BIOGEOCHEMICAL RESEARCH NEEDS IN THE BALTIC SEA

... and the integrated use of observational data, models, and remote sensing

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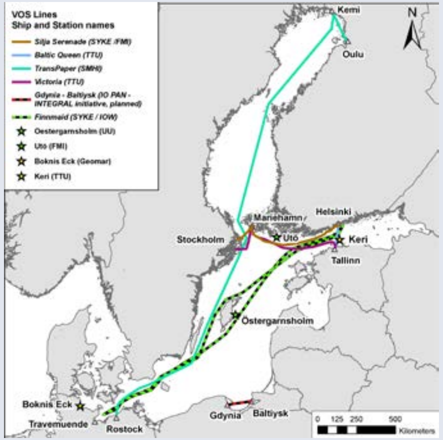
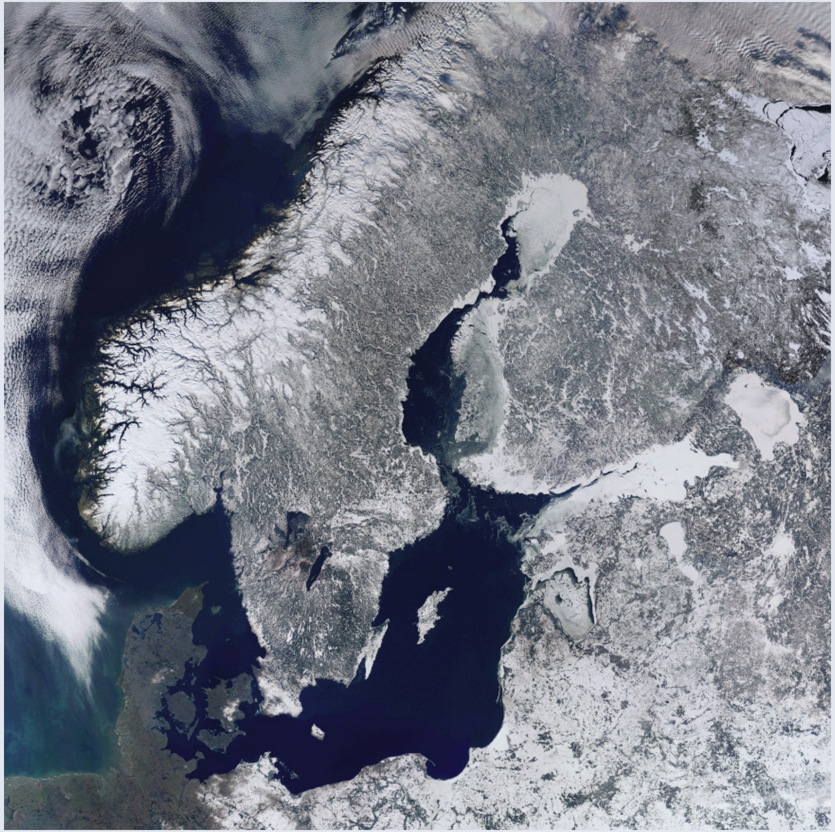
LEIBNIZ INSTITUTE FOR BALTIC SEA RESEARCH WARNEMÜNDE

Baltic Earth



Outline

- What first comes to people's mind
- Baltic Sea Biogeochemistry in a Nutshell
  - Drainage basin
  - External versus internal nutrient loads
  - Coastal versus central nutrient ratios
  - Deep basin oxygen deficiency
  - (Summer) cyanobacterial bloom (N-fixation period)
- A "Wishlist" of what we would like to know
- Some examples of what non EO-people can offer

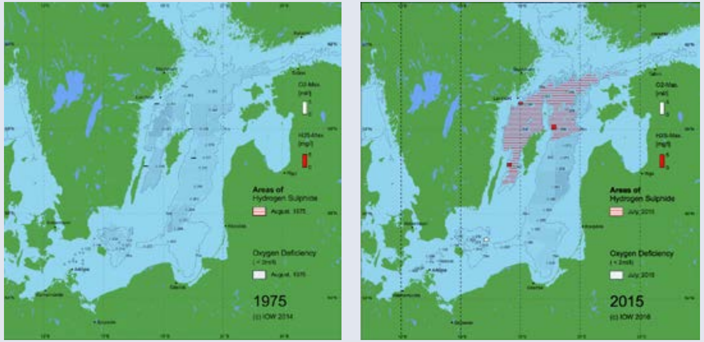


Scandinavia, 15-24 Feb. 2003, Modis compilation, albedo39, Claudius Diemer

Key biogeochemical problems of the Baltic Sea

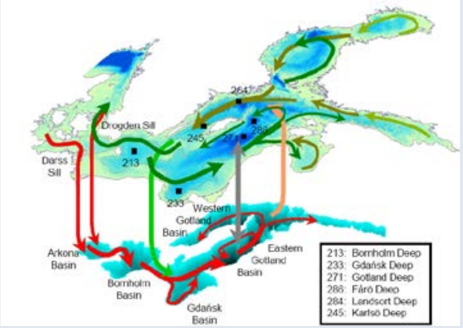
What first comes to people's mind

- **Eutrophication**
  - *(the bad algae problem)*
- **Oxygen deficiency below the halocline**
  - *(the death zone problem)*
- **C,N,P,O,(S) cycles**
- Emerging (organic) pollutants and accumulation
- **Quantification land– sea fluxes** and
- **Near-coast transformations**
- **Biogeochemical assessment in the framework of immense spatiotemporal variability**
- Regional Air-Sea exchange

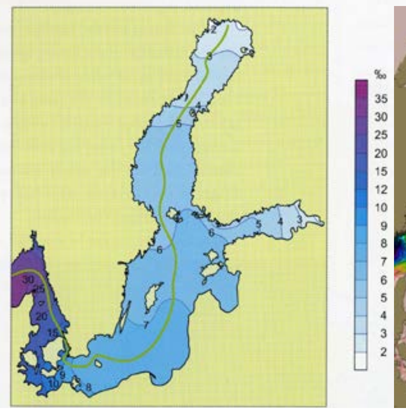


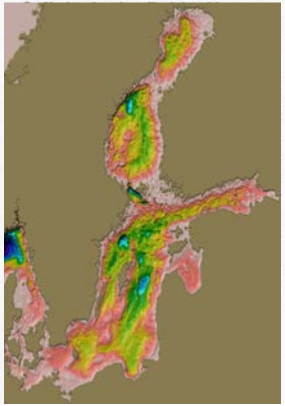
BS Biogeochemistry in a nutshell (I)

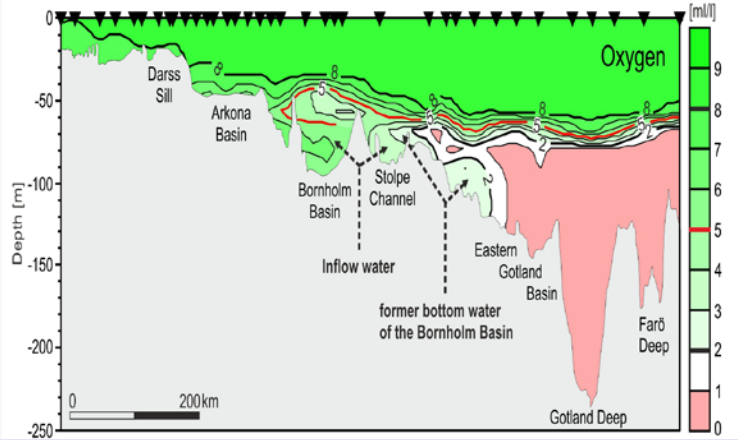
- **Physical Setting**
  - A classical “silled estuary setting” with multiple basins
  - Limited exchange of (dense) seawater
  - Freshwater surplus
  - Brackish characteristics



- **Strong horizontal and vertical salinity gradients**
- **Limited ventilation of the deep basins**
- **Tendency for deep water hypoxia**







BS Biogeochemistry in a nutshell (II)

Eutrophication

- Huge Drainage area
- Increased nutrient loads led to increased inventory of N and P, fostering enhanced primary production
- Reduction of inputs since the mid-80th
- Reduction of inventory is however less pronounced

=> Internal cycling dominates the nutrient availability in the Baltic

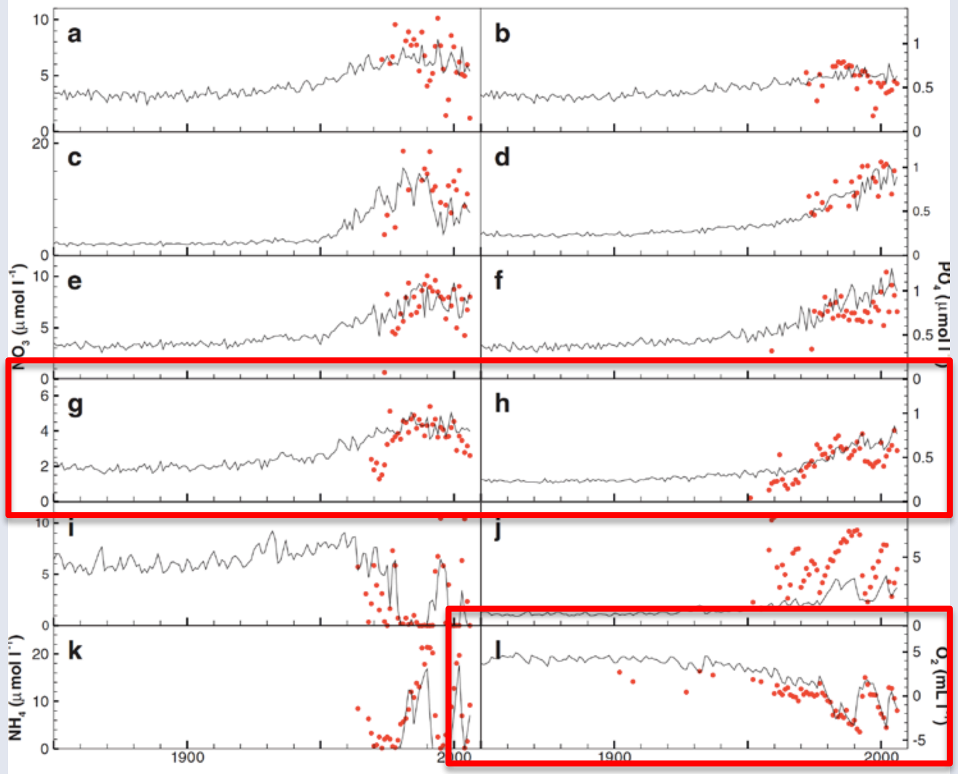


Figure 1.2. Winter average surface nitrate and phosphate concentrations in southern Kattegat (a, b), Gulf of Riga (c, d), Gulf of Finland (e, f), and Gotland Sea (g, h). Annual average nitrate (i), phosphate (j), ammonia (k), and oxygen (l) concentrations at 200 m depth in Gotland Sea. Lines are modelled and red dots are averages made from observations. Oxygen concentrations before 1950 are averaged over 5-year periods because of few available data. (Source: Gustafsson et al. 2012)

BS Biogeochemistry in a nutshell (III)

Nutrient Retention

- N to a large fraction lost coastal-near, with lifetime in the order of a few years (Radke et al.)
- P lifetime in excess of 30 years in accordance to simple mass balance consideration (Radke et al.)

⇒ **Coastal-near biogeochemical turnover of peculiar importance**

- – Different from open basins
- – Determines water quality for „user“
- – Huge impact on remediation strategies

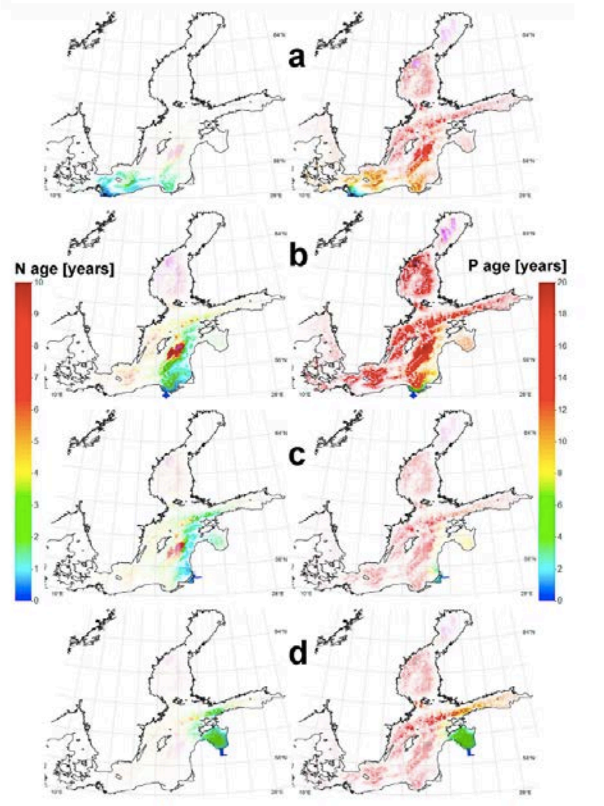


Figure 1. Age and spatial distribution of nitrogen and phosphorus from the rivers (a) Oder, (b) Vistula, (c) Neman and (d) Daugava in the active sediment. Full intensity represents a concentration of 50 mmolN/m² and 5 mmolP/m², areas with higher concentrations are shown darker. All data represent average values for the years 1992–1996, i.e., 30 years after the start of the nutrient labeling. Phosphorus age may be a lower estimate, as the model has not run to steady state, see discussion in the text.

Radke et al 2014

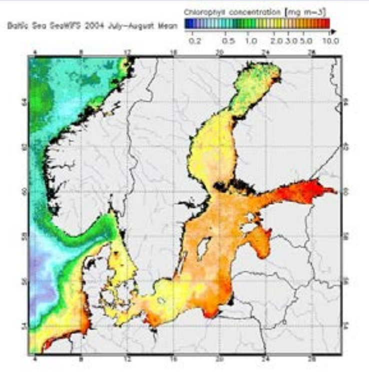
BS Biogeochemistry in a nutshell (IV)

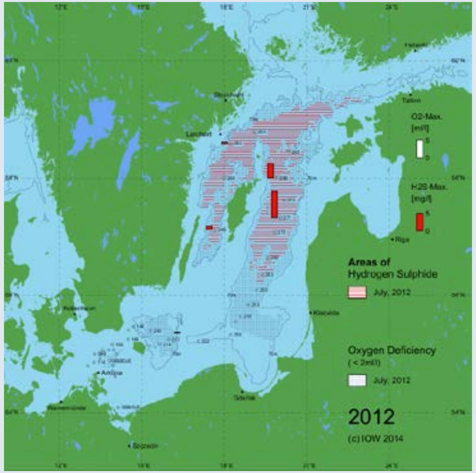
Eutrophication - Indicators

- **Winter Surface P- and N inventory**
- **Secci depth summer**
- **Chl*a* summer**
- **Phytoplankton biomass (pot. species dependent)**
- **Oxygen dept below the halocline**

⇒ **What is really though after is a measure of <u>productivity and export productivity</u>**

Nixon 95: Eutrophication - *"An increase in the rate of supply of organic matter to an ecosystem"*

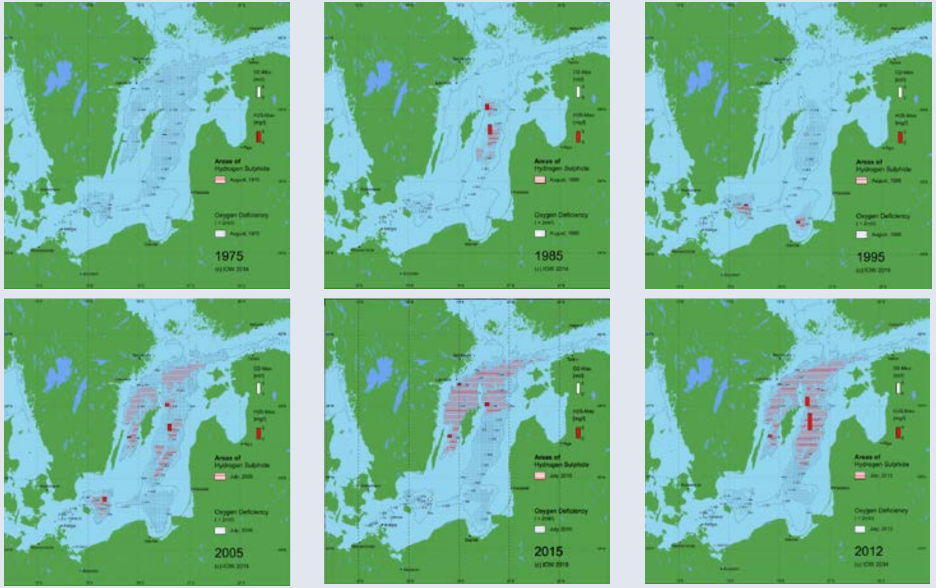


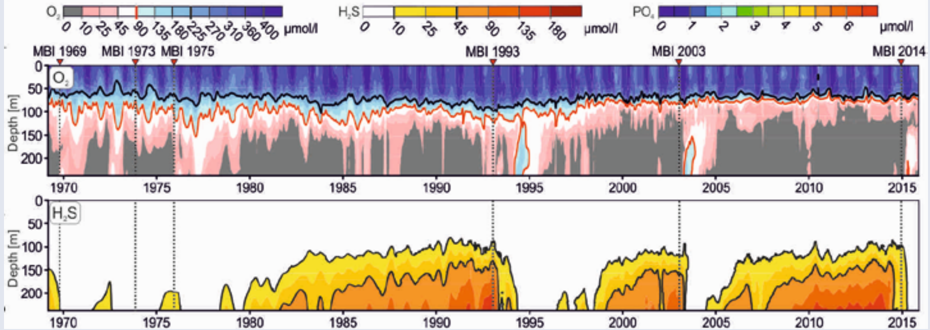


BS Biogeochemistry in a nutshell (V)

Deep water oxygen deficit

- Organic matter (from export PP) is mineralized in the deeper basins
- In stagnation periods limited ventilation (i.e. oxygen supply)
- Oxygen deficiency, anoxia,
- Oxygen “debt” illustrates the additional need of oxygen for hydrogen sulfide re-oxidation

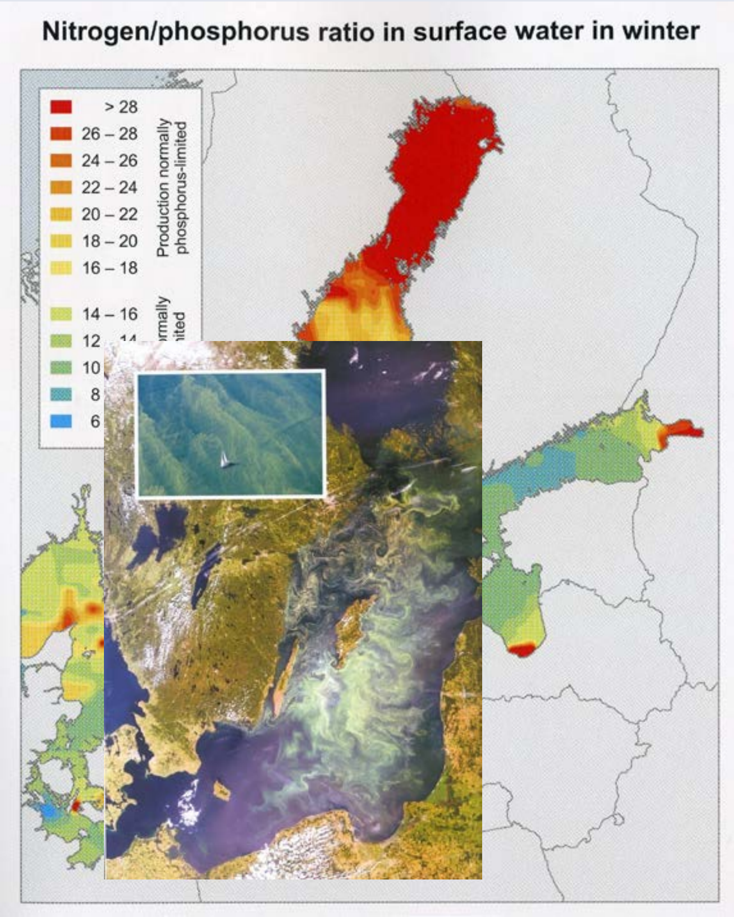




BS Biogeochemistry in a nutshell (VI)

Summer cyanobacteria

- External N:P in the (current) order of 50:1
- Better coastal an suboxic removal of N leads to central P-deficiency
- Resulting N-fixation bloom in summer, probably earlier
- Control mechanisms rather unclear



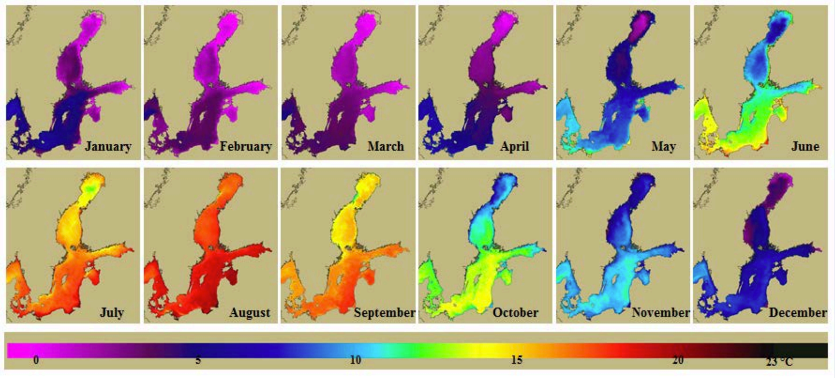
Redfield Ratio (1963):

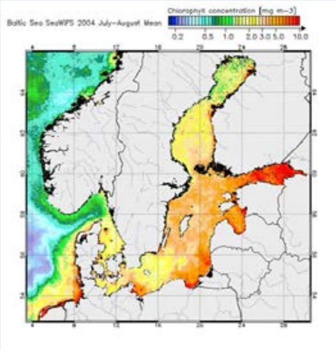
106 C :16 N : 1 P

$$106CO_2 + 16NO_3^- + HPO_4^{2-} + 122H_2O + 18\,H^+ \rightarrow (CH_2O)_{106}(NH_3)_{16}(H_3PO_4) + \underline{\mathbf{138O_2}}.$$

A biogeochemist's wishlist to EO:

- **Sea surface temperature**
- **Sea surface salinty**
- **Mixed layer depth**
- **Phosphate and Nitrate in the mixed layer**
- **Primary productivity in the mixed layer**
  - **Species dependent?**
- **(C)DOM and linked DOM**
- **pCO_2 or better C_T in the mixed layer**



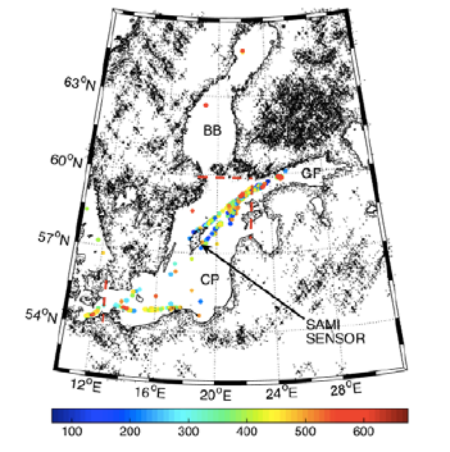


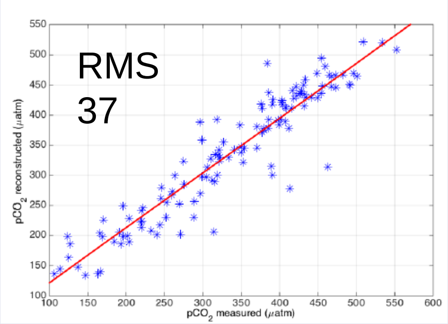
SST monthy mean compilation 2015 (NOAA AVHRR, processed BSH and IOW); True color picture of July 31st, 2008 (Meris (ESA) and Western Baltic Sea of Sept. 15th, 2016 (Modis Aqua) ; courtesy of H. Siegel, IOW

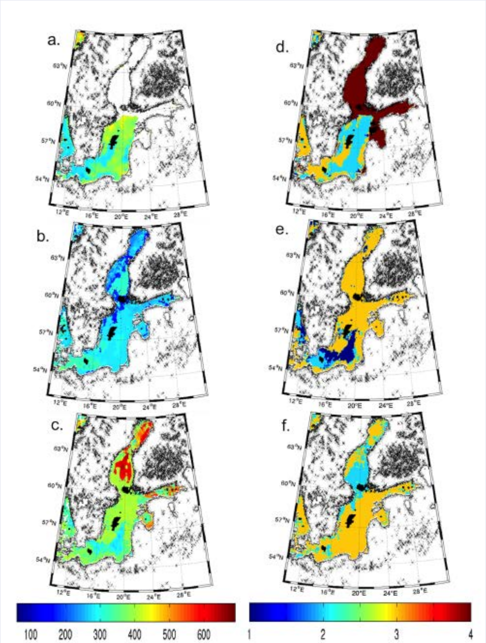
Estimation vs. measurement of pCO_2

Parard et el. 2015

- pCO_2 data from VOS Finnmaid, Östergarnsholm, and SMHI carbon data
- Neural network learning based on SST, CDOM, NPP, MLD, Time
- Deviation between measured values and NN-approach







(**a, b,** and **c**) reconstruction of the pCO_2 map, (**d, e,** and **f**) the flag for each map. **(a, d)** March 2010, **(b, e)** July 2010, **(c, f)** September 2010. **(From Parard et al., 2015)**

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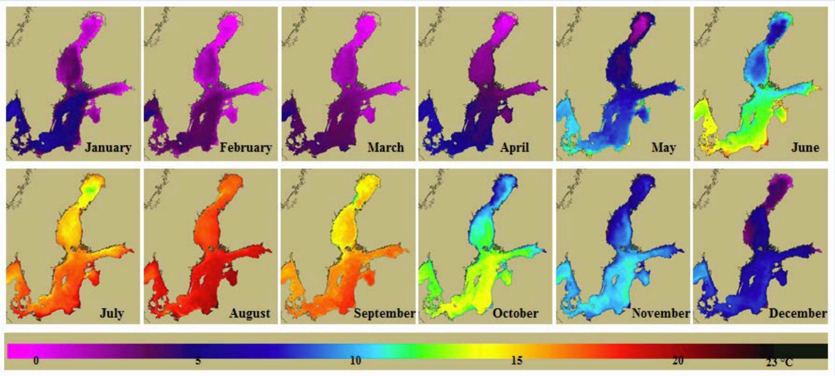
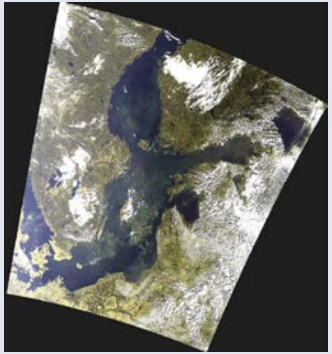
But isn't interdisciplinary science all about

Mutual Give and Take !!





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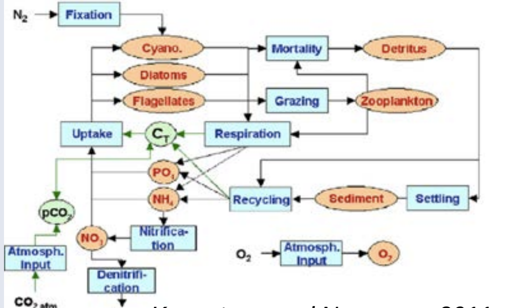
The Unique Setting

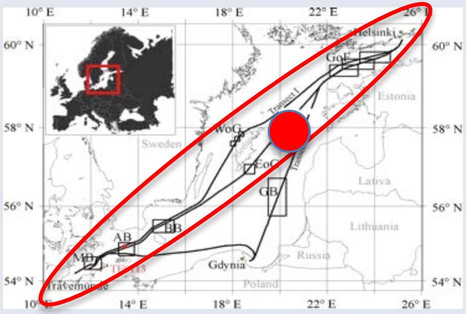
- Very dense observational network, including regular RV-based monitoring, fixed stations, and ships of opportunity
- Various physical and biogeochemical modelling approaches of different resolution and complexity
- Airborne observations??
- Complex gradients and variability, making EO-studies difficult, but at the same time precious

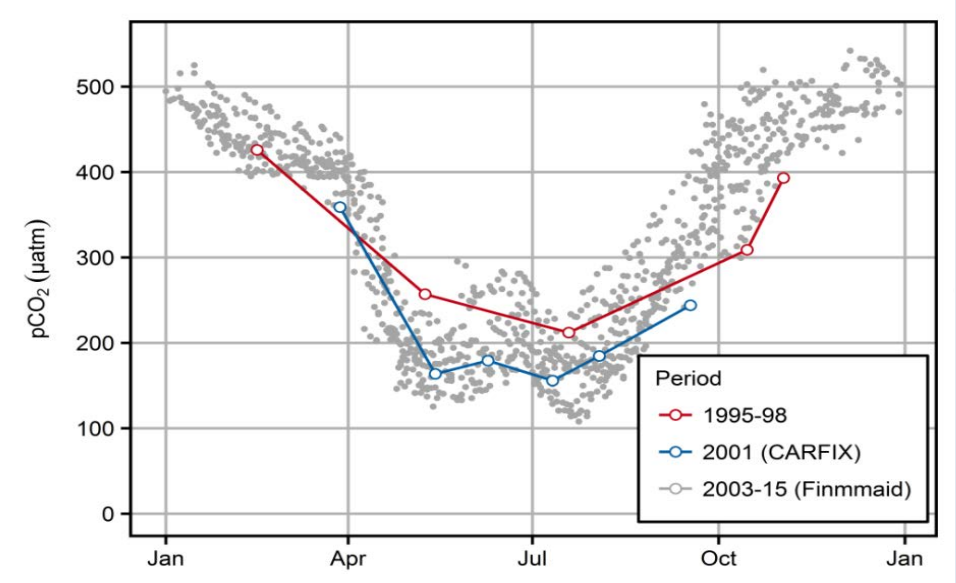


Kusnetzow and Neumann, 2011

VOS Finnmaid

- Part of ICOS-D ICOS INTEGRATED CARBON OBSERVATION SYSTEM
- Operating between Lübeck and Helsinki and back ~ every 3 days
- Part of Alg@line project (SYKE)
- Instrumentation for pCO_2, pCH_4, pO_2 (IOW)
- Amendments planned: pN_2O, ^{13}C-CO_2





BIOGEOCHEMICAL RESEARCH NEEDS IN THE BALTIC SEA

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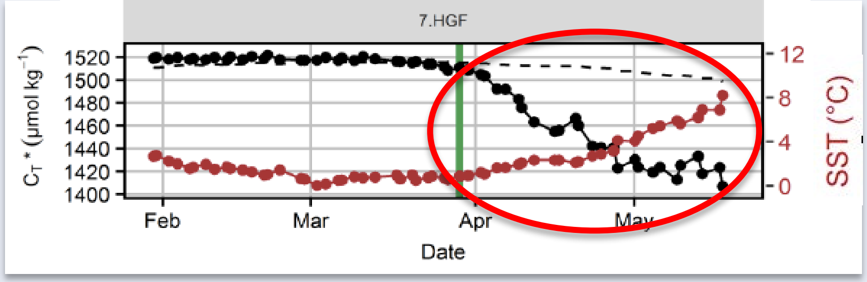
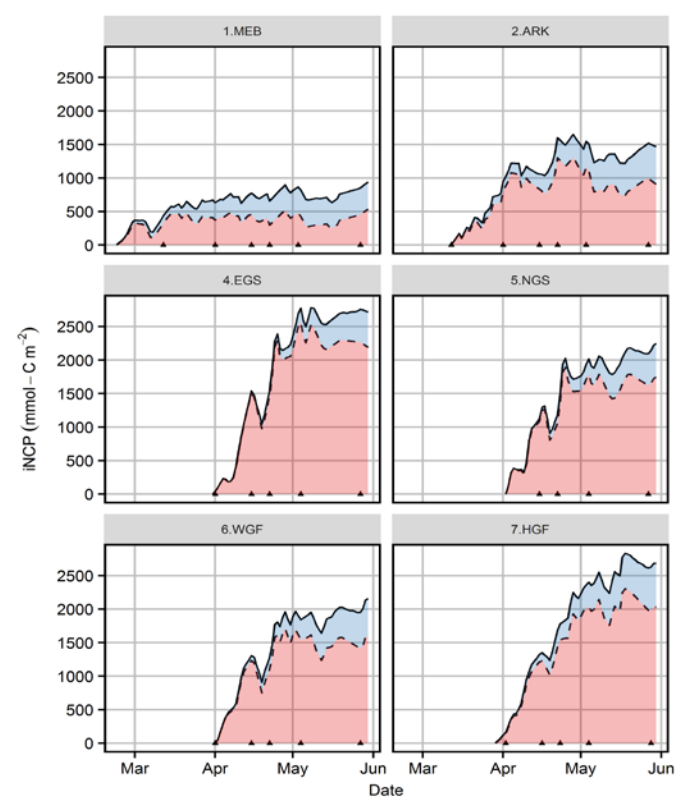
Baltic Earth

Tools for biogeochemical assessment

Example IIa : Net primary production SB





Calculated net carbon production in the different basins during the spring bloom for 2009.
Schneider and Müller, in prep.

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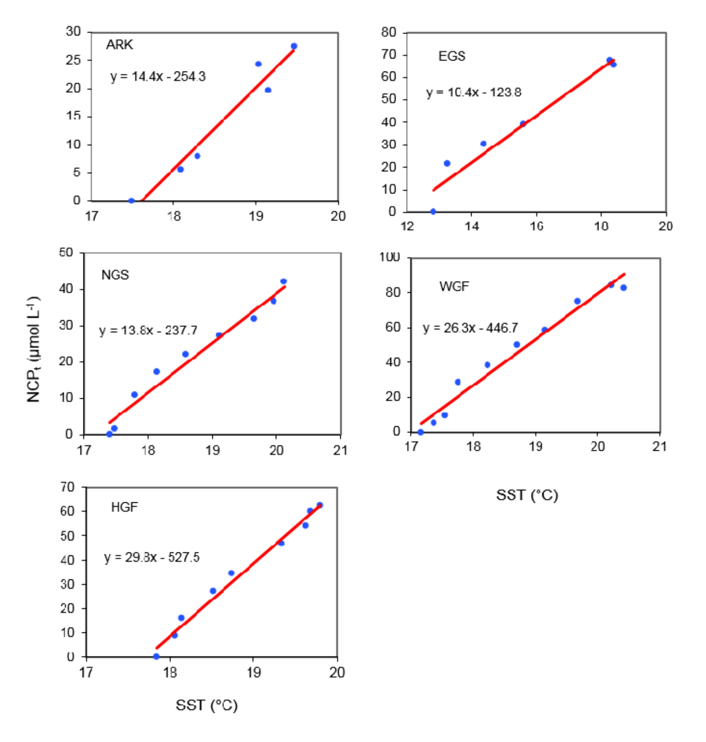
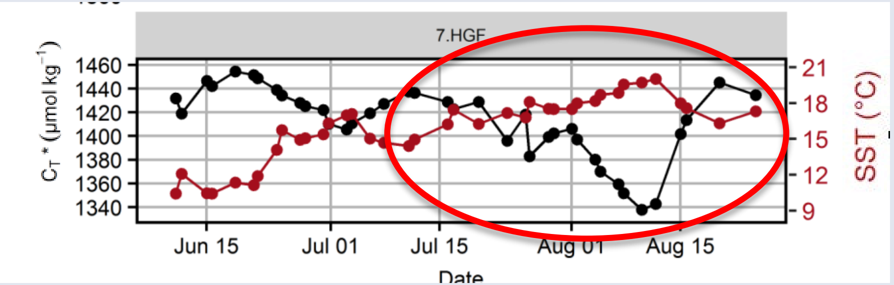


Calculated net carbon production in the different basins during the summer 2009 productive period.
Schneider and Müller, in prep.

Tools for biogeochemical assessment

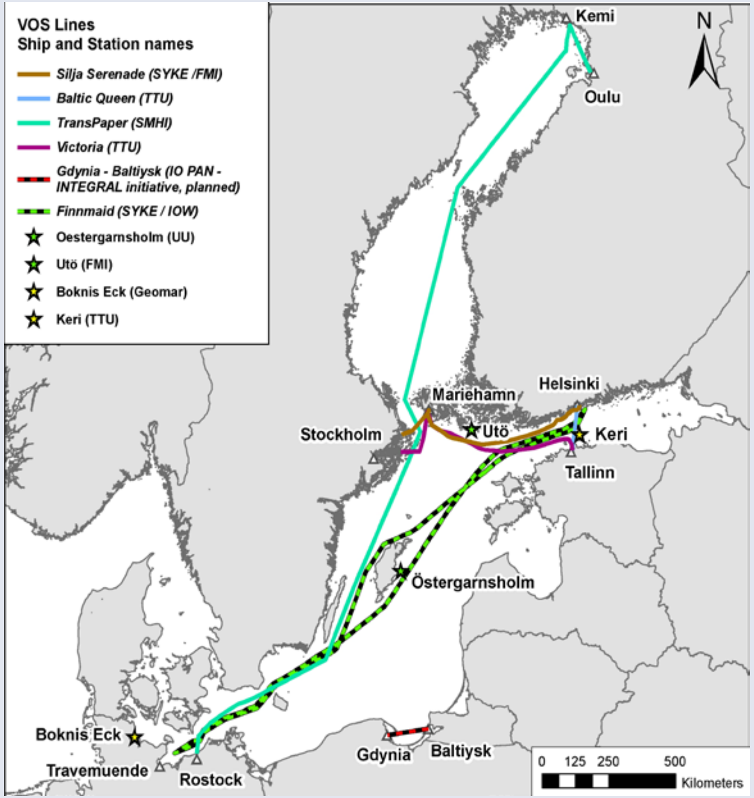
Example IIb : Net primary production SB



BONUS INTEGRAL

A project announcement

- **Currently under national and BONUS negotiation, expected starting date July 1st, 2017, 3 years**
- 8 Partners from 5 countries
- Including three current Baltic ICOS stations



Infrastructure network to be used for carbon dioxide and trace gas studies within BONUS INTEGRAL

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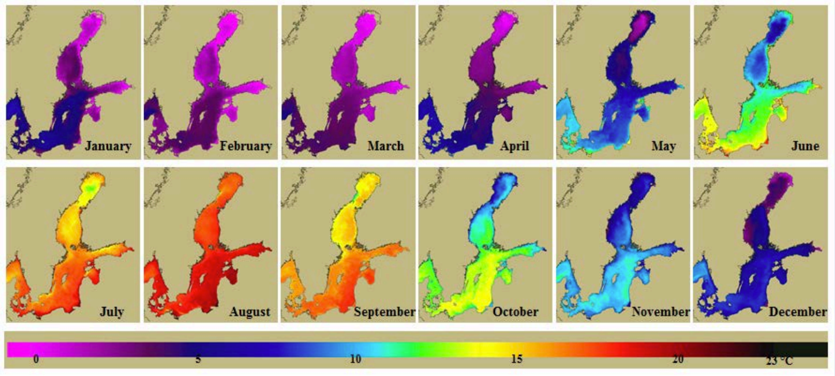

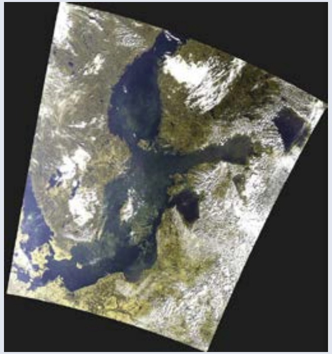

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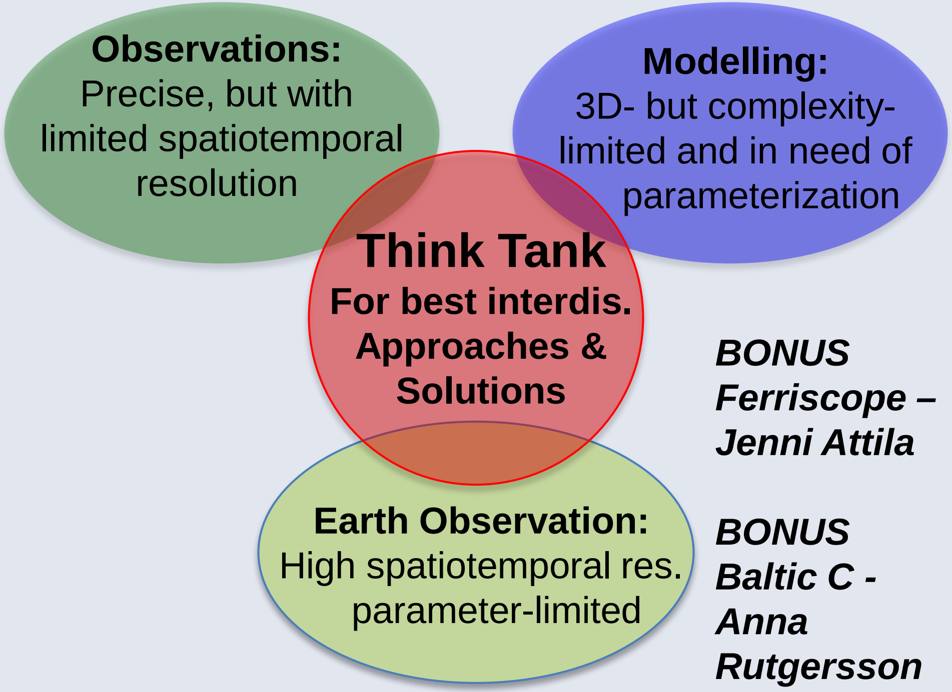
The interdisciplinary vision

- **Maximum mutual benefit requires integrated research (and projects) including field measuring biogeochemists, modellers, and earth observation specialists**

- **Derivation of best quantitative EO-products requires tailored field studies and modeling studies**

- **Extrapolation approaches based on multi-variable fitting requires very solid analysis of the relation of output and input variables**



BONUS Ferriscope – Jenni Attila

BONUS Baltic C - Anna Rutgersson

Thank you for your attention

Baltic Earth

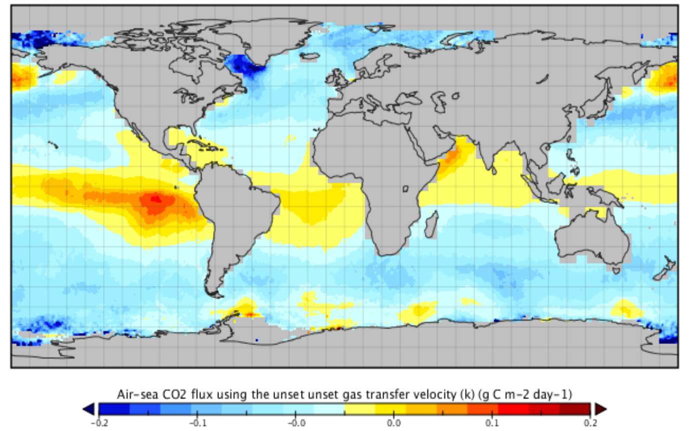
Interest in the work
of the BE WG on Biogeochemical Feedbacks
Let me know: **gregor.rehder@io-warnemuende.de**

oceanflux evolution
support to science element

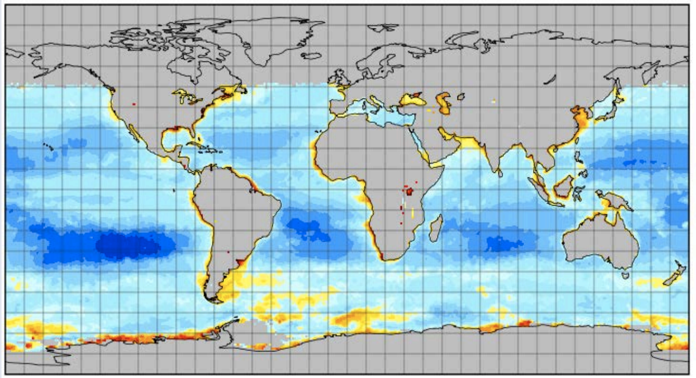
FluxEngine – air-sea gas flux toolbox

- Toolbox developed for community use:
- Open source license (python and PERL based).
- Standard NetCDF data input and output.
- Net flux tool with traceable land/ocean/basin templates.
- User configurable gas flux calculation.
- Extensively verified using published data.

Shutler, J. D., Piolle, J-F., Land, P., Woolf, D. K., Goddijn-Murphy L.,, Paul, F., Girard-Ardhuin, F., Chapron, B., Donlon, C. J., (2016) Flux Engine: A flexible processing system for calculating air-sea carbon dioxide gas fluxes and climatologies, *Journal of Atmospheric and Oceanic Technology.*



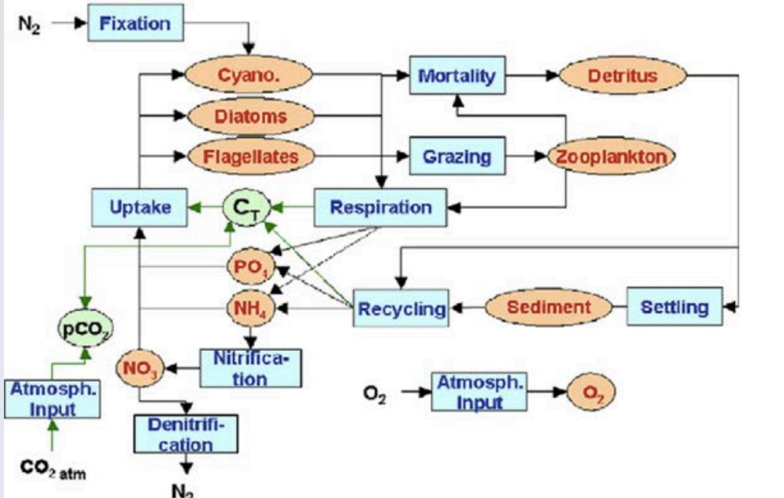
Example mean daily flux output



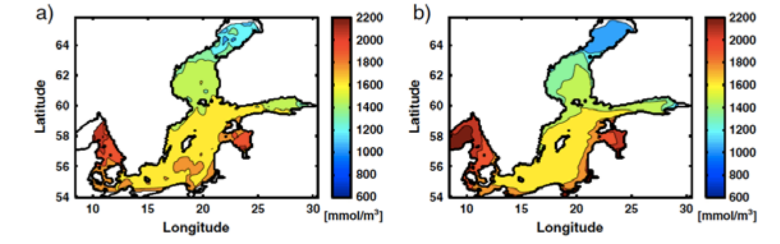
Example process indicator layer output using ESA Climate Change Indices chl-a

Carbon system modelling

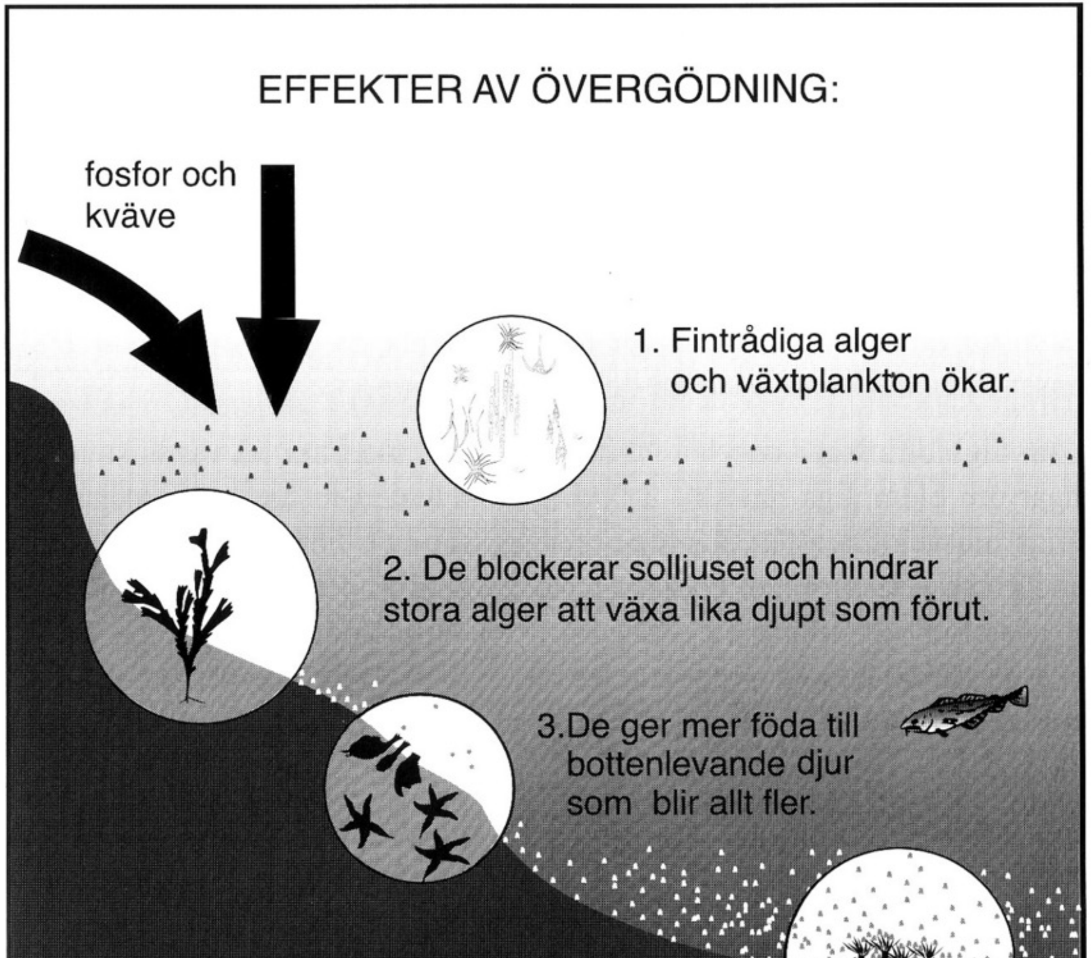
- Well established MOM-ERGOM framework
- Potentially increased horizontal resolution
- Expansion of carbon system description using all available information
- Evaluation of carbon system as biogeochemical indicator variable
- Model based assessment of monitoring strategy



Kusnetzow and Neumann, 2011



Schematic of biogeochemical module of ERGOM and comparison of average A_T (1978 to 2005) compiled from the ICES data base (lower left) versus average A_T from hindcast simulation using ERA 40 atmospheric forcing (lower right)


EFFEKTER AV ÖVERGÖDNING:
fosfor och
kväve
1. Fintrådiga alger
och växtplankton ökar.
2. De blockerar solljuset och hindrar
stora alger att växa lika djupt som förut.
3.De ger mer föda till
bottenlevande djur
som blir allt fler.