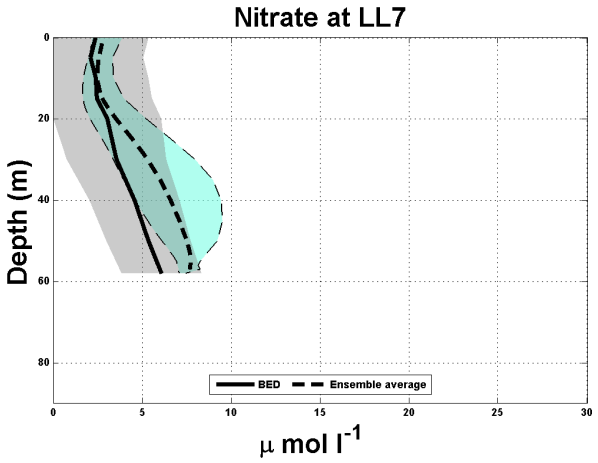
Annual average 1970-2005

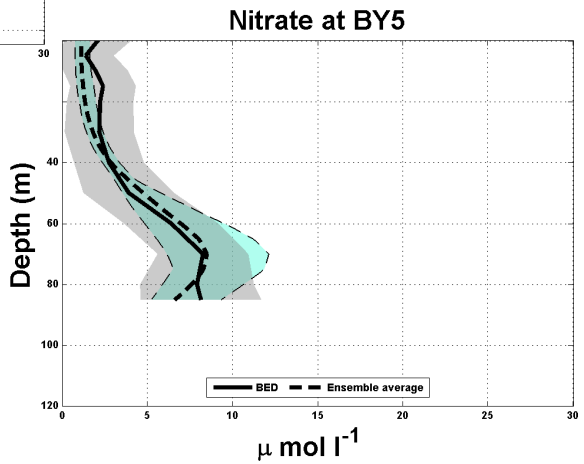


Station list

Nitrate







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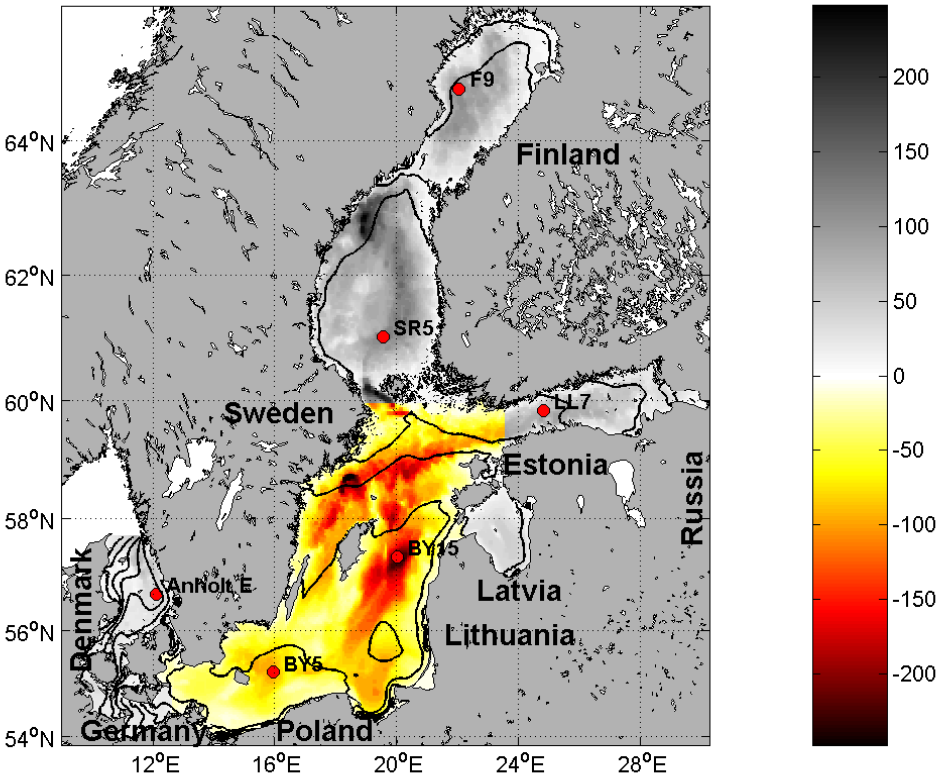
Hypoxic area and cod reproduction volume



Baltic Proper area defined by the colored depth scale

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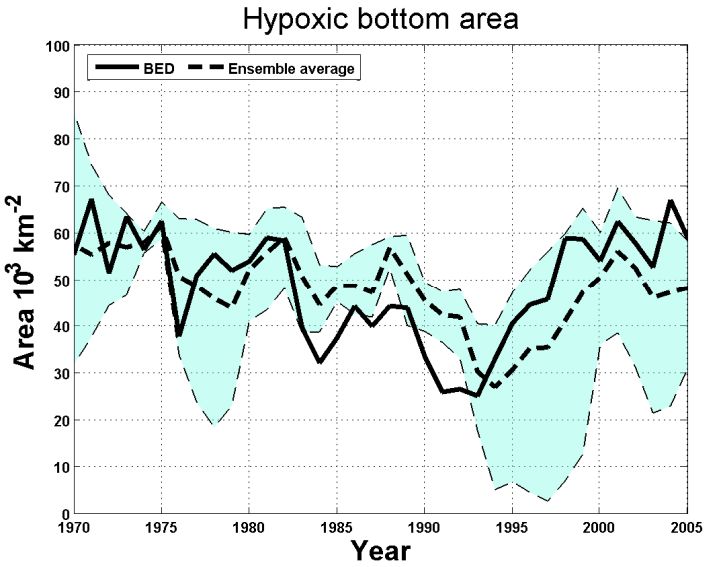
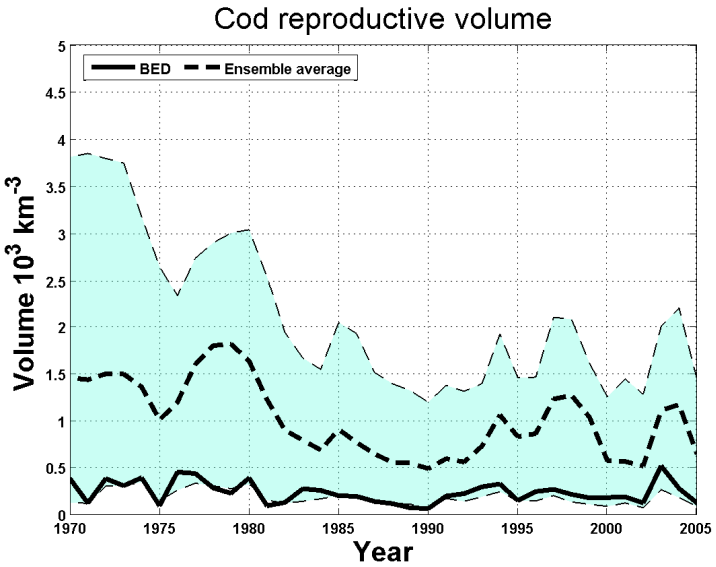
Hypoxic area and cod reproduction volume
Baltic proper





Annual average bottom area covered with O_2 < 2 ml/l

Annual average water volume with O_2 > 2 ml/l and salinity > 11psu

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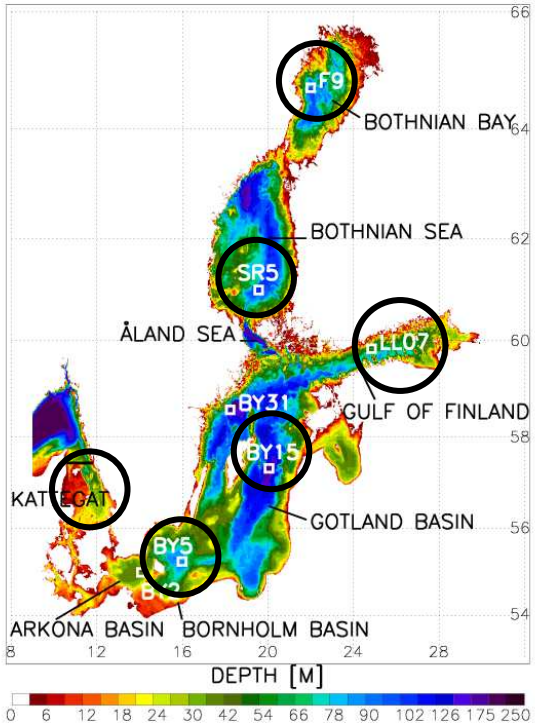
Ensemble cost function 1970-2005

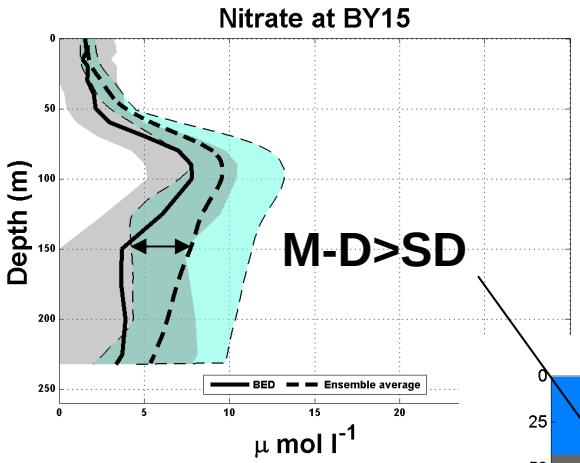


Station list

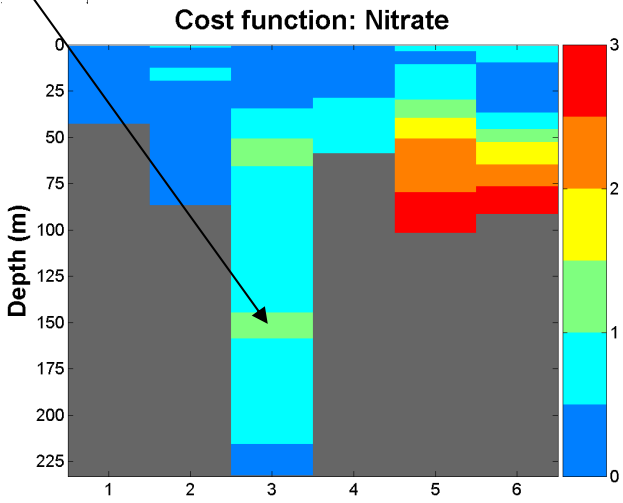
Nitrate

$$C = \left| \frac{M - D}{SD} \right|$$

$0 \le C < 1$ (good)
$1 \le C < 2$ (reasonable)
$2 \le C$ (poor)



M-D>SD

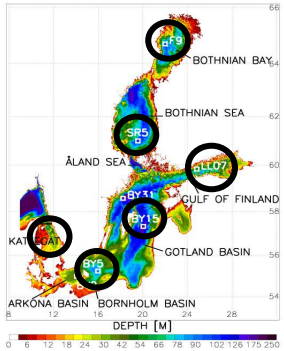


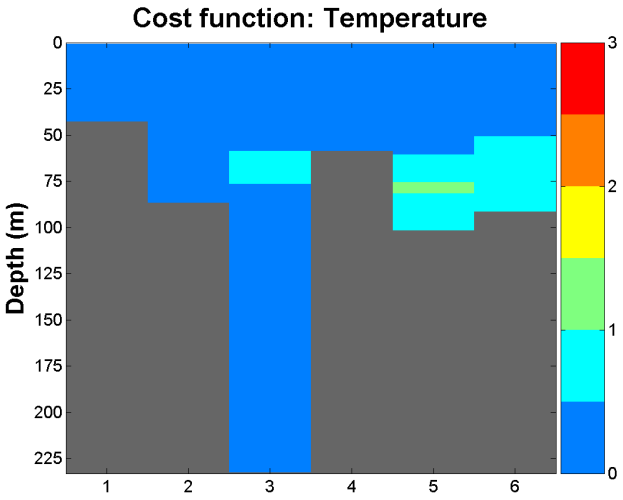
Station number

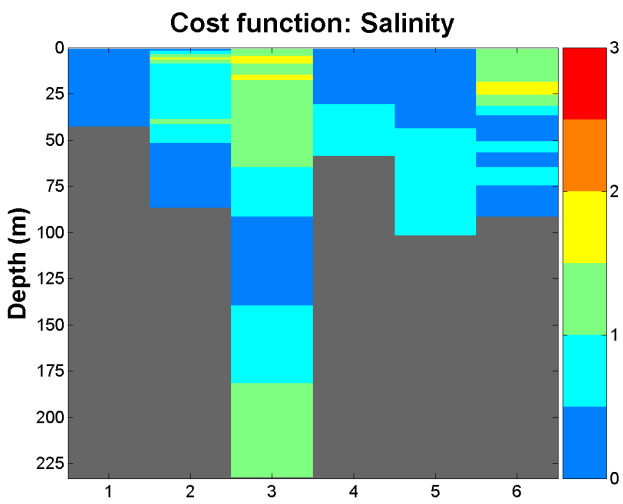
1. Anholt E
2. Bornholm Deep BY5
3. Gotland Deep BY15
4. Gulf of Finland W LL07
5. Bothnian Sea SR5
6. Bothnian Bay F9

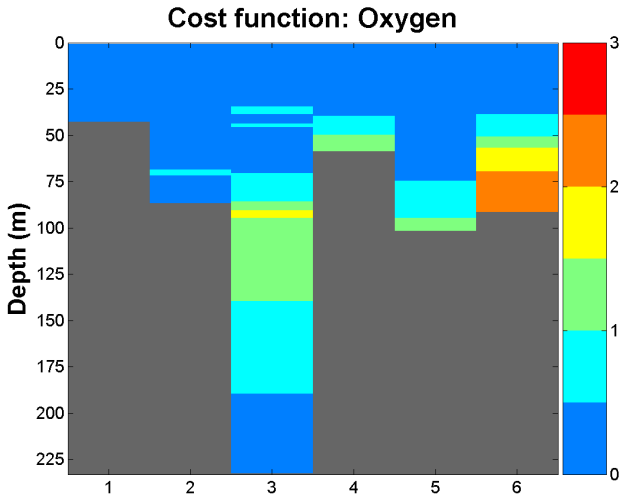
ECOSUPPORT

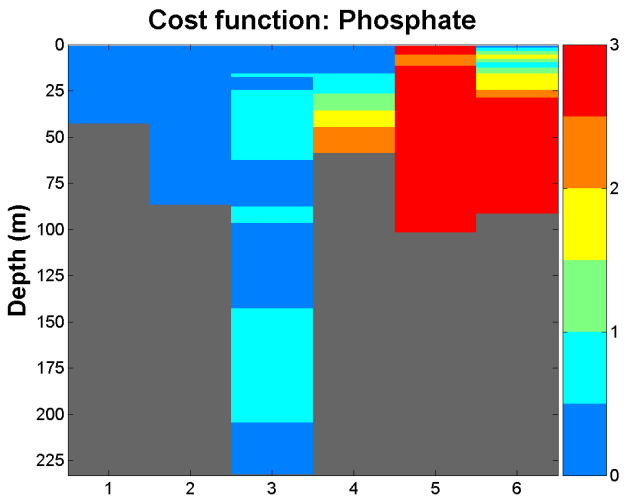
Cost function 1970-2005

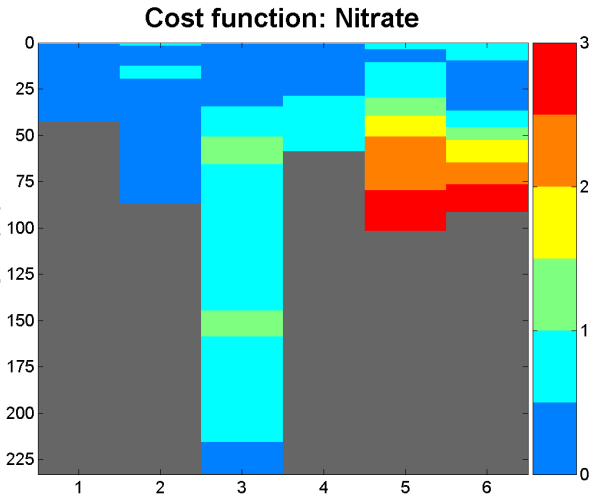












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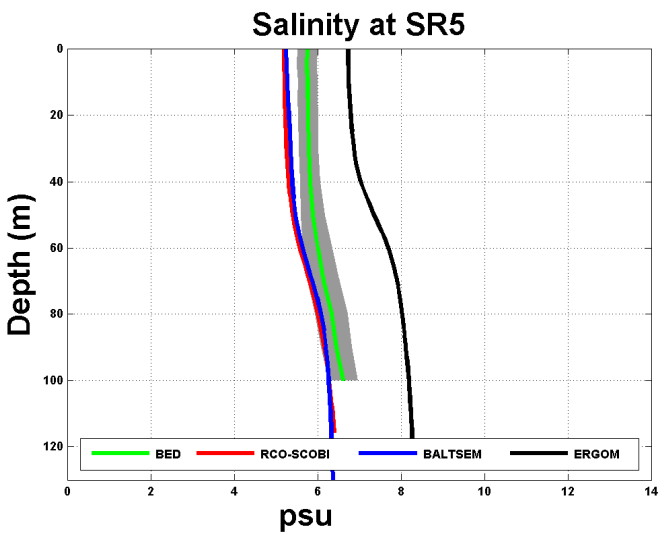
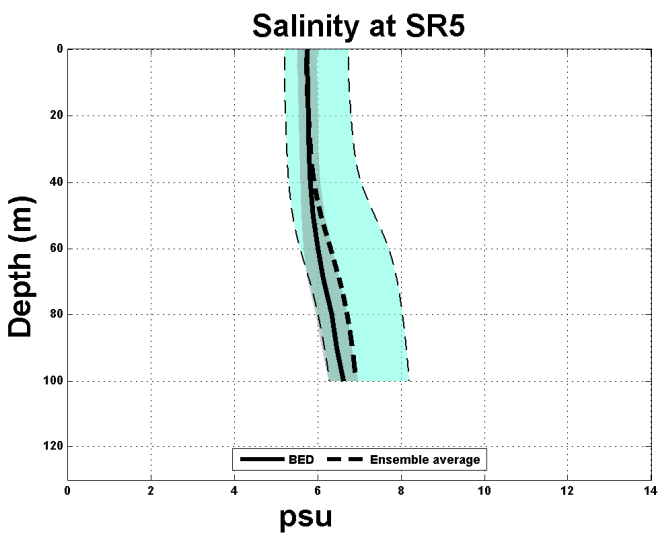
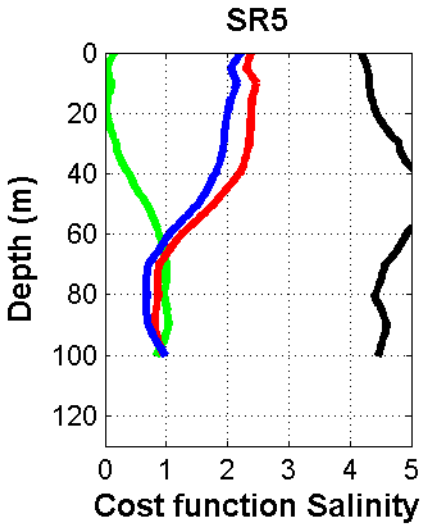
Ensemble mean, median or individual models?





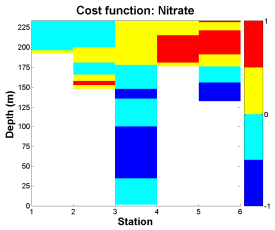
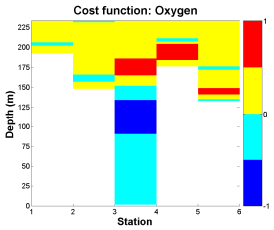
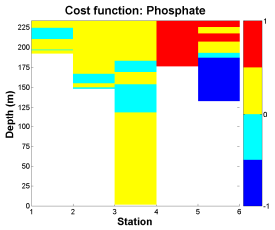
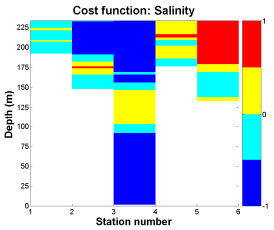
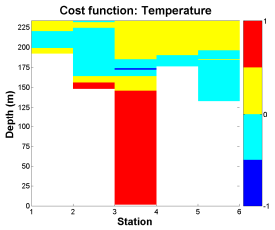
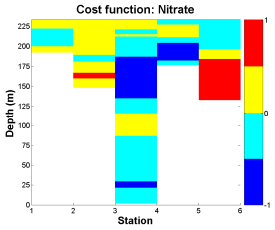
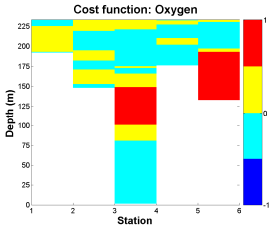
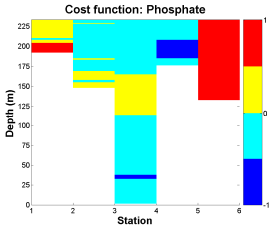
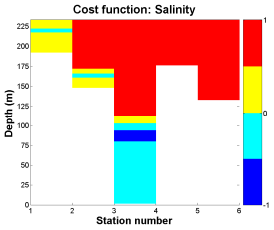
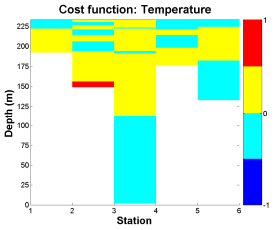
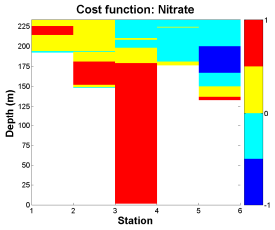
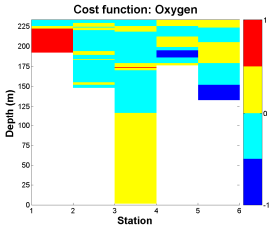
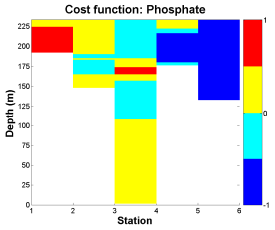
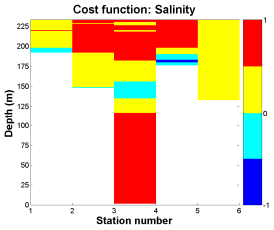
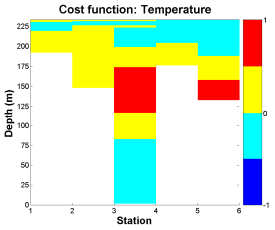
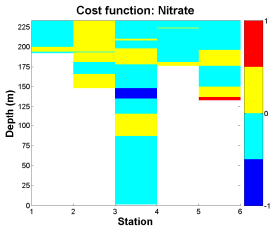
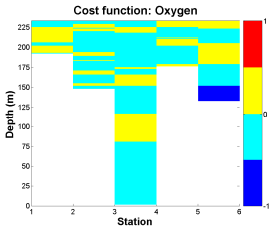
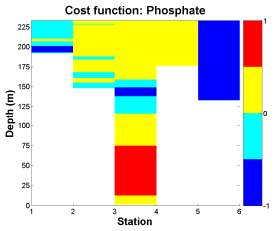
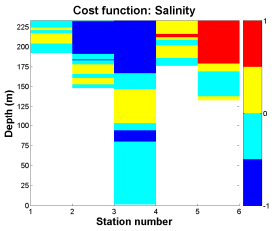
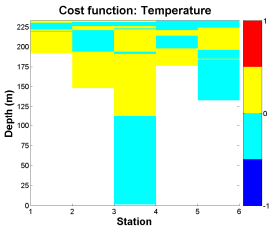


Left: Vertical profiles of mean values for salinity (left) at SR5 of BED (green), RCO-SCOBI (red), BALTSEM (blue) and ERGOM (black) data sets.

Midle: Ensemble mean and spread of salinity profiles.

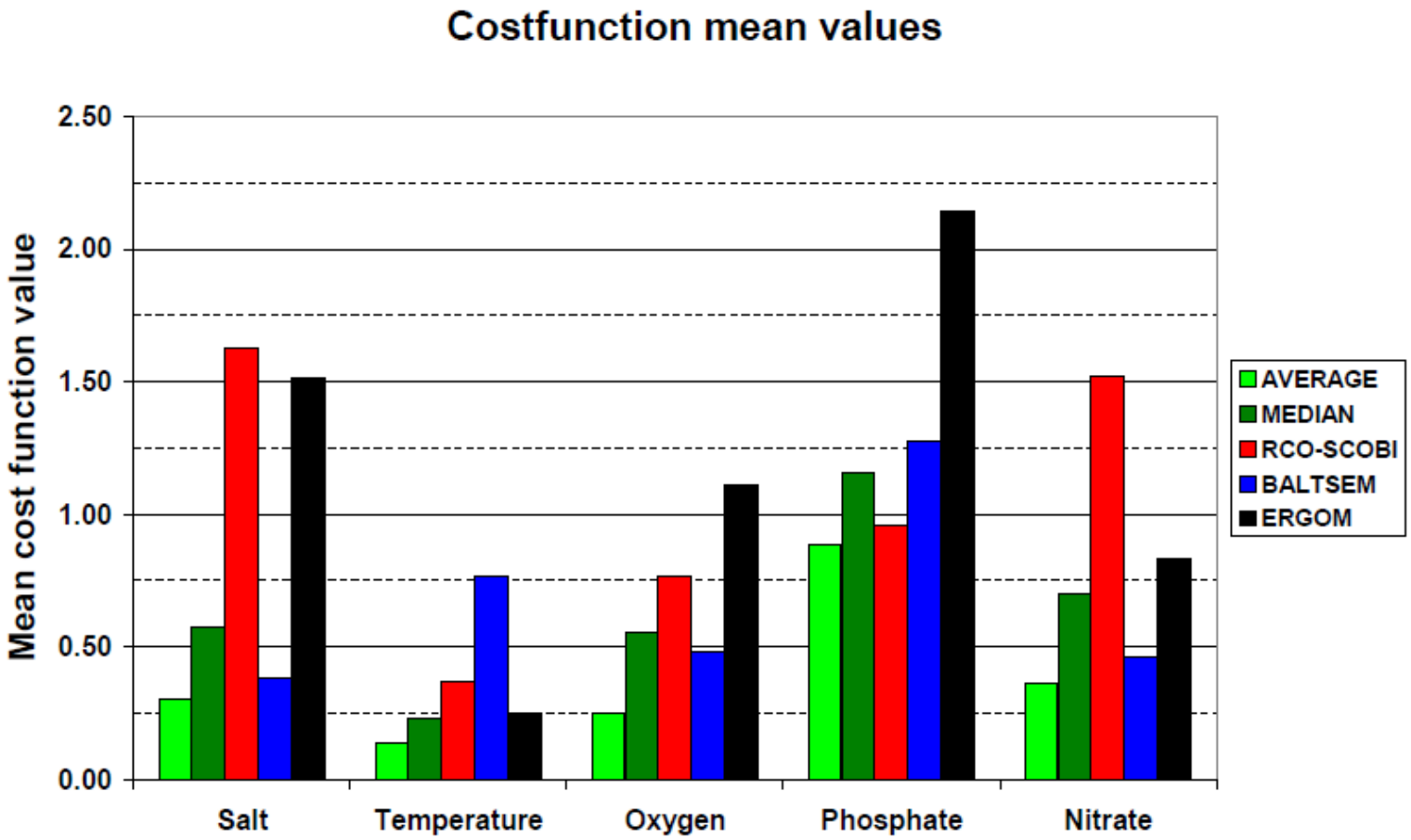
Right:Vertical profiles of cost function values for salinity (left) at SR5 of the ensemble average (green), RCO-SCOBI (red), BALTSEM (blue) and ERGOM (black) data sets.

RESULTS - individual and median CF difference to ensemble mean CF

	NO3	OXY	PO4	SALT	TEMP
BALTSEM					
ERGOM					
RCO-SCOBI					
MEDIAN					

RESULTS - individual and median CF difference to ensemble mean CF

What is the average cost function value at all stations and depths?



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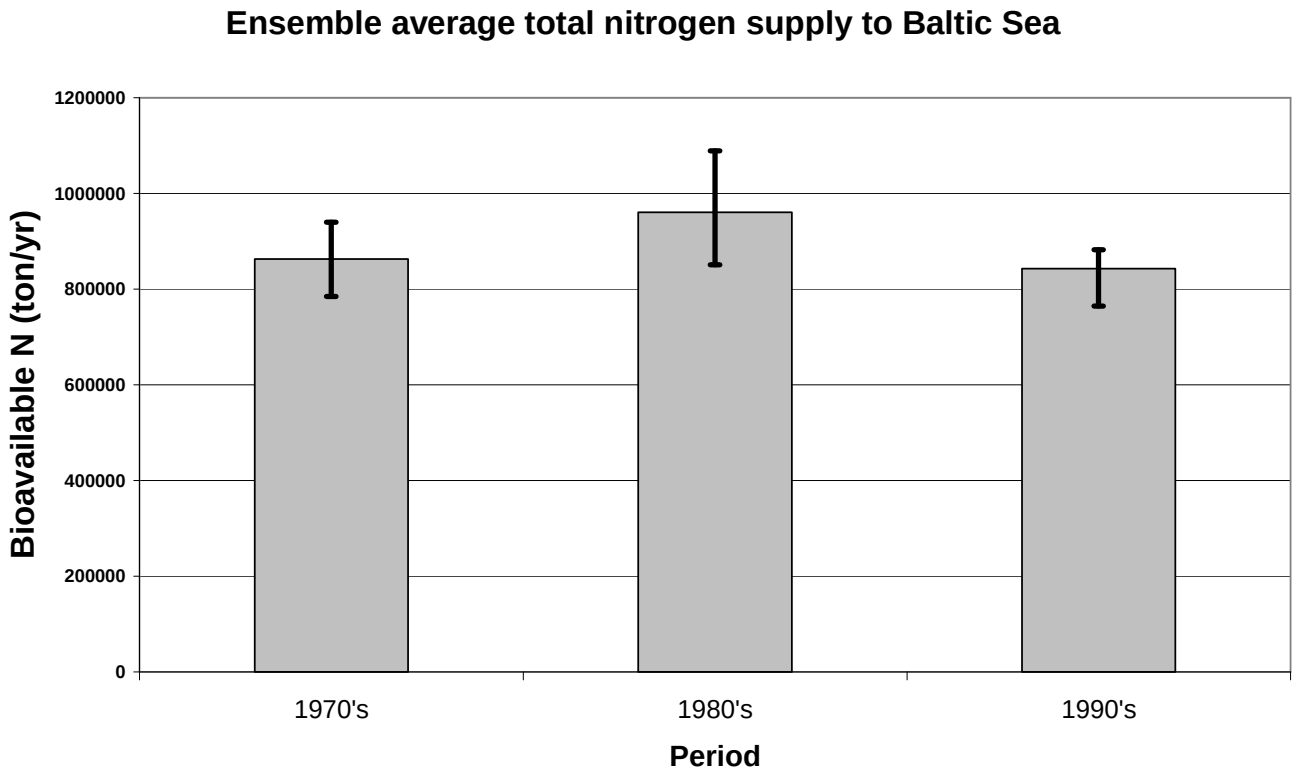
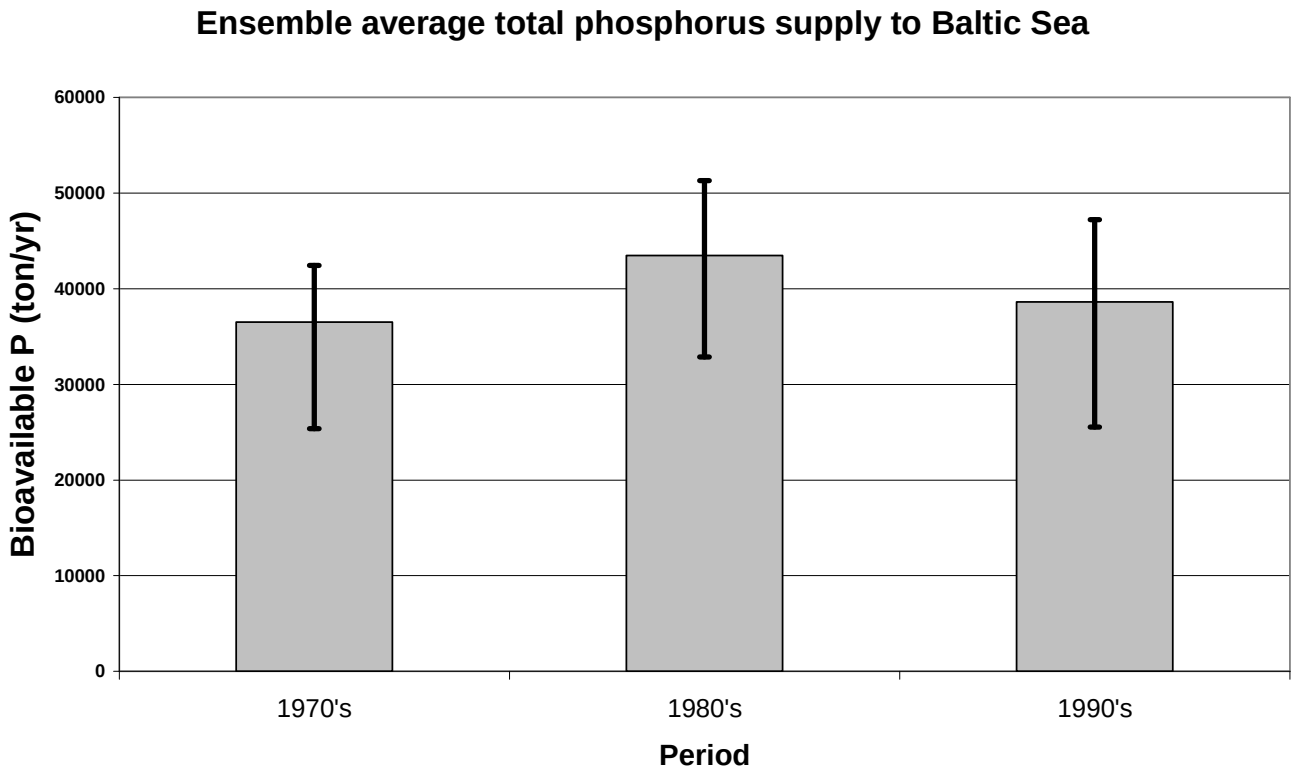
Baltic Sea bioavailable nitrogen loads



Differences between model loadings of N (error bar) are in the range 14-25 % of the ensemble average supplies (grey bar).

ECOSUPPORT

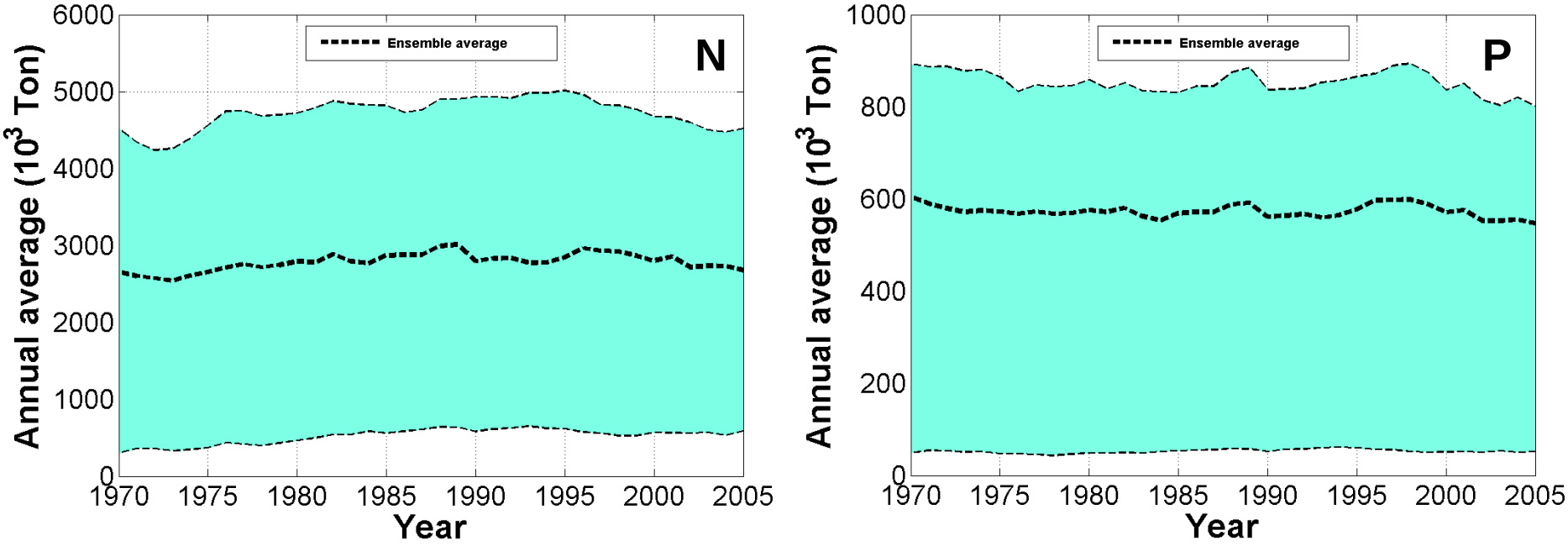
Baltic Sea bioavailable phosphorus loads



Differences between model loadings of P (error bar) are in the range 42-56 % of the ensemble average supplies (grey bar).

ECOSUPPORT

Baltic Proper sediment content



Spread between modelled sediment contents of N and P (blue shaded area) is in the range 140-150 % of the ensemble average content (dashed line).

Challenges and future outlook

√ • Ongoing discussions about the introduction of harmonized nutrient loadings to the models and about the key processes that cause uncertainties for the sediment pools and fluxes

√ • The atmospheric forcing of the models will be updated

√ • The model calibrations and validations will be repeated with updated forcing and nutrient loading

√ • Methods to quantify model ensemble results and uncertainties related to the different models results will be further discussed and developed

√ • The results from each individual model and the causes to differences between models will be further analyzed

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Main conclusions

√ • All models and the ensemble mean describe the variability of biogeochemical cycles and hypoxic area well

√ • Ensemble mean cod reproduction volume and DIN and DIP in the Gulf of Bothnia and in the deepest parts of the Gulf of Finland need improvement

√ • The ensemble mean is relatively strongly influenced by any one model member that by some reason give very poor results in some region

√ • Uncertainties are related to bioavailable fractions of nutrient loadings from land and key processes like sediment fluxes that are presently not well known

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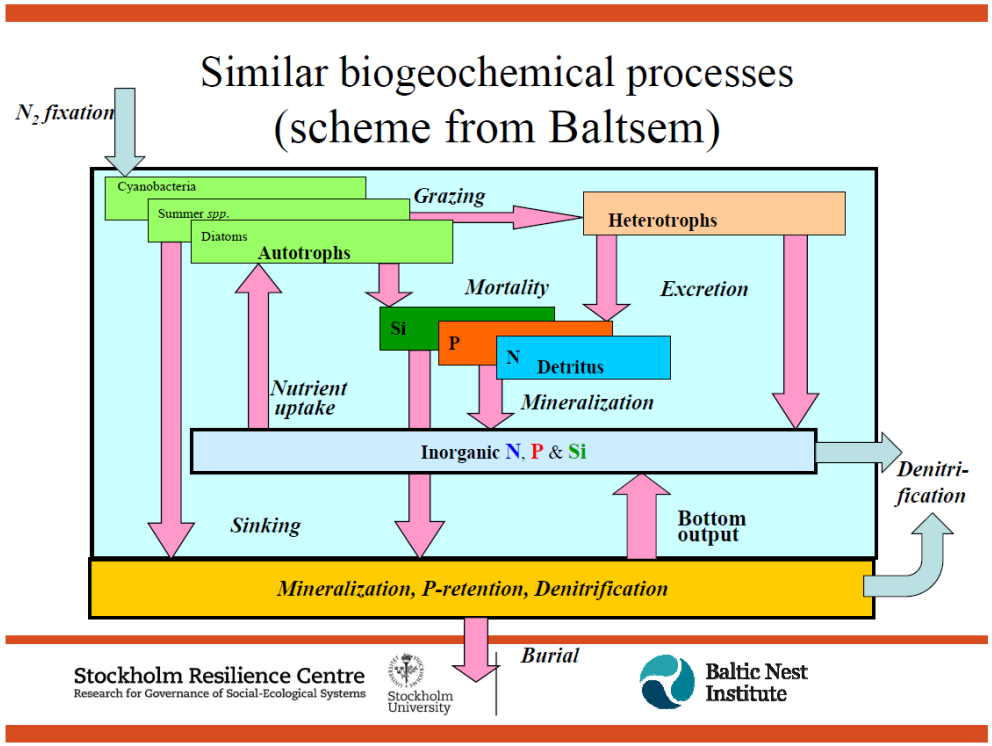
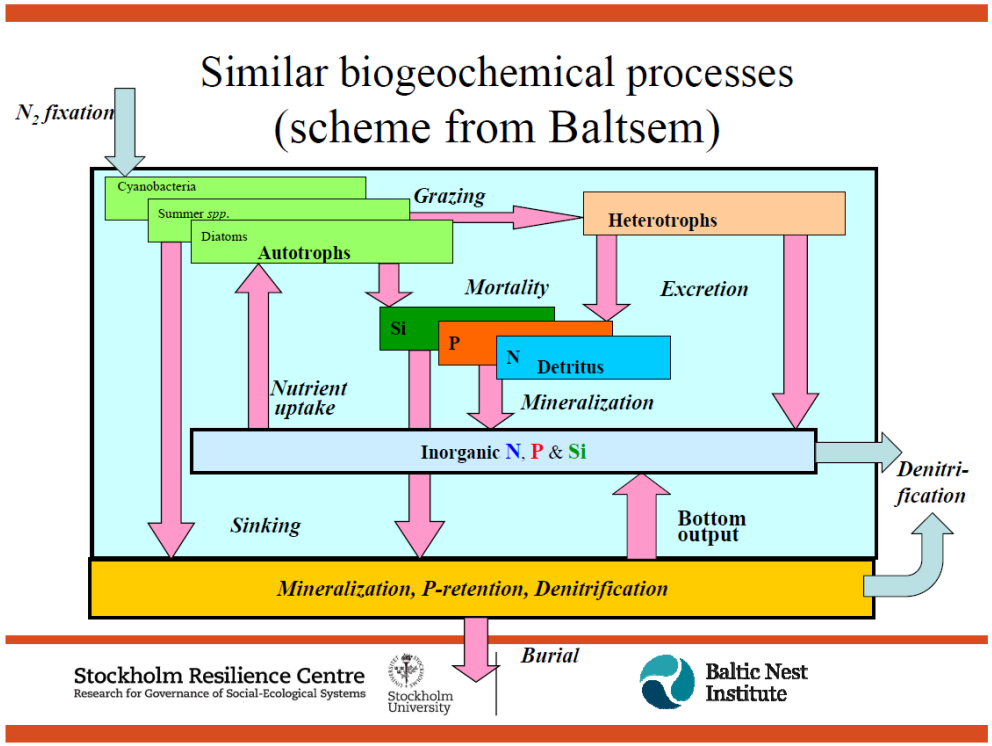
Thank you !

Questions ?

Advanced modeling tool for scenarios of the Baltic Sea ECOsystem to SUPPORT decision making



The ERGOM, RCO-SCOBI and BALTSEM models are similar in that they handle dynamics of nitrogen, oxygen and phosphorus including the inorganic nutrients, nitrate, ammonia and phosphate (and also silicate in BALTSEM and inorganic carbon in ERGOM), and particulate organic matter consisting of phytoplankton (autotrophs), dead organic matter (detritus) and zooplankton (heterotrophs). Primary production assimilates the inorganic nutrients by three functional groups of phytoplankton, diatoms, flagellates and others, and cyanobacteria. Organic material may sink and accumulate in the model sediment as benthic nitrogen and phosphorus (and silicate in BALTSEM).



Key differences:

•Differences in treatment of dead organic matter: one state-variable for each nutrient vs. a single variable with constant N/P ratio

•Differences in parameterizations of P sediment dynamics, in particular redox dependent P processes

•Resuspension and sediment transport: mechanistic description (from waves and currents) vs. simple parameterization

•Resolving coastal boundary and deep pits vs. large-scale horizontally integrated sub-basins

•Different vertical resolution

•In addition there are other “minor” quantitative (relationships) and qualitative (numerical values of constants) differences in parameterizations of similar pelagic and sediment biogeochemical processes that have not been listed and analyzed yet.

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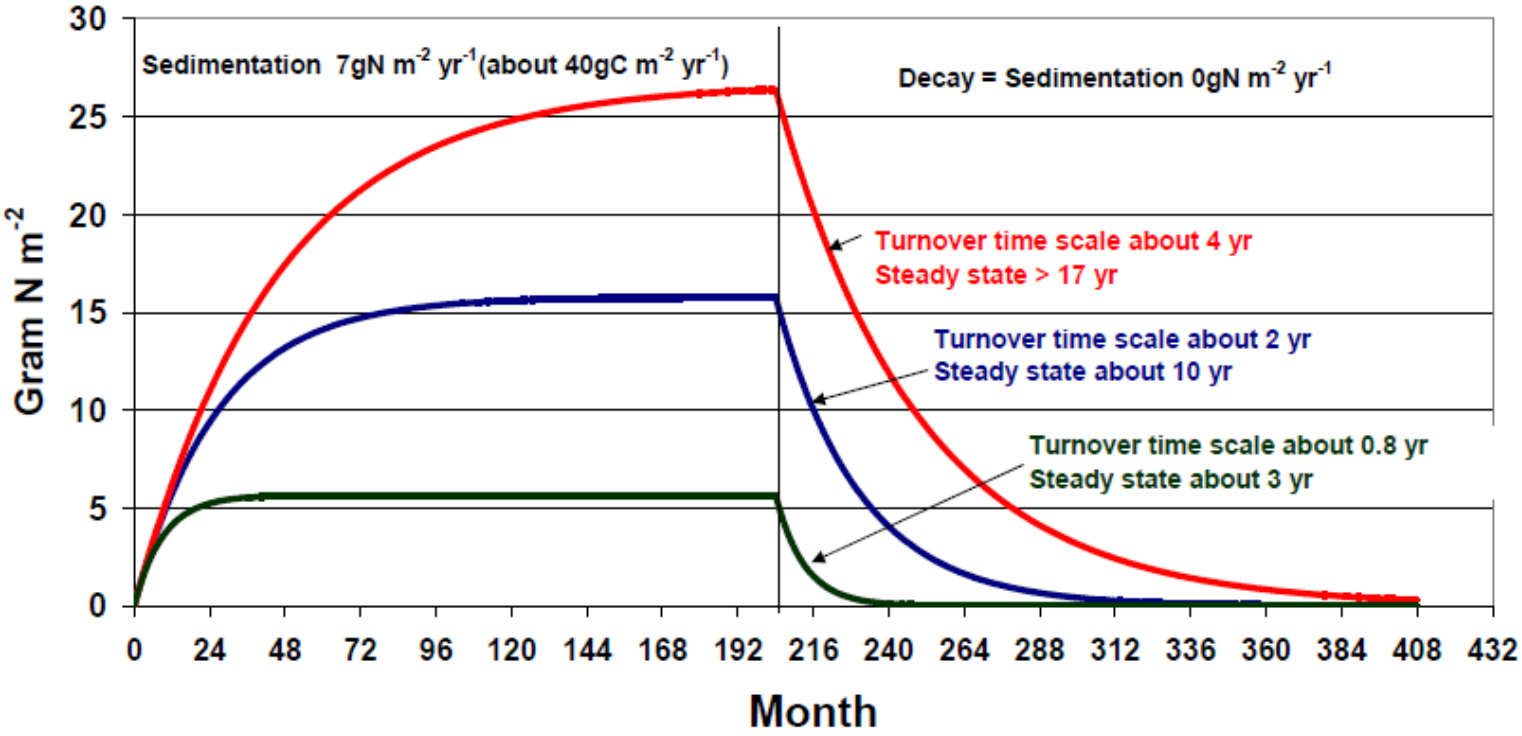
Sediment concentrations discussion

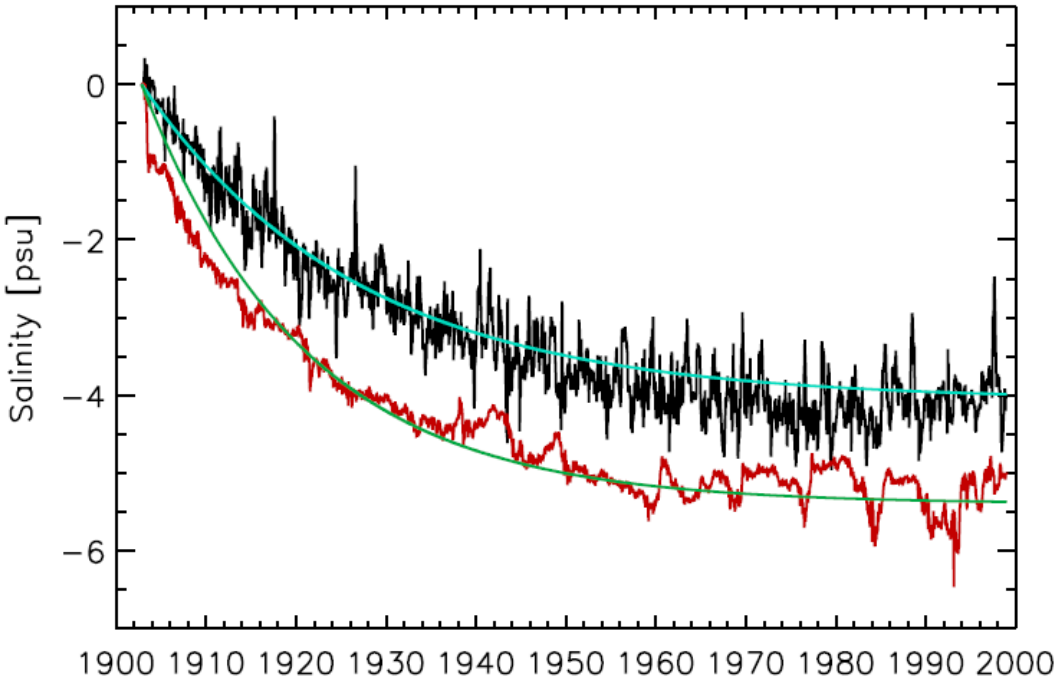


Theorethical consideration based on decomposition and burial rates in the models.

The sediment N turnover time scales in the models vary from about 1 to 4 yr

The time scales of steady state in the sediment N vary from about 5 to >25 yr

ECOSUPPORT
System time scales discussion



The time scale of changes of passive tracers at BY15, surface (black) and bottom (red) (Salinity of RCO from Meier 2006).