Do we need better models?

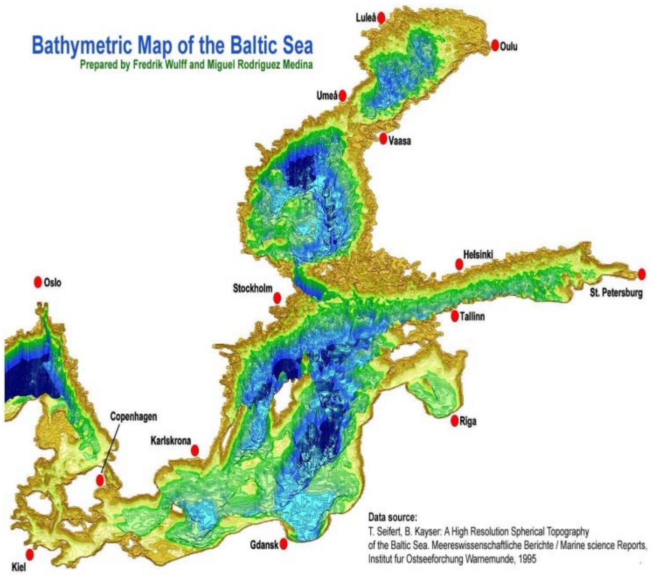
Workshop SMHI 2014

Presentation: Kari Eilola,
Elin Almroth-Rosell and Ivan Kuznetsov

The Baltic Sea Nutrient Cycling

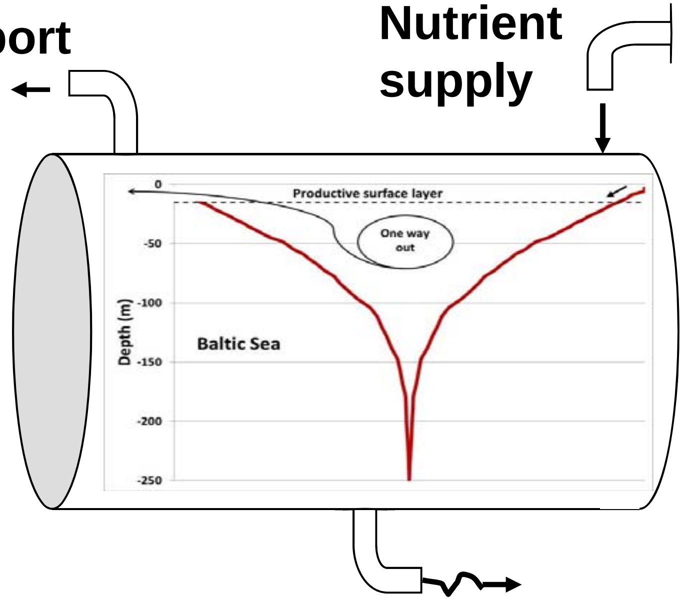
SMHI

Biogeochemical reactor



Nutrient export

Nutrient supply



Internal nutrient removal

1. External nutrient input.
2. Internal nutrient cycling.
3. Internal nutrient removal.
4. Net nutrient export.

Sink efficiency

The fraction of the supply that is removed in the Baltic.

Bioavailable Nutrient Budgets

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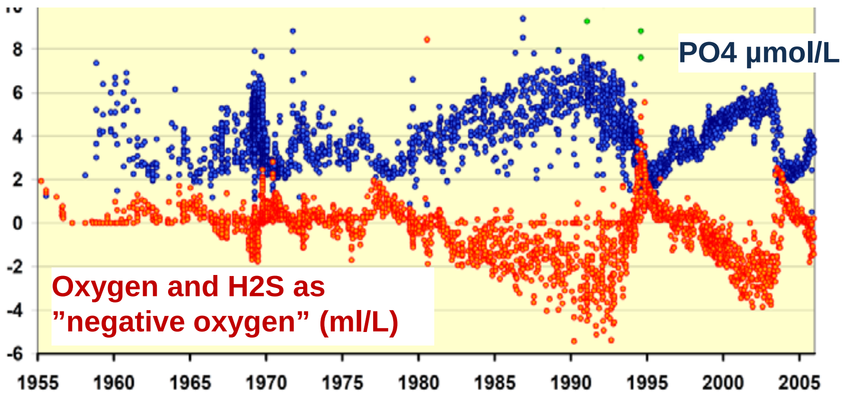
Ecosupport model ensemble
Meier et al. (2012a)

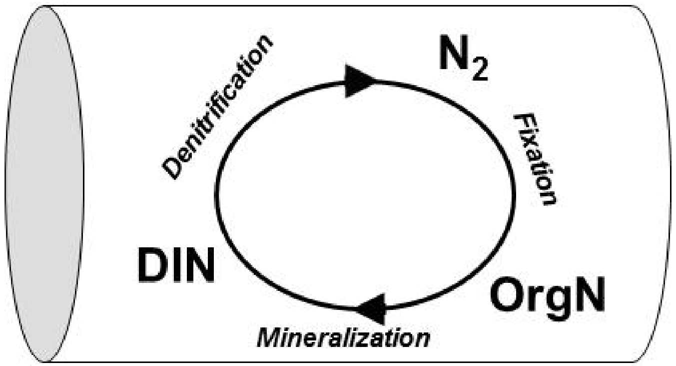
	Nutrient export		Nutrient supply	
Present	23 N 6 P		835 N 39 P	
Future (REF) (BAU)	37 N 13 P	69 N 19 P	819 N 39 P	1108 N 51 P

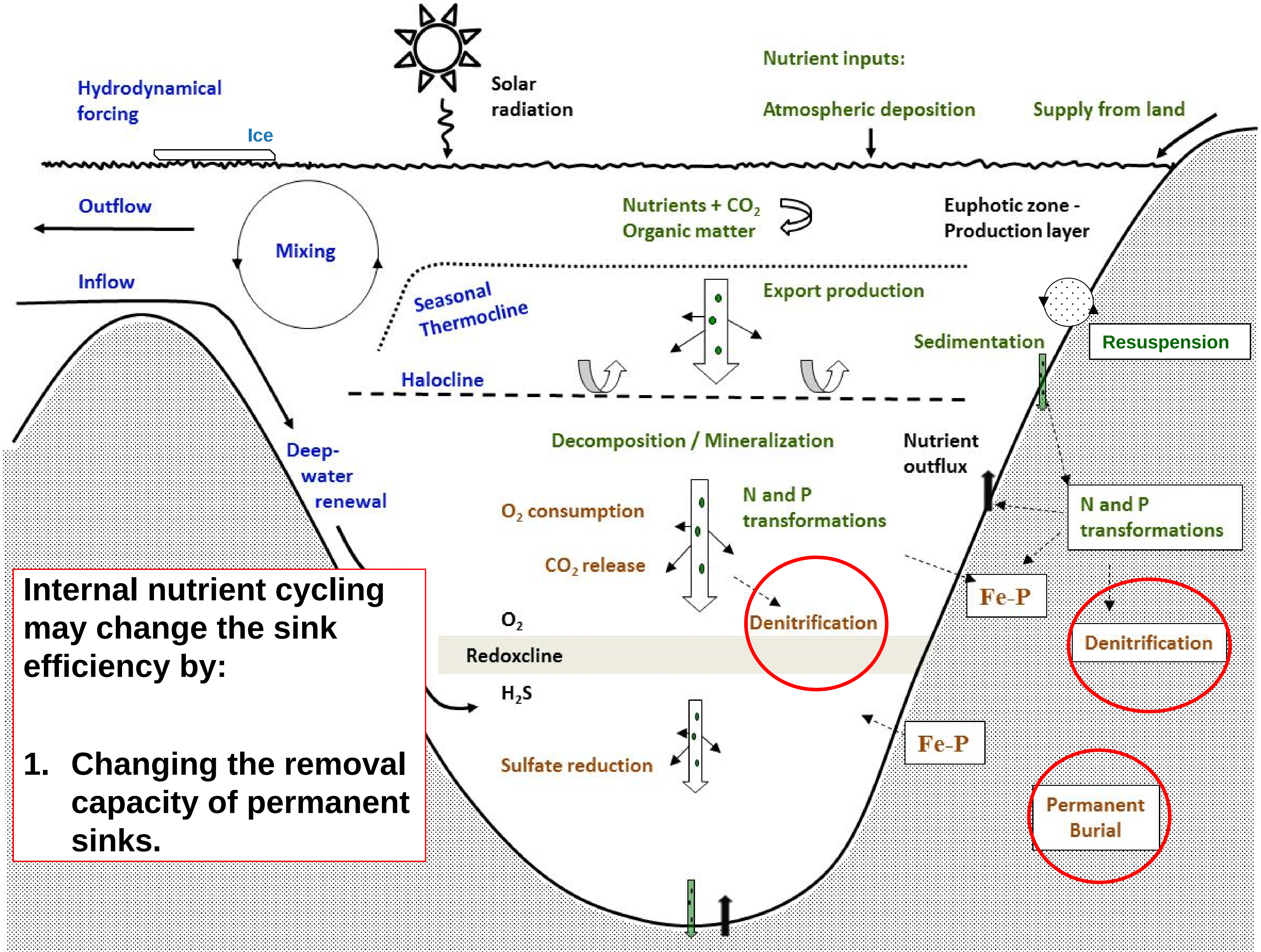
Sink efficiency

- N= 97% (95%, 94%)
- P= 85% (67%, 64%)

- ***No net internal sources, only possible sinks and internal nutrient cycling!***

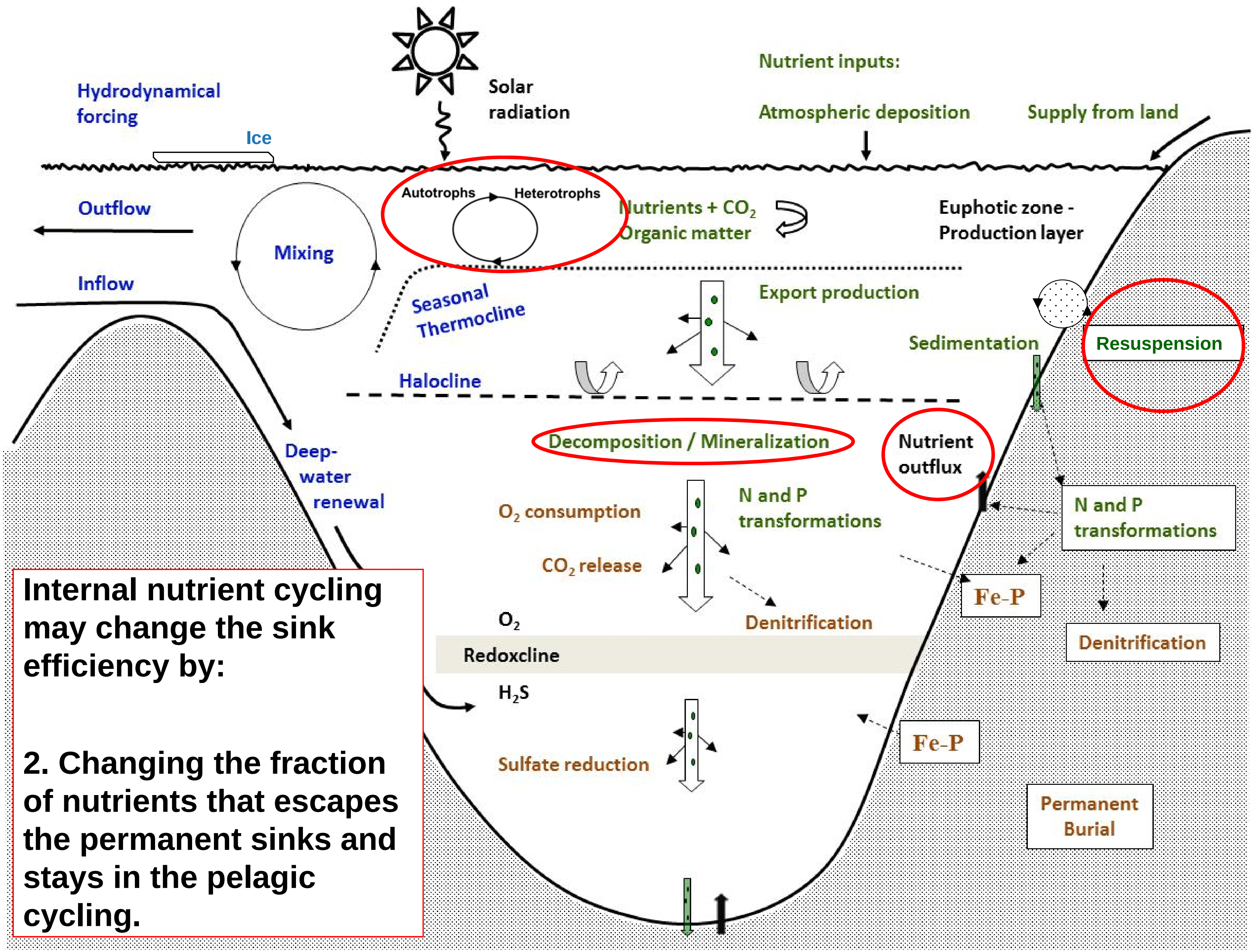






Internal nutrient cycling may change the sink efficiency by:

1. **Changing the removal capacity of permanent sinks.**

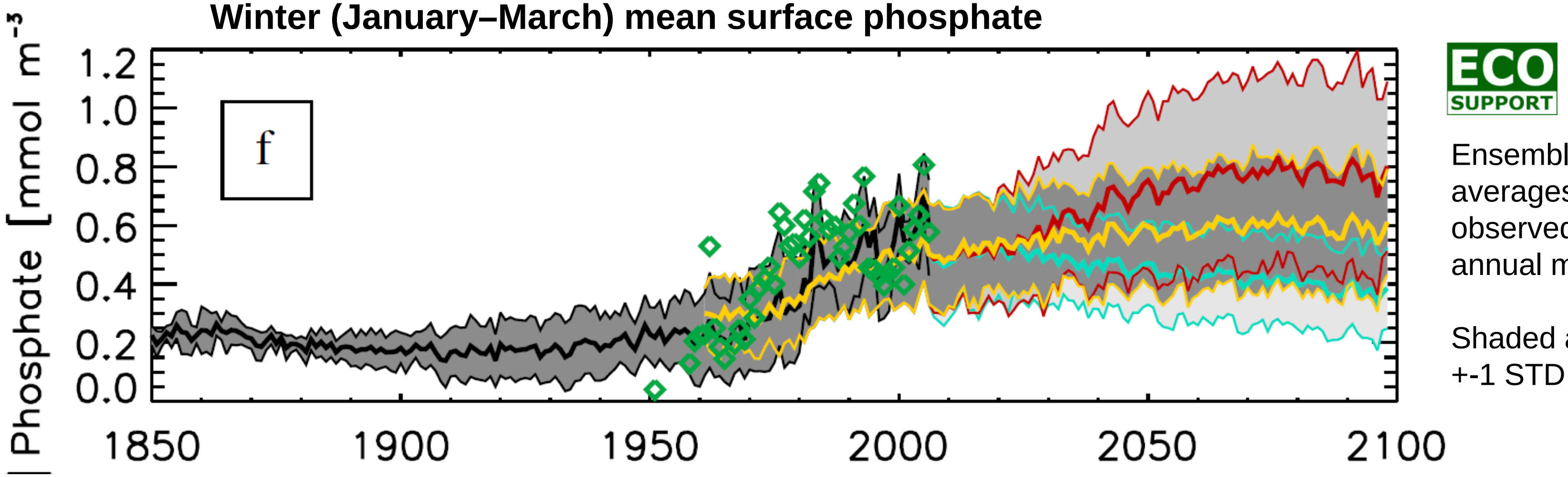


Internal nutrient cycling may change the sink efficiency by:

2. Changing the fraction of nutrients that escapes the permanent sinks and stays in the pelagic cycling.

Simulated past and future variations

Winter (January–March) mean surface phosphate



Ensemble averages and observed annual mean

Shaded areas +-1 STD

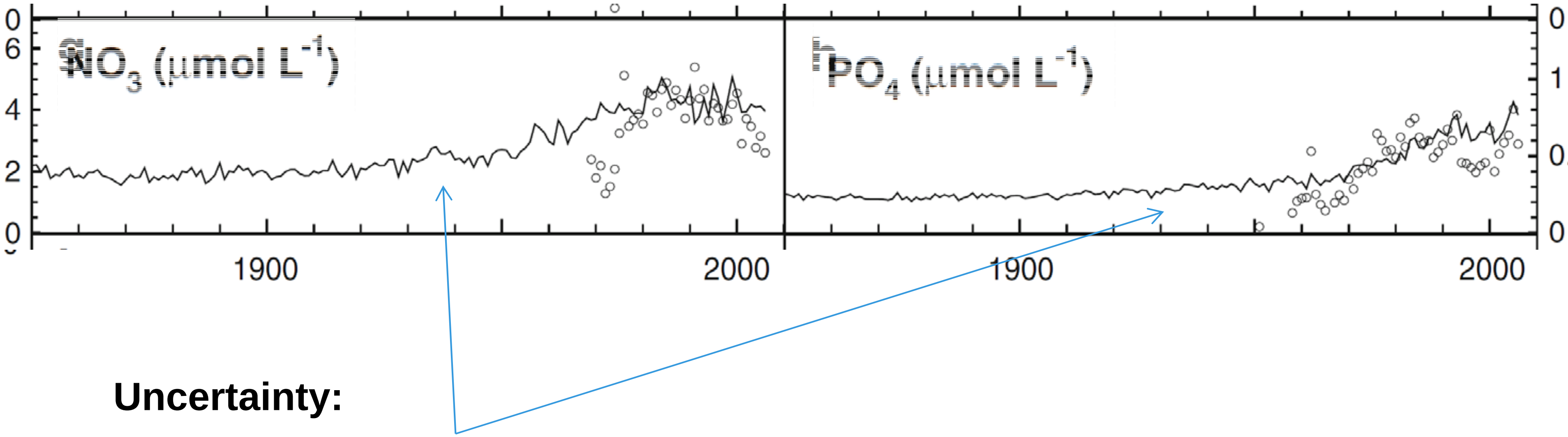
Uncertainty:

- **Historical spread caused by differences in model responses to changing nutrient loads and physical forcing**
- **Future spread in addition caused by different climate and socio economic scenarios**

Simulated unknown past (?) variations

Gustafsson et al. 2012

Reconstructing the Development of Baltic Sea Eutrophication 1850–2006

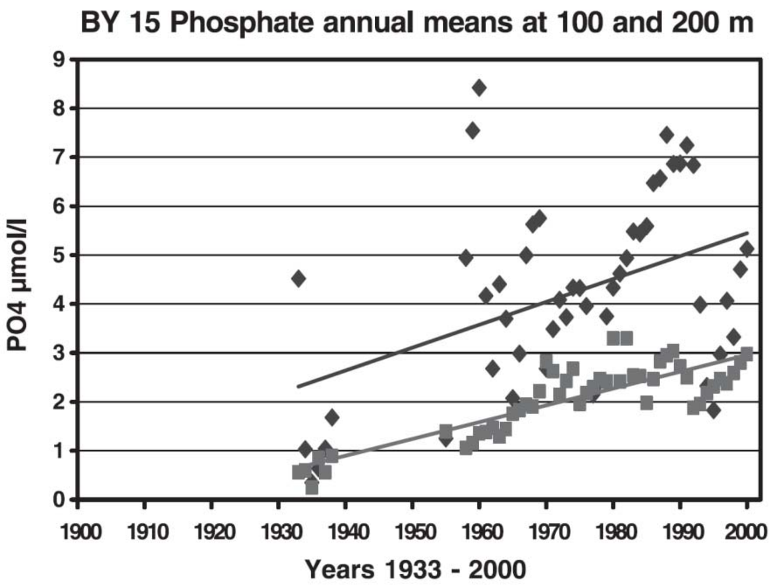


Uncertainty:

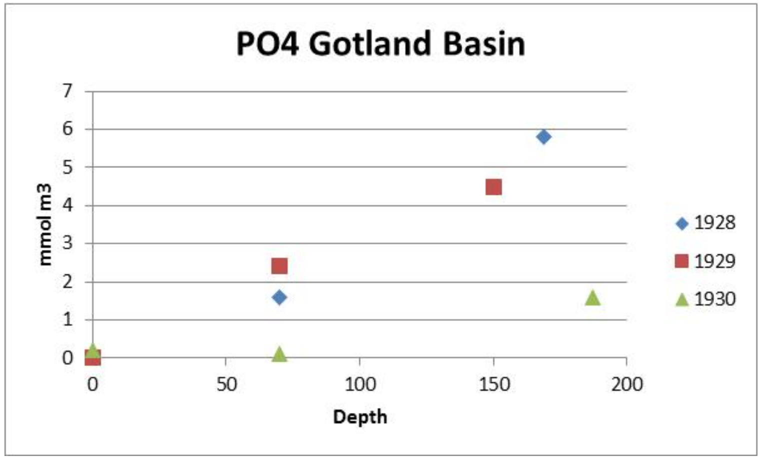
- **No data for comparison. How do we know the model results are true (realistic)?**

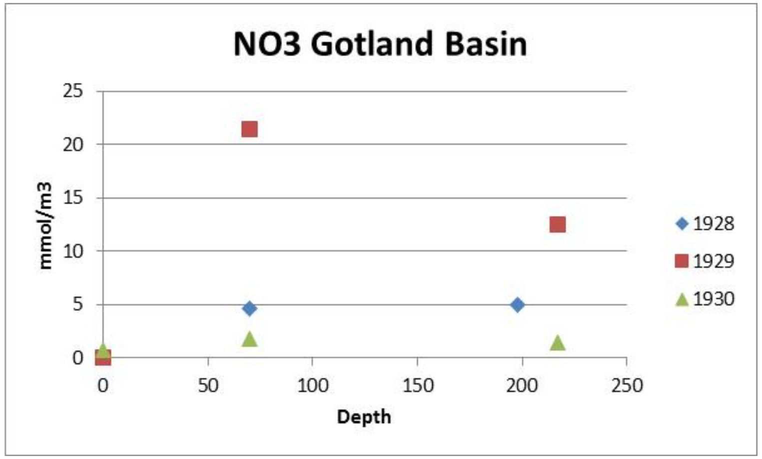
Historical Baltic Sea, ground truth ?

Fonselius and Valderama (2003)



More data available in data bases ?





Model validation:

- **Available data?**
- **Uncertainty?**

Historical Baltic Sea, ground truth ?

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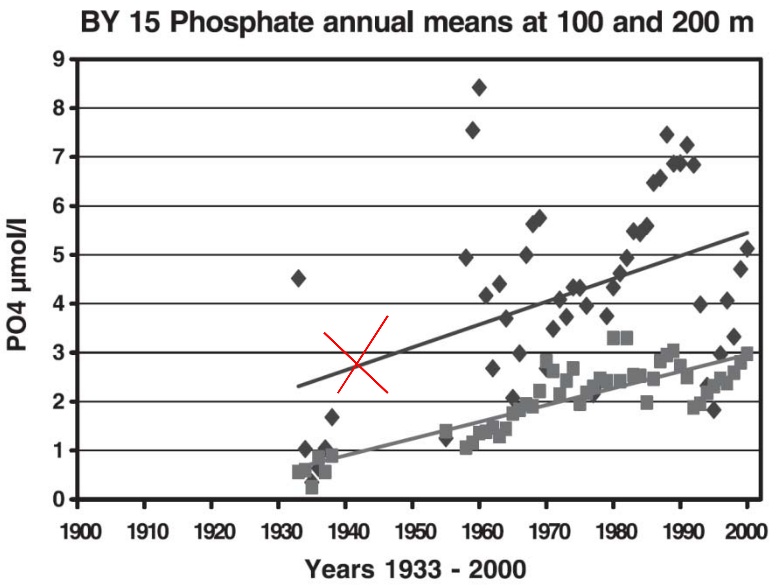
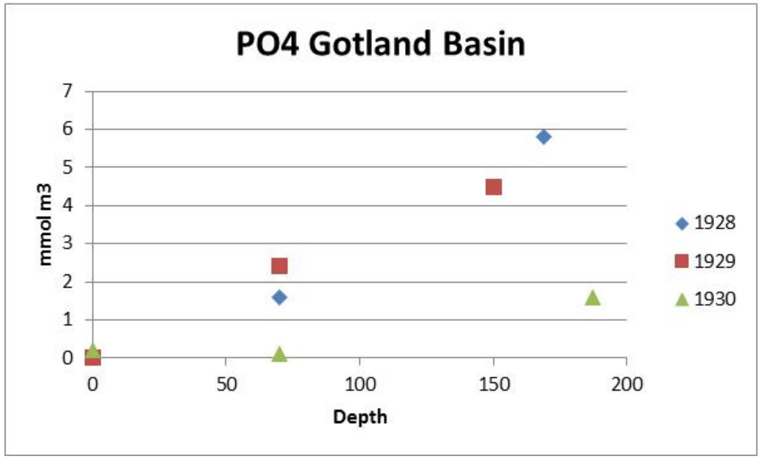
Fonselius and Valderama (2003)

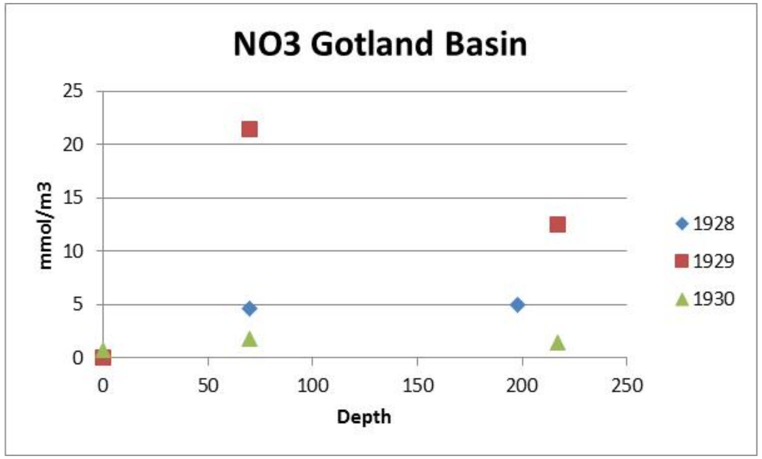


Every data point is a Rembrandt painting!

The only historical in-situ information that exist. Restore and make the data useful.

More data available in data bases ?





Historical Baltic Sea, ground truth

Problem example:

- **Old and new TotP data in the same database are not directly comparable.**

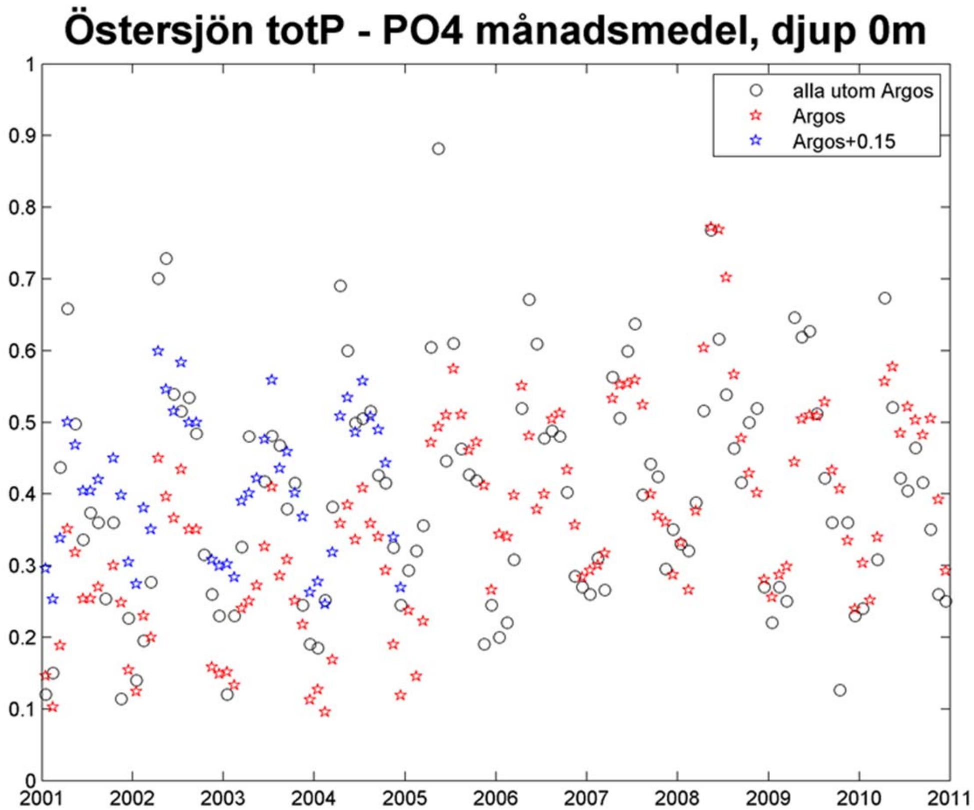
Needed:

- **Common processed and comparable data sets.**

SMHI: Method shift 1.1.2005

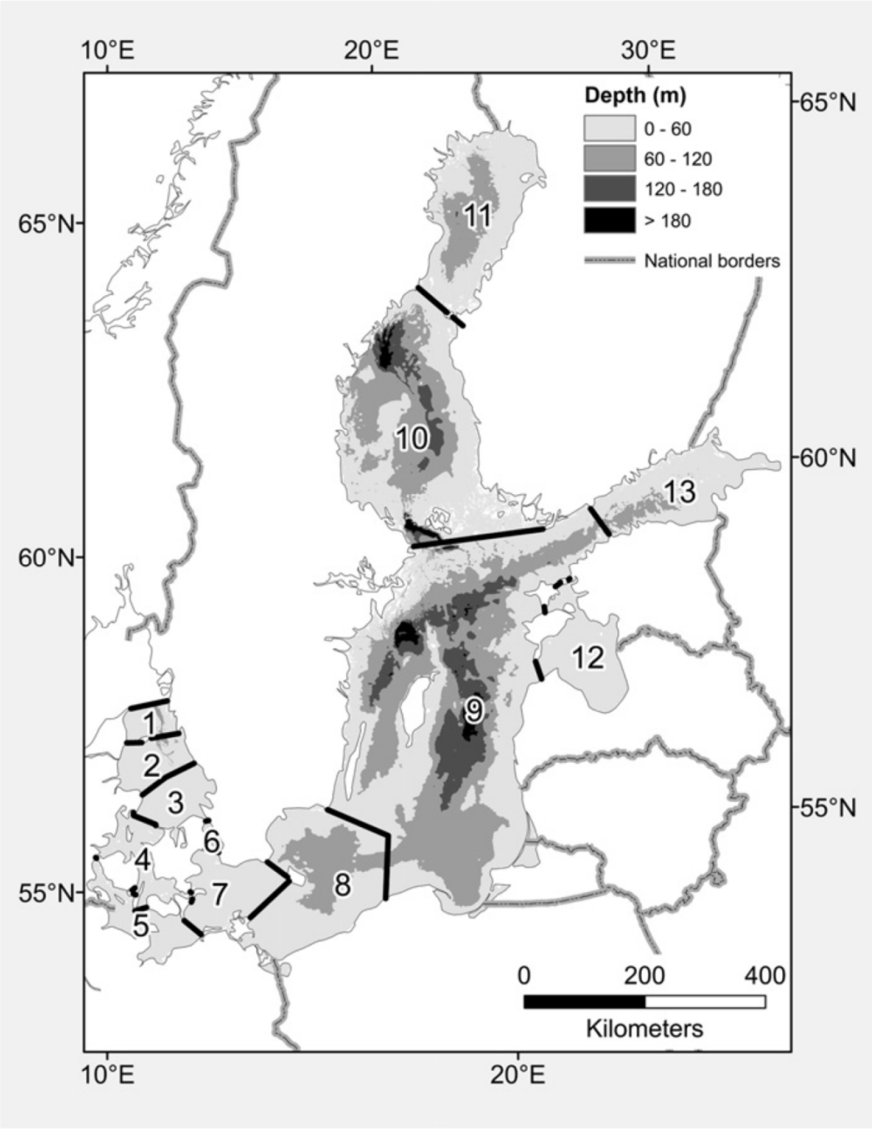
- **New TotP laboratory method introduced at SMHI**
- **Method change cause an increase of TotP, on average 0.15 µM.**
- **Method change is well documented including parallell measurements.**

Take care of present day data for the future!



Resolution of processes

- **Spatial and temporal resolution of 3D-models require further understanding of regional to local processes.**
- **We still treat the basins much as horizontally homogenous regarding to biogeochemical processes though the horizontal resolution is much higher in the 3D-models.**



Burial (main P sink)

- **Spatial and temporal changes of burial are not well resolved or understood in the models.**

Annually accumulated sediment layer (mm/year)

	AAL 0-2cm	Age* Years	Ratio to BP	AAL ~10 cm	Ratio to BP
Bothnian Bay	3.5	6	1.3	1.9	2.4
Bothnian Sea	6.2	3	2.4	3.7	4.6
Gulf of Finland	5.6	4	2.2	2.4	3.0
Baltic Proper	2.6	8	1.0	0.8	1.0

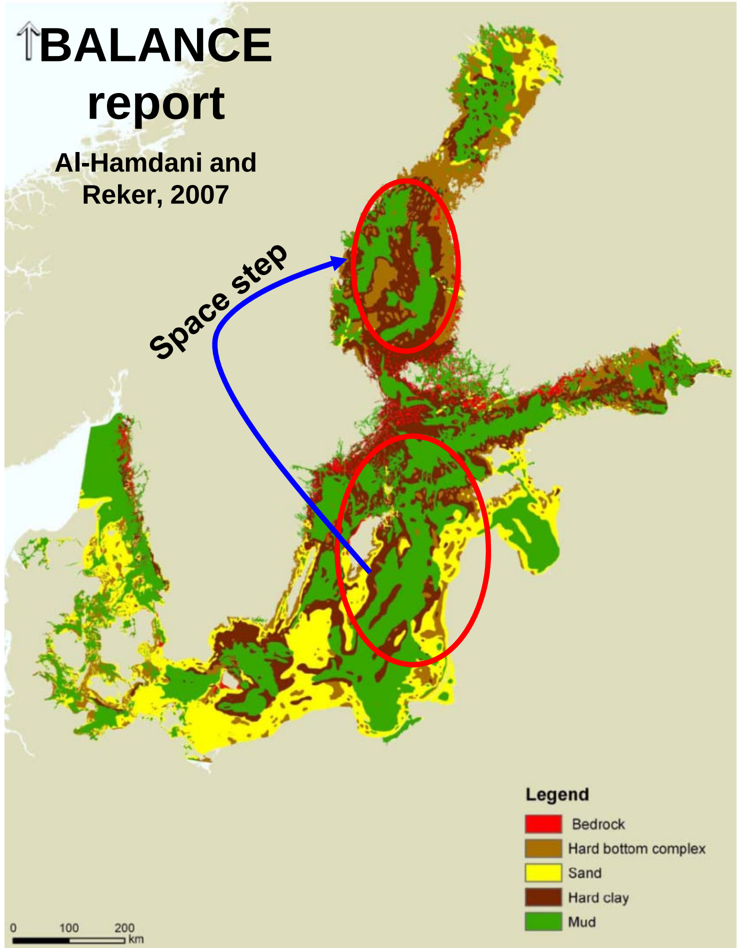
** Age at 2cm depth.*

Time

Space

AAL data from Mattila et al. (2006)

- **Factor 3-5 diff in time and space of median AAL**



Sediment oxygen conditions and phosphorus dynamics

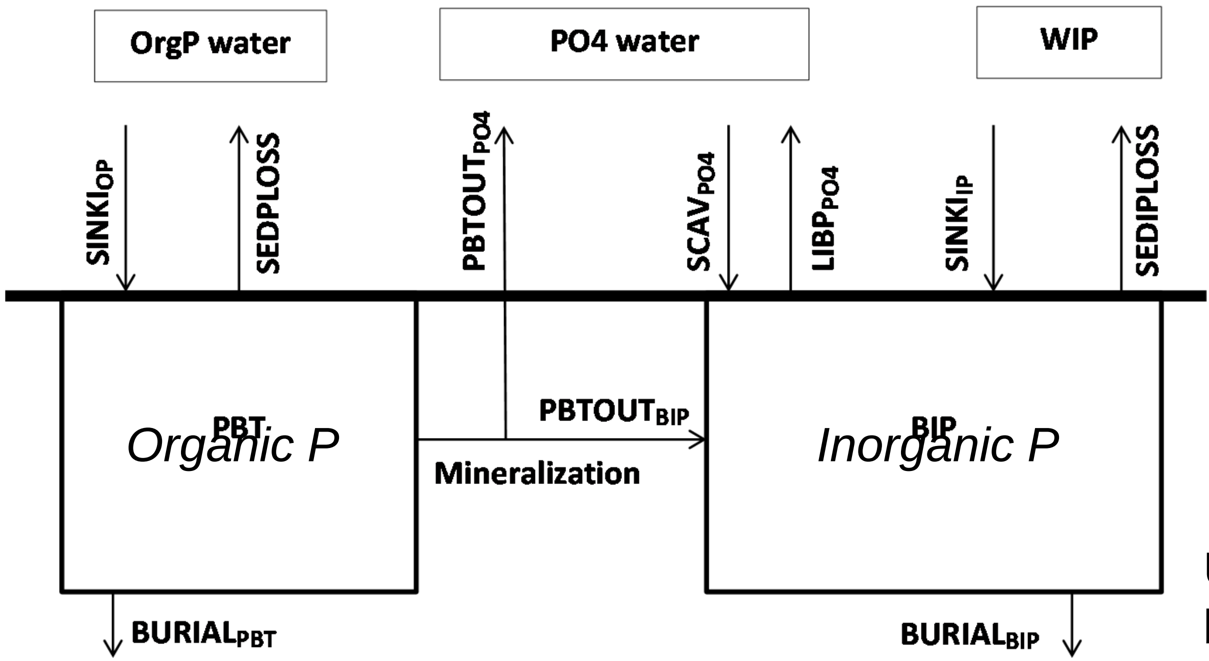
Elin Almroth-Rosell, Kari Eilola, Ivan Kuznetsov, Per O.J. Hall, Markus Meier

Submitted Tellus 2014

$$OPD = 2\emptyset D_s \frac{[O_2]_{Bw}}{F^0_{O_2}}$$

$$D_s = \frac{D}{1-\ln(\emptyset^2)}$$

Separated N, P detritus



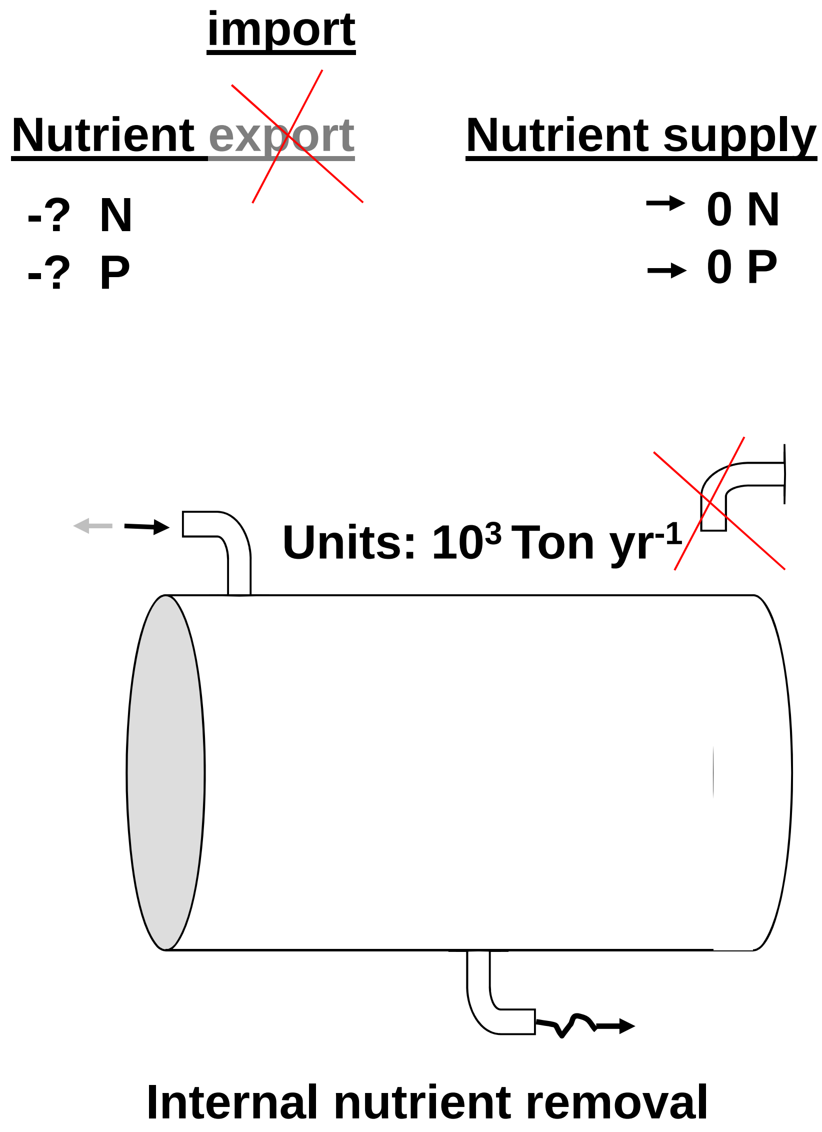
Understanding burial processes

- ***Negative export ?***

- **No supply.**
- **At some point the net export will become negative.**

- **The net import will finally be balanced by the internal nutrient removal.**

- **Challenge: Understand the role of <u>open boundary conditions</u> in pre-industrial times and in a future with climate driven sea level changes.**



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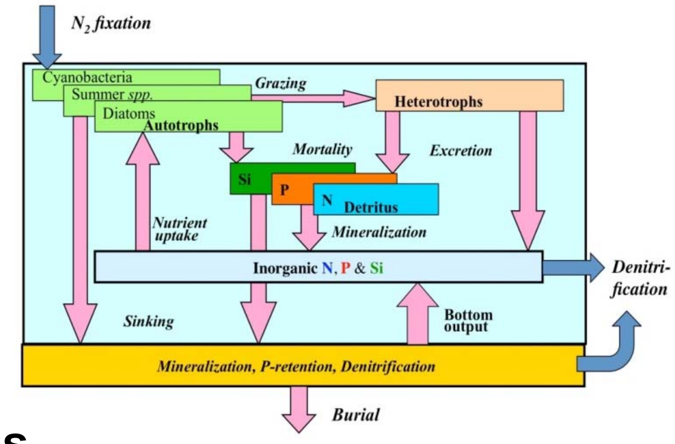
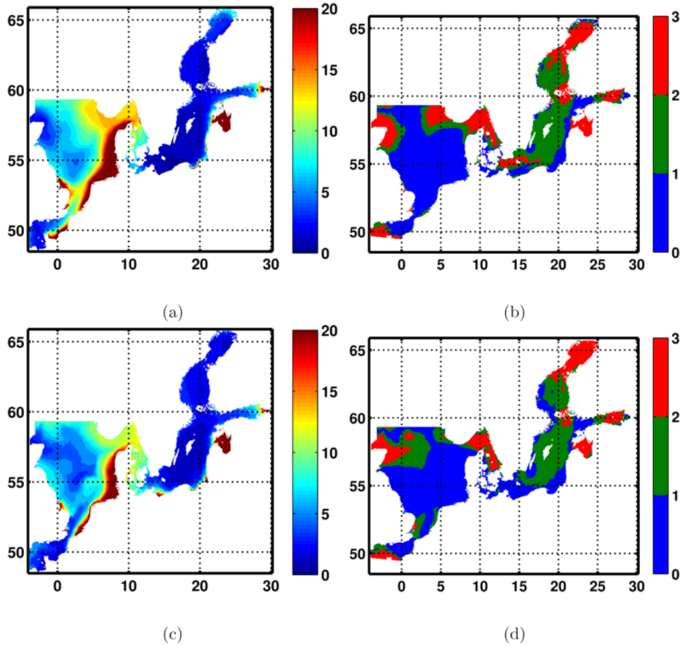
NEMO-Nordic-SCOBI

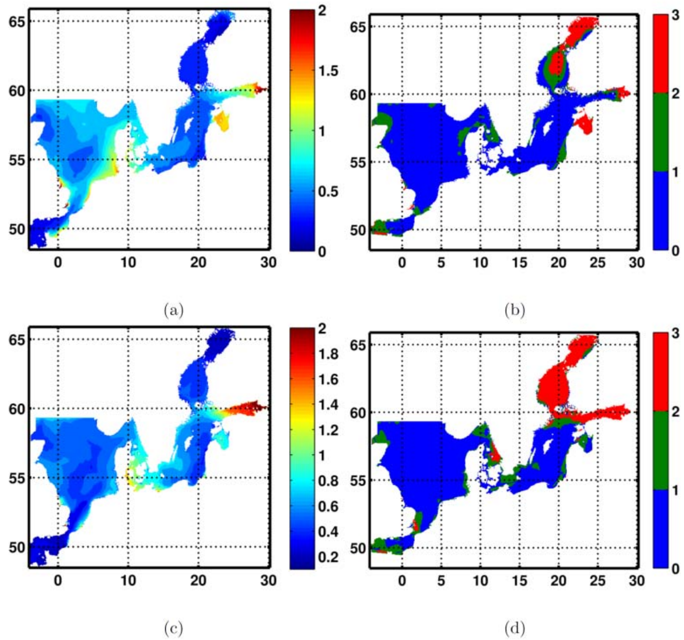
I. Kuznetsov, R. Hordoir, C. Dieterich, A. Höglund, M. Meier

Silicate and separated N, P, Si detritus



Baltic Sea boundary and the Swedish Western Seas

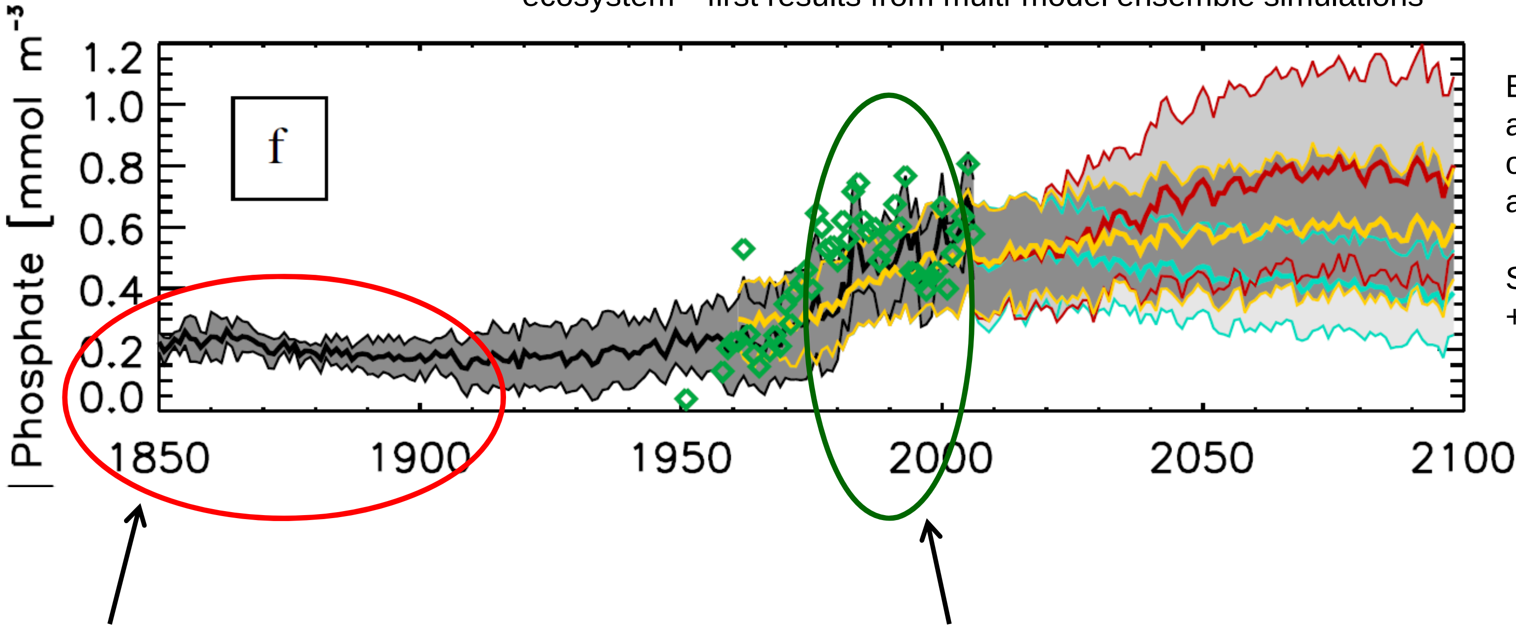




re 4: Winter (DJF) sea surface DIN (a – run A, c – run B) and corresponded cost functior 5: Winter (DJF) sea surface DIP (a – run A, c – run B) and corresponded cost functions

Historical Baltic Sea, modeling

Meier et al. (2012b) Comparing reconstructed past variations and future projections of the Baltic Sea ecosystem—first results from multi-model ensemble simulations



Ensemble averages and observed annual mean

Shaded areas +-1 STD

- Historical P very low.
- Comparable to Bothnian Bay dynamics ?

- Main model development in P-rich period.

The Baltic Sea Nutrient Cycling

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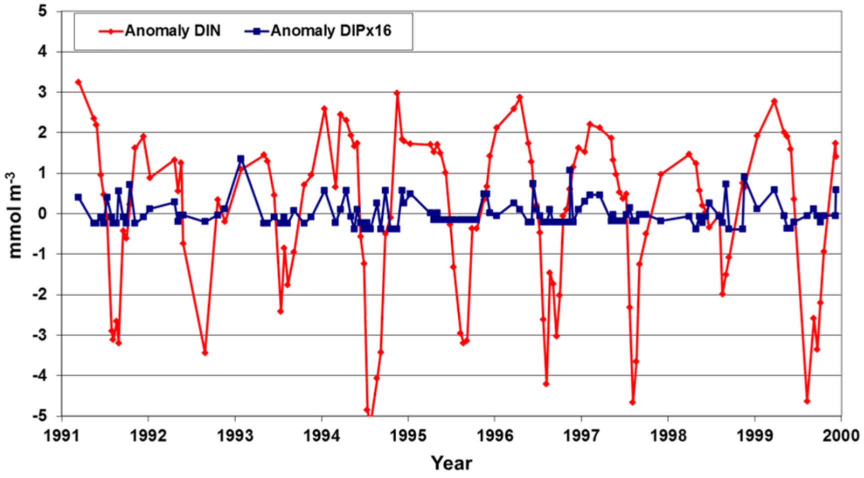
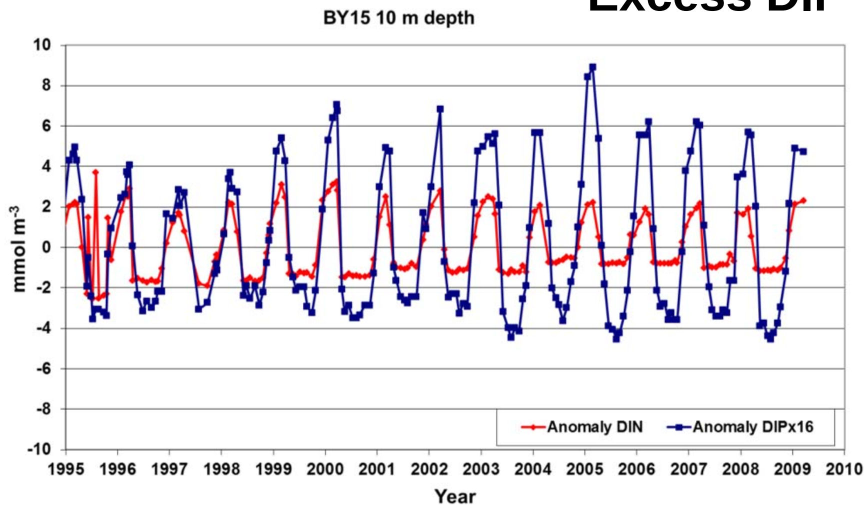
Excess DIN



Bothnian Bay

- **Anomaly relative to annual mean of DIN and DIPx16**
- **Challenge: Understand missing DIP. (Bacterial recycling?)**

Excess DIP

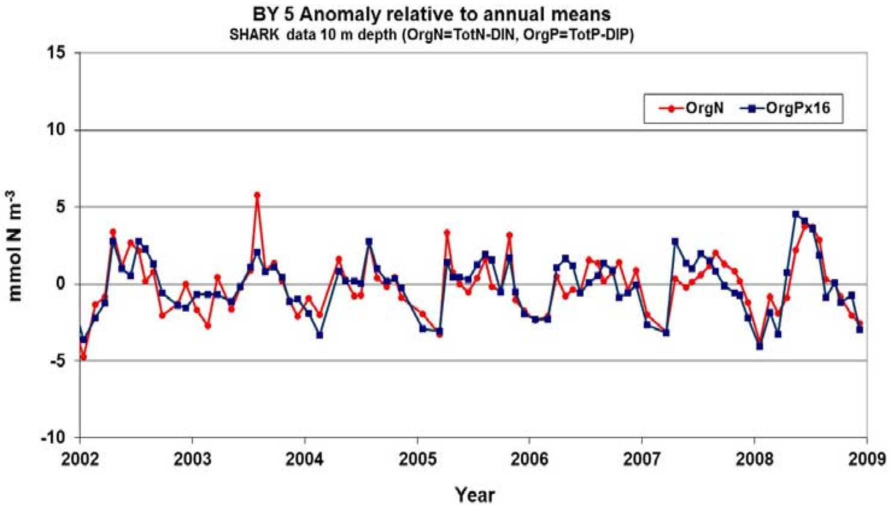


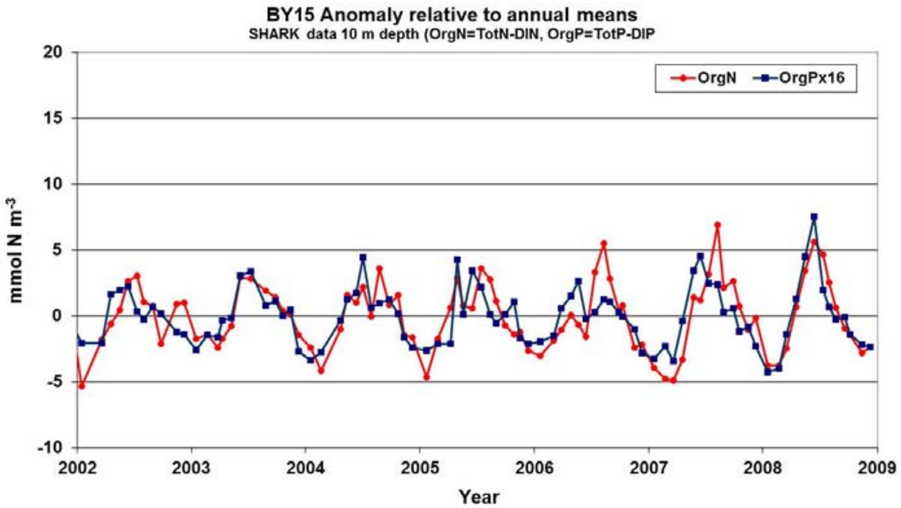
Eastern Gotland Basin

- **Anomaly relative to annual mean of DIN and DIPx16**
- **Challenge: Understand missing DIN. (Deviations from Redfield ratio? Nitrogen fixation?)**

Plankton model

- Redfield plankton model (N:P=16:1) simple visualization based on simultaneous N and P observations in the central and southern Baltic Sea.
- Calculate **OrgN** (TotN-DIN) and **16xOrgP** (TotP-DIP)
- Plot anomaly relative to annual mean in each year



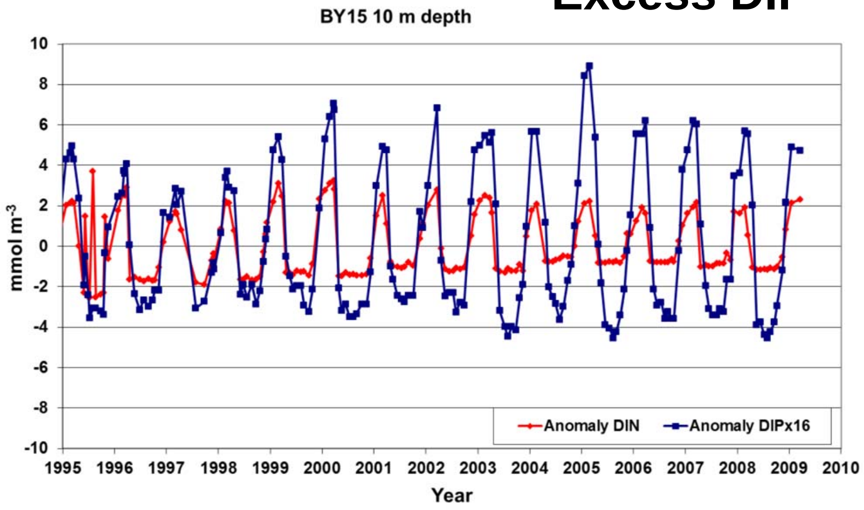


Data from Bornholm basin
10 m depth

Data from Gotland deep
10 m depth

Internal nitrogen cycling

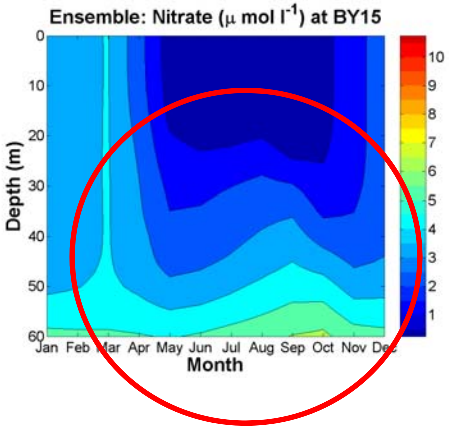
Excess DIP



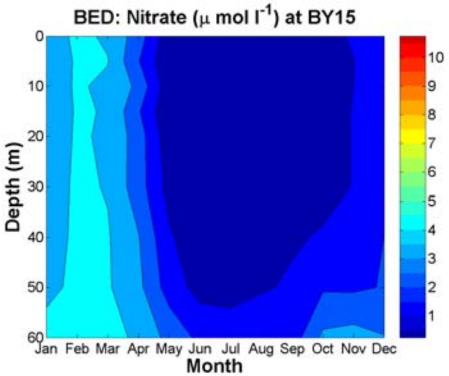
Eastern Gotland Basin

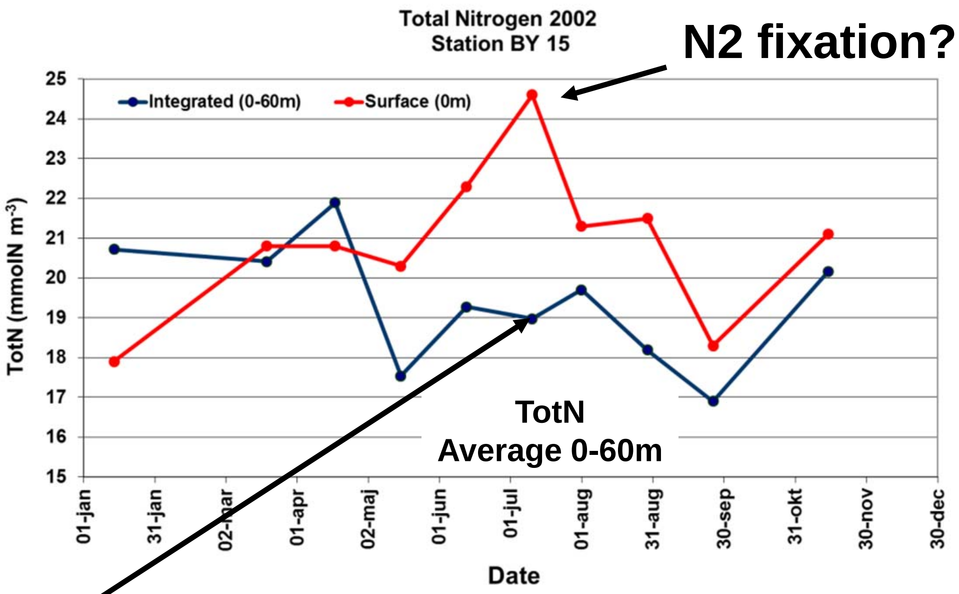
- **ECOSUPPORT models showed high NO3 below summer thermocline.**
- **Average TotN 0-60m show no large summer increase.**

ECOSUPPORT ensemble Monthly mean 1970-2005



Observations





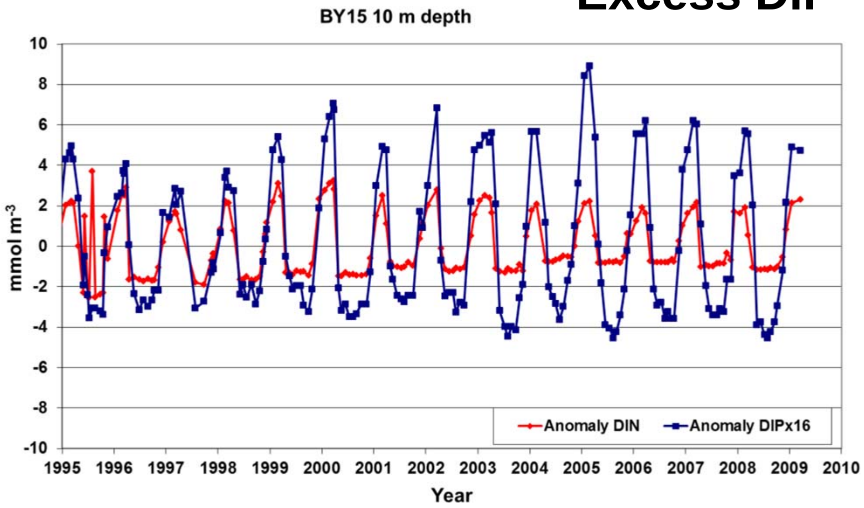
N2 fixation?

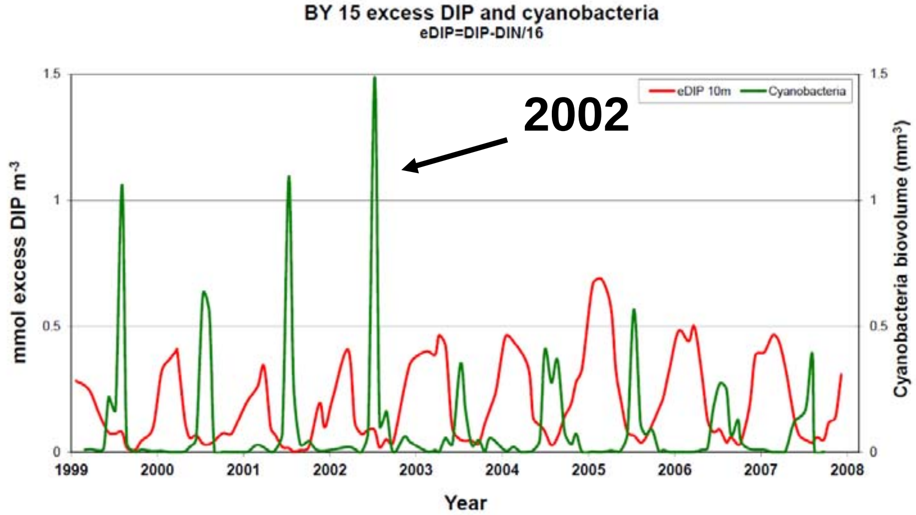
Physical, migration, denitrification?

Migrating cells?

Internal nitrogen cycling

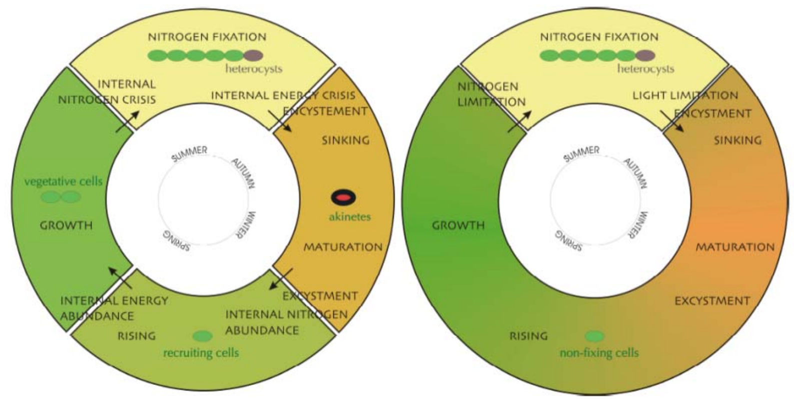
Excess DIP



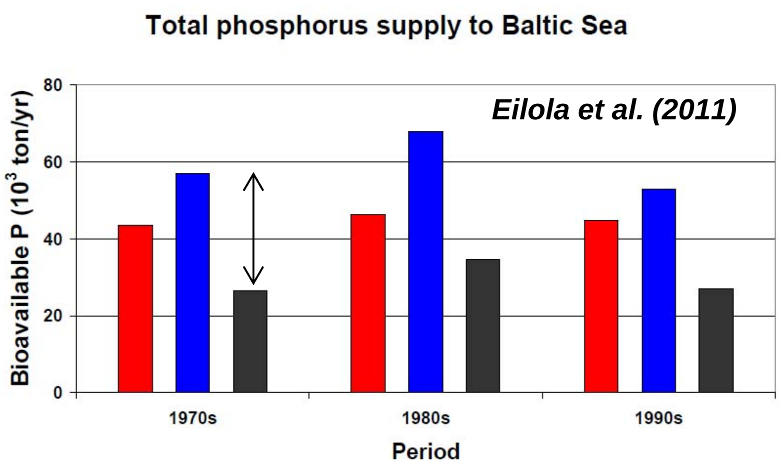


N-fix Formas project

Implement the life cycle model into the 3D biogeochemical model RCO-SCOBI to further study dynamics of cyano bacteria.



Cyanobacteria life cycle models

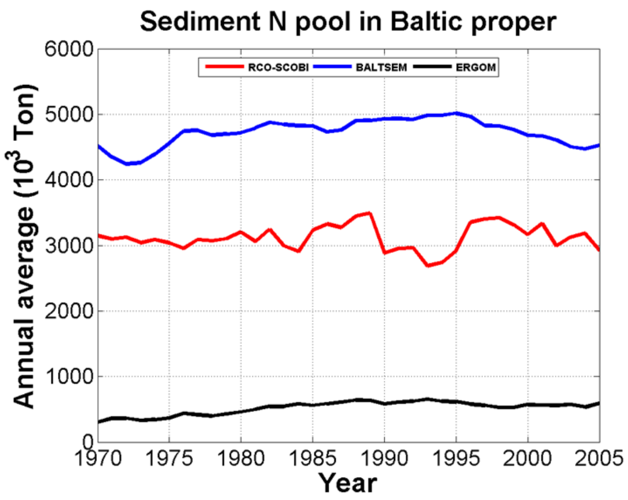


- **The P-loads differ by about 100%, from the smallest to the highest P-loads in the ECOSUPPORT state of the art ensemble. 70% of OrgN loads are neglected as "not bioavailable".**

Nutrient supplies

- **Challenge: Understand the actual supplies contributing to the Baltic Sea internal nutrient cycling.**
- **Understand the dynamics of the biological availability of nutrients under different environmental conditions.**

Eilola et al. (2011)



Nutrient inventory

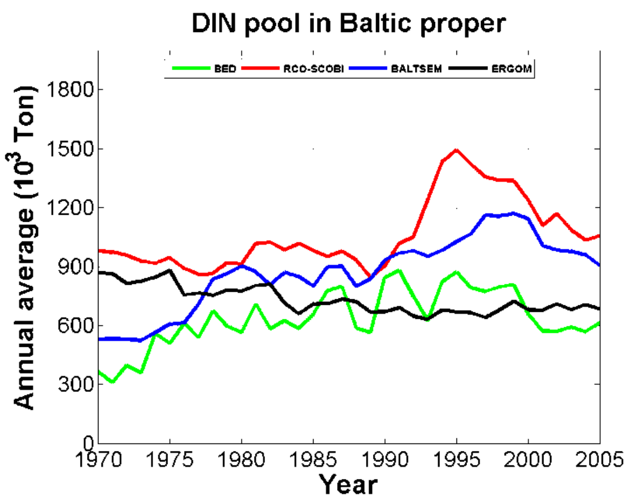
- **Challenge: Understand the inventory of different pools of nutrients actually contributing to the Baltic Sea nutrient cycling on centennial time scales.**

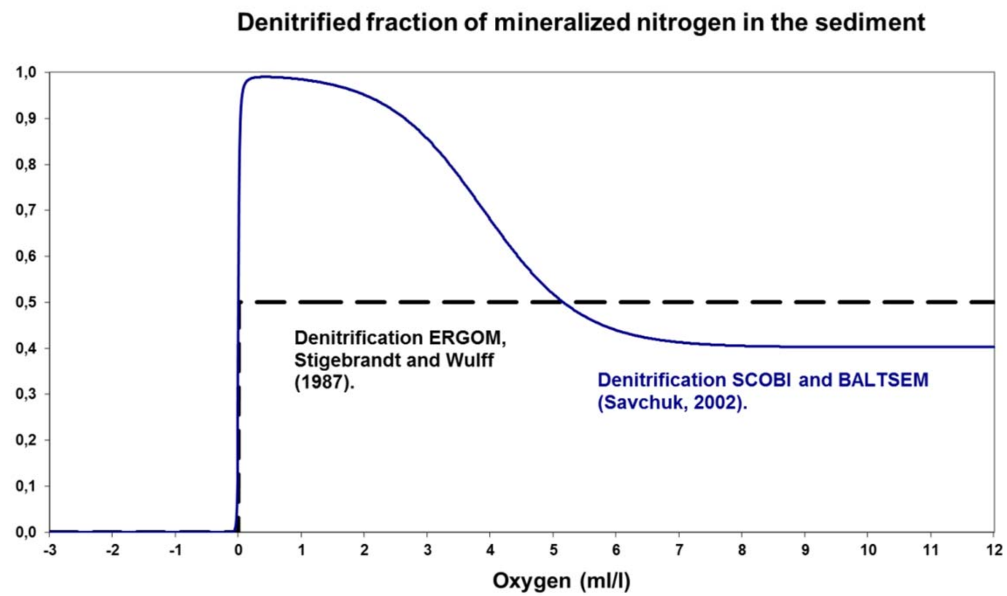
- ***The comparability of simulated pools to the amount of sediment nutrients in reality involved into biogeochemical cycles is still an open question.***

Denitrification (main N sink)

- **Bottom water oxygen dependent sediment denitrification and the denitrification in coastal river deltas differ among state of the art Baltic Sea models.**

- **Challenge: Understand dynamics of nitrogen removal.**





State of the art models

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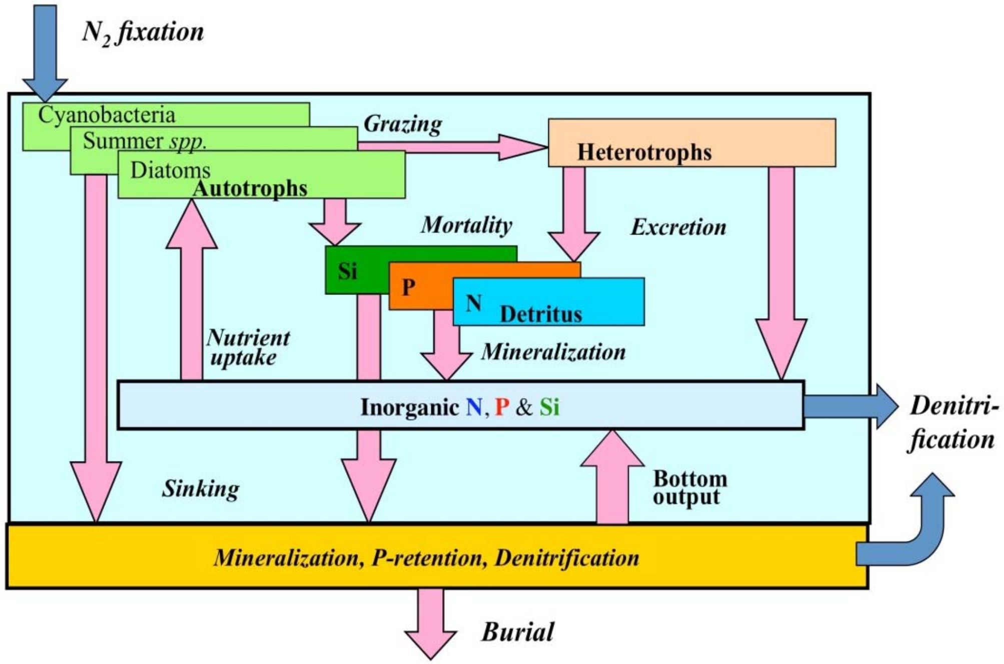
ECO SUPPORT

Baltic Nest Institute

Leibniz Institute for Baltic Sea Research Warnemünde IOW

Biogeochemical models
Simplified description from BALTSEM.



Coupled physical-biogeochemical models

1. RCO-SCOBI	(3D, 2nm)	SMHI	Sweden
2. BALTSEM	(1D, 13 basins)	BNI	Sweden
3. ERGOM	(3D, 3nm)	IOW	Germany

Key differences

- Representation of dead organic matter
- Sediment P dynamics
- Resuspension and sediment transport
- Horizontal resolution
- Vertical resolution

N, P and O_2 dynamics

- Inorganic and organic
- Sediment dynamics
- Redfield plankton dynamics

Eilola et al. (2011) Evaluation of biogeochemical cycles in an ensemble of three state-of-the-art numerical models of the Baltic Sea.