Biogeochemical transformation processes along lateral gradients

Christoph Humborg

Stockholm University

- Improve understanding on biogenic element inputs from the catchment
- Disentangle dynamics of terrestrial and marine derived DOM
- The role of DOC, DON and DOP on PP, pCO_2, denitrification etc patterns

Land cover of the Baltic Sea Basin

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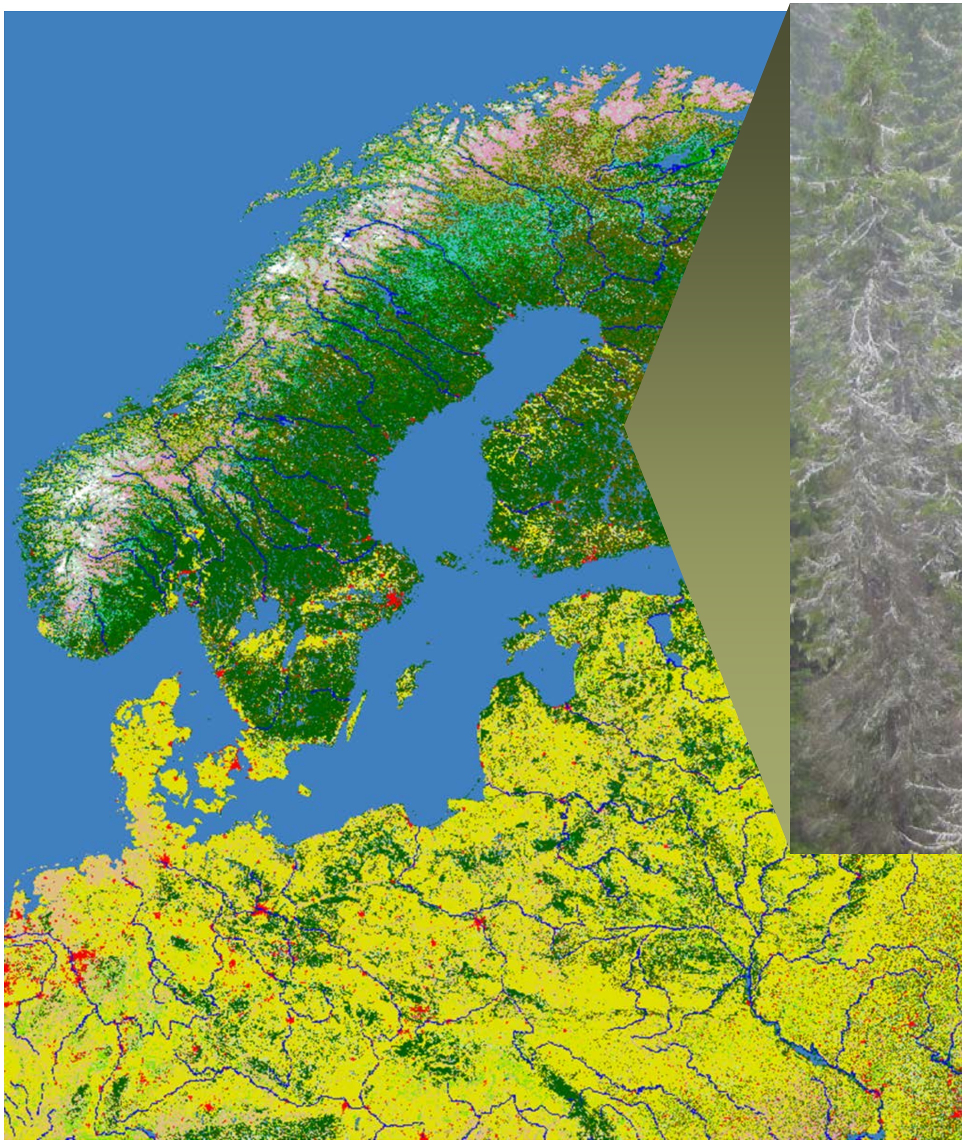
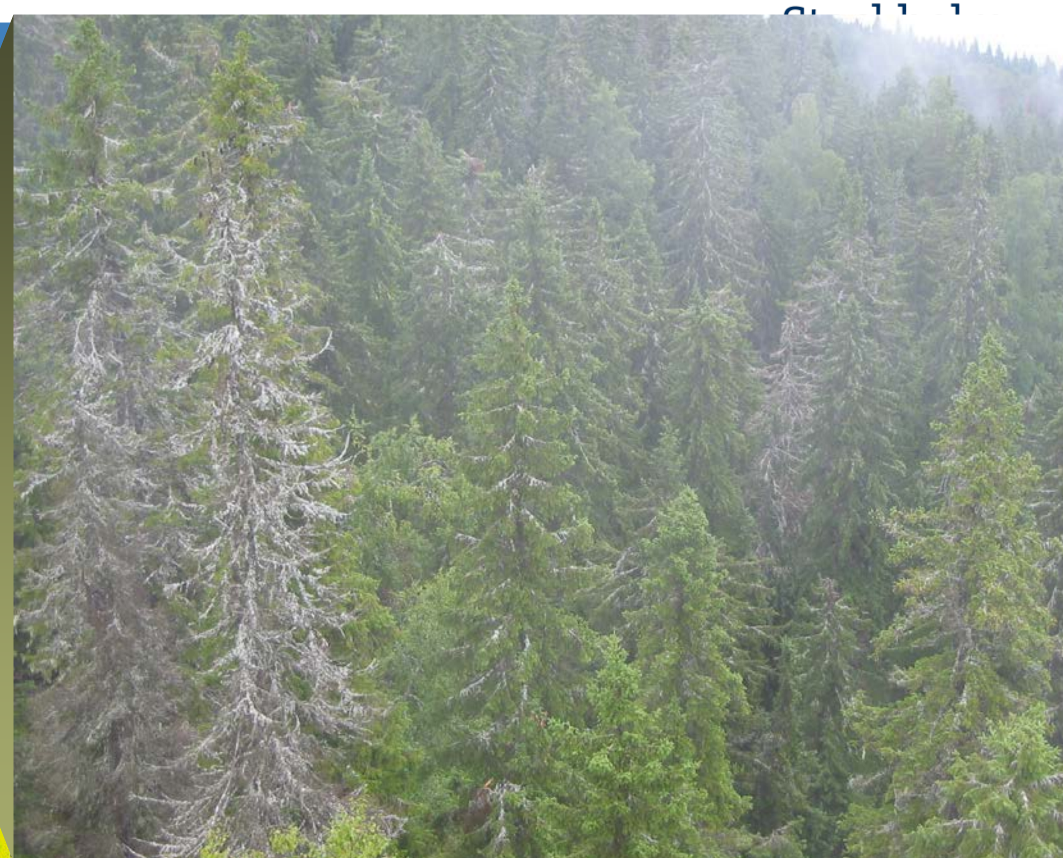
- Urban areas
- Bare areas
- Cultivated land
- Pastures and natural grassland
- Open herbaceous vegetation with shrubs
- Lichens and mosses
- Cropland-woodland mosaic
- Wetlands
- Snow and ice
- Sparse vegetation
- Broadleaved deciduous closed forest
- Broadleaved deciduous open forest
- Mixed closed forest
- Mixed open forest
- Needleleaved closed forest
- Needleleaved open forest
- Water

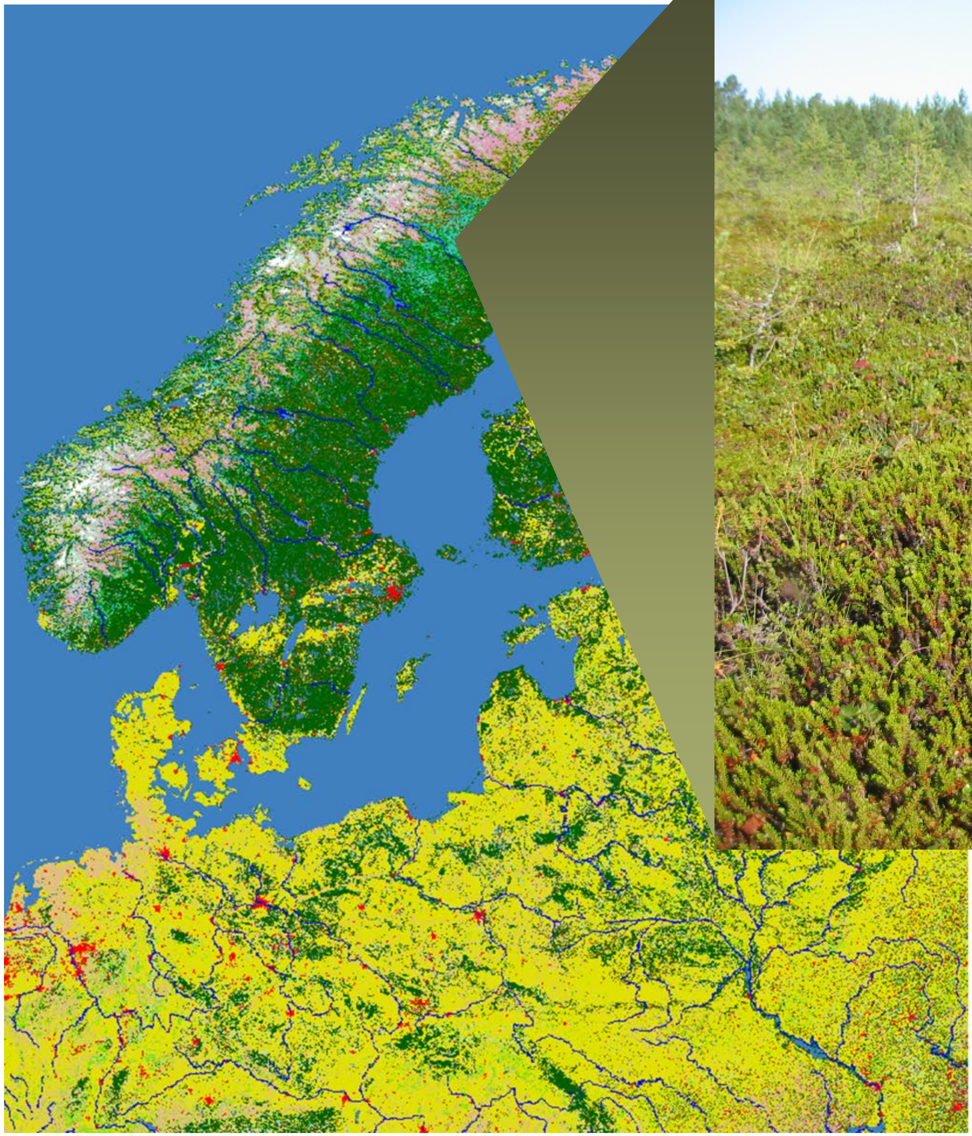
Ledwith (2003), GLC2000 project

Land cover of the Baltic Sea Basin





Land cover of the Baltic Sea Basin



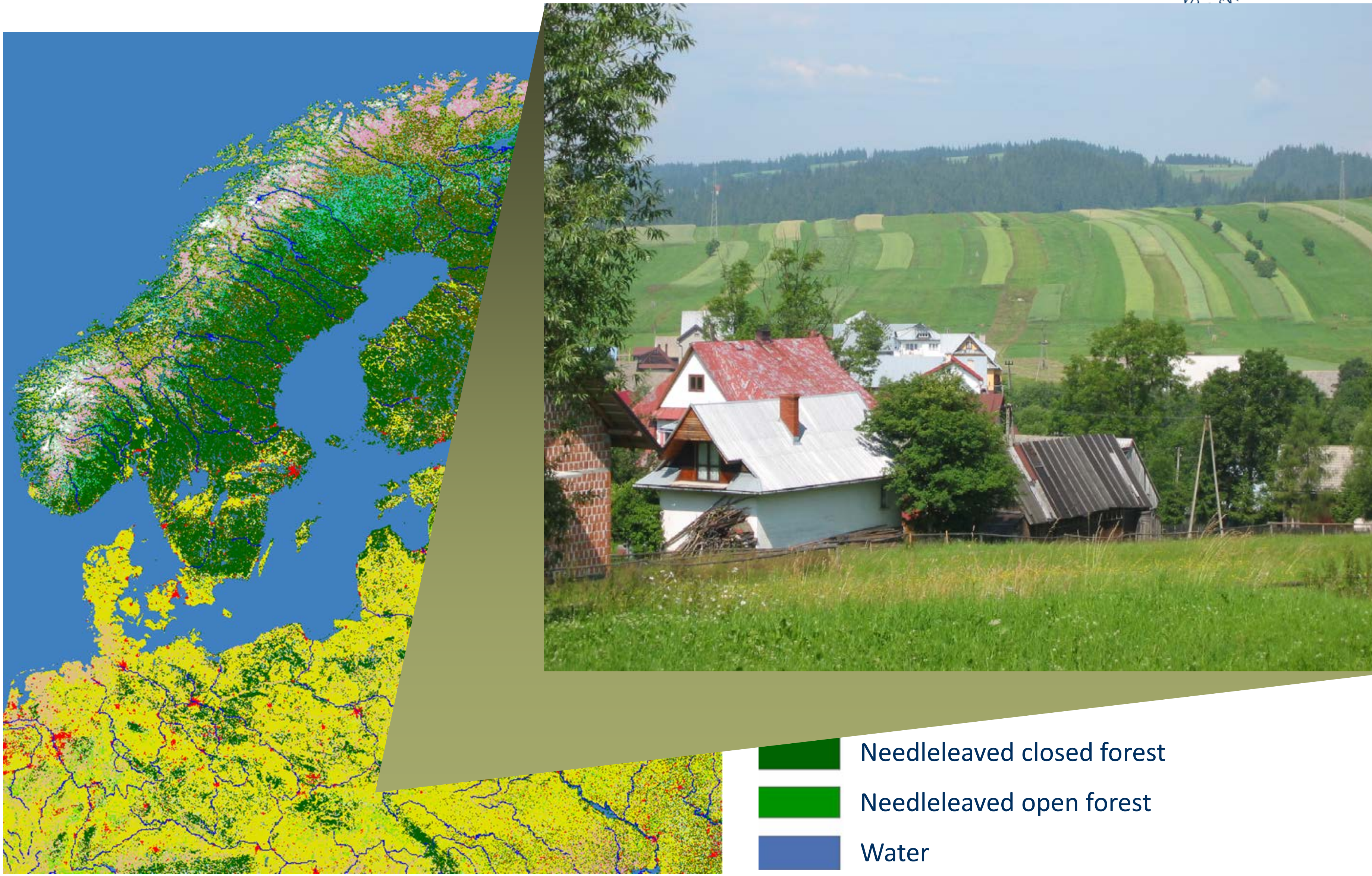
Mixed open forest

Needleleaved closed forest

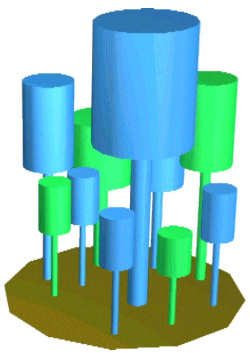
Needleleaved open forest

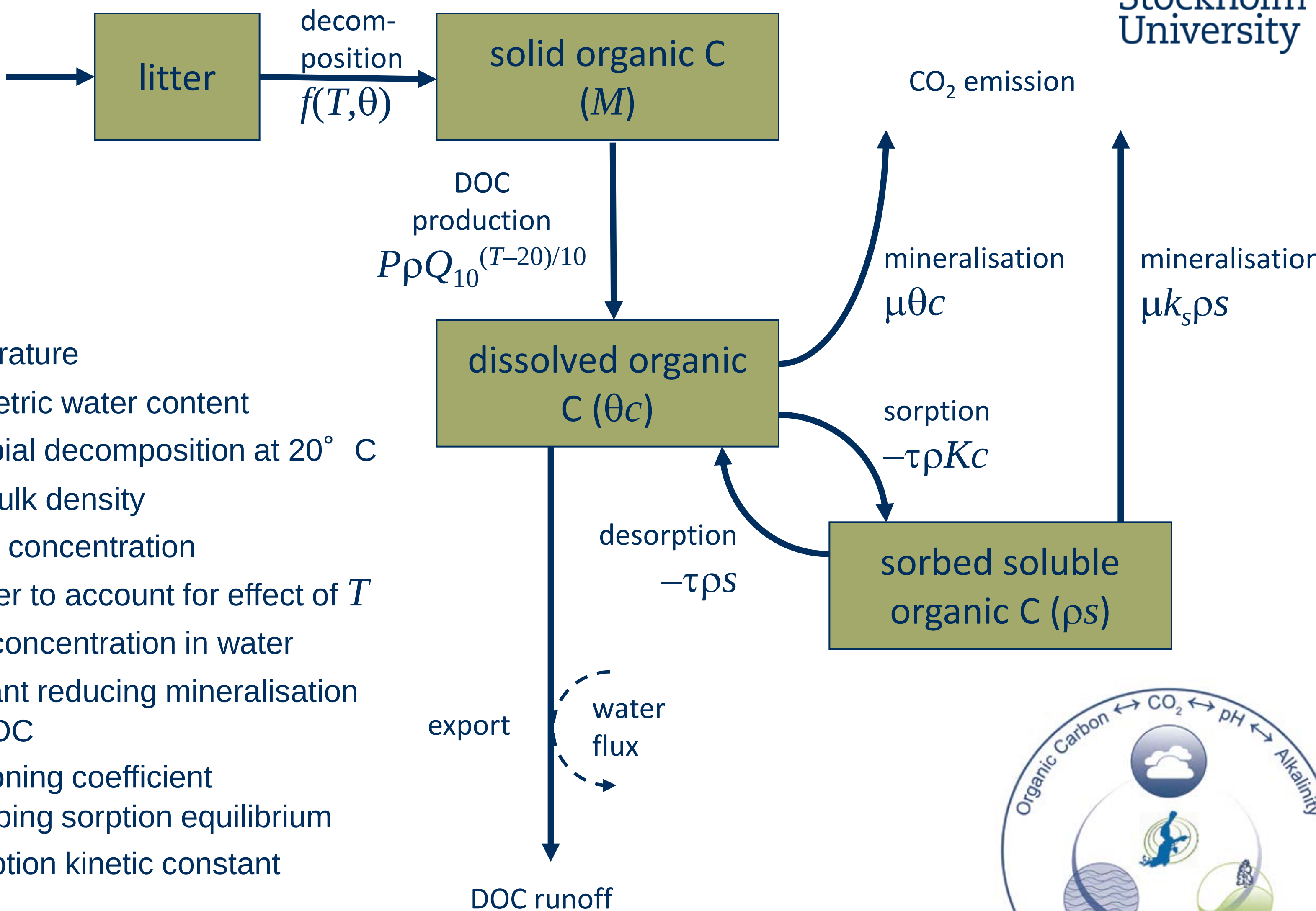
Water

Land cover of the Baltic Sea Basin



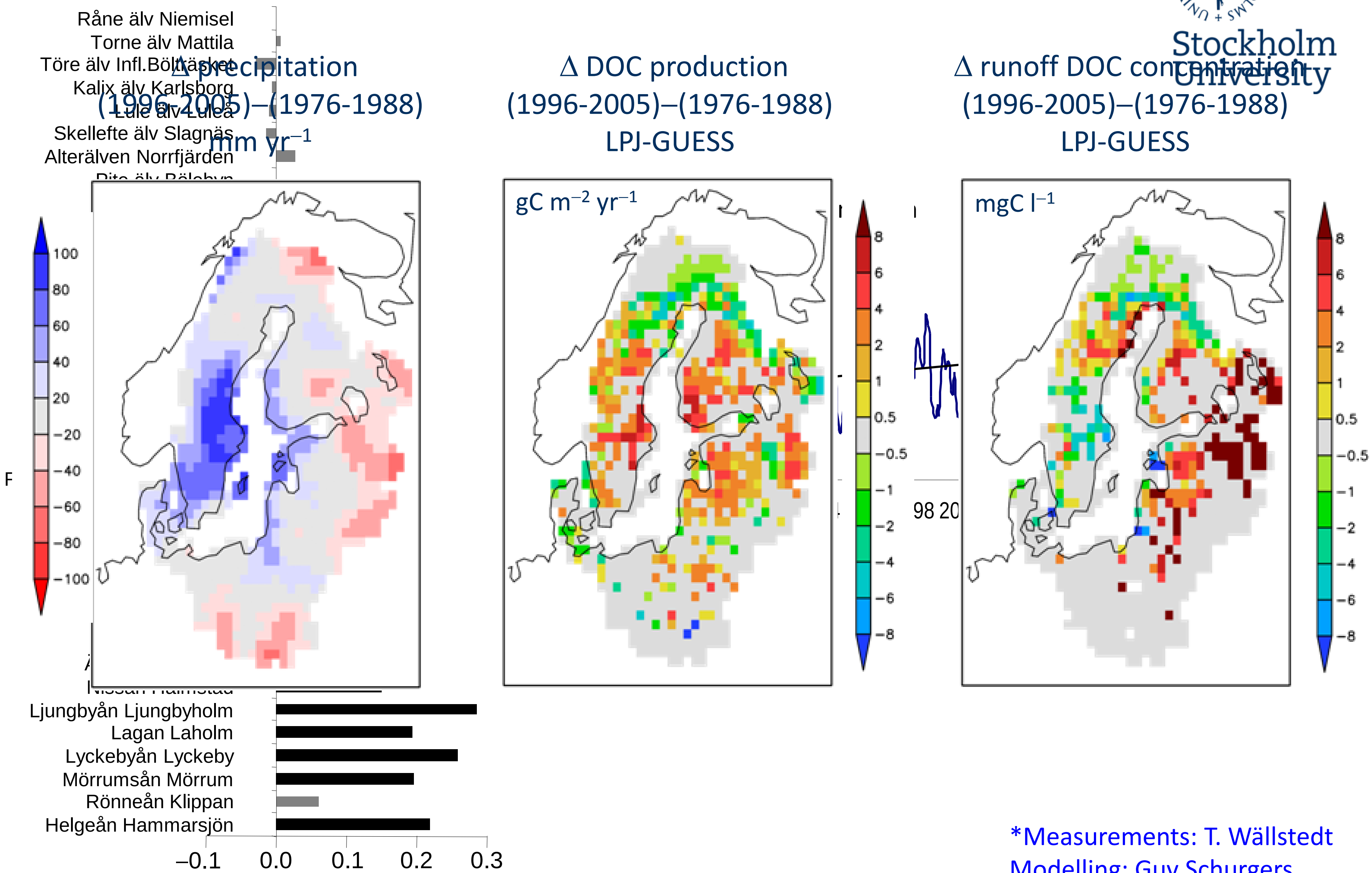
Improve DOC production:
Dissolved organic carbon (DOC) submodel*





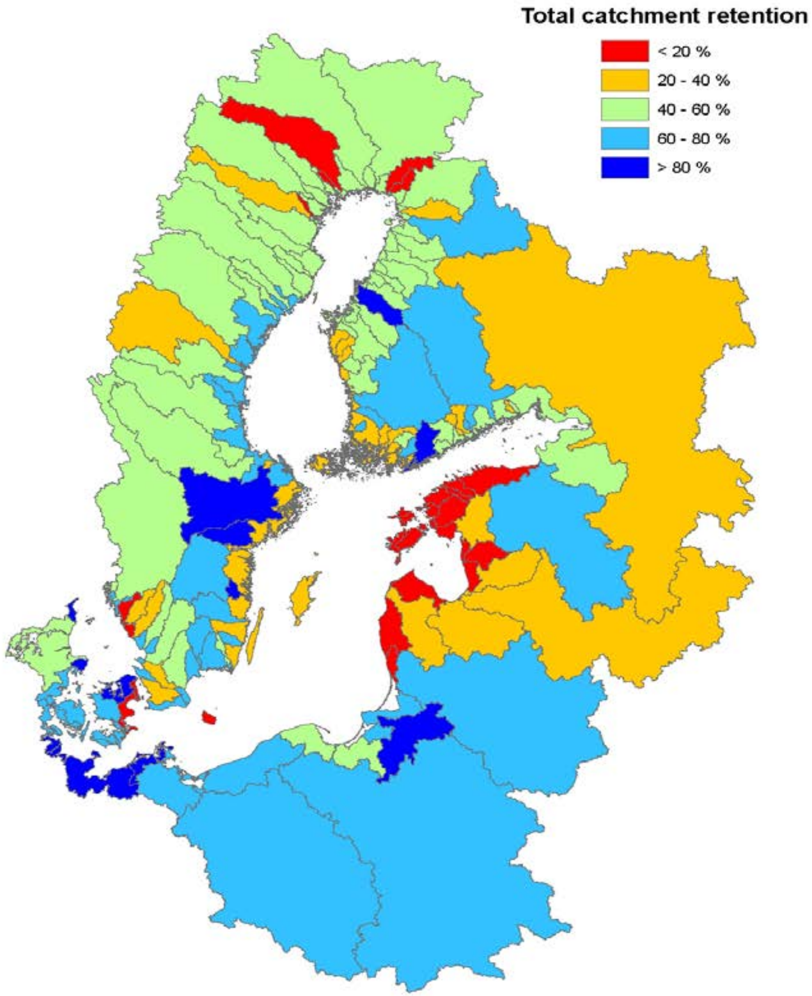
T	temperature
θ	volumetric water content
P	microbial decomposition at 20° C
ρ	peat bulk density
s	SSOC concentration
Q_{10}	modifier to account for effect of T
c	DOC concentration in water
k_s	constant reducing mineralisation of SSOC
K	partitioning coefficient describing sorption equilibrium
τ	desorption kinetic constant

Simulated versus observed DOC concentration trends*



TOC concentration trend (mgC l^{-1} yr^{-1})

*Measurements: T. Wällstedt
Modelling: Guy Schurgers
(wetlands only)



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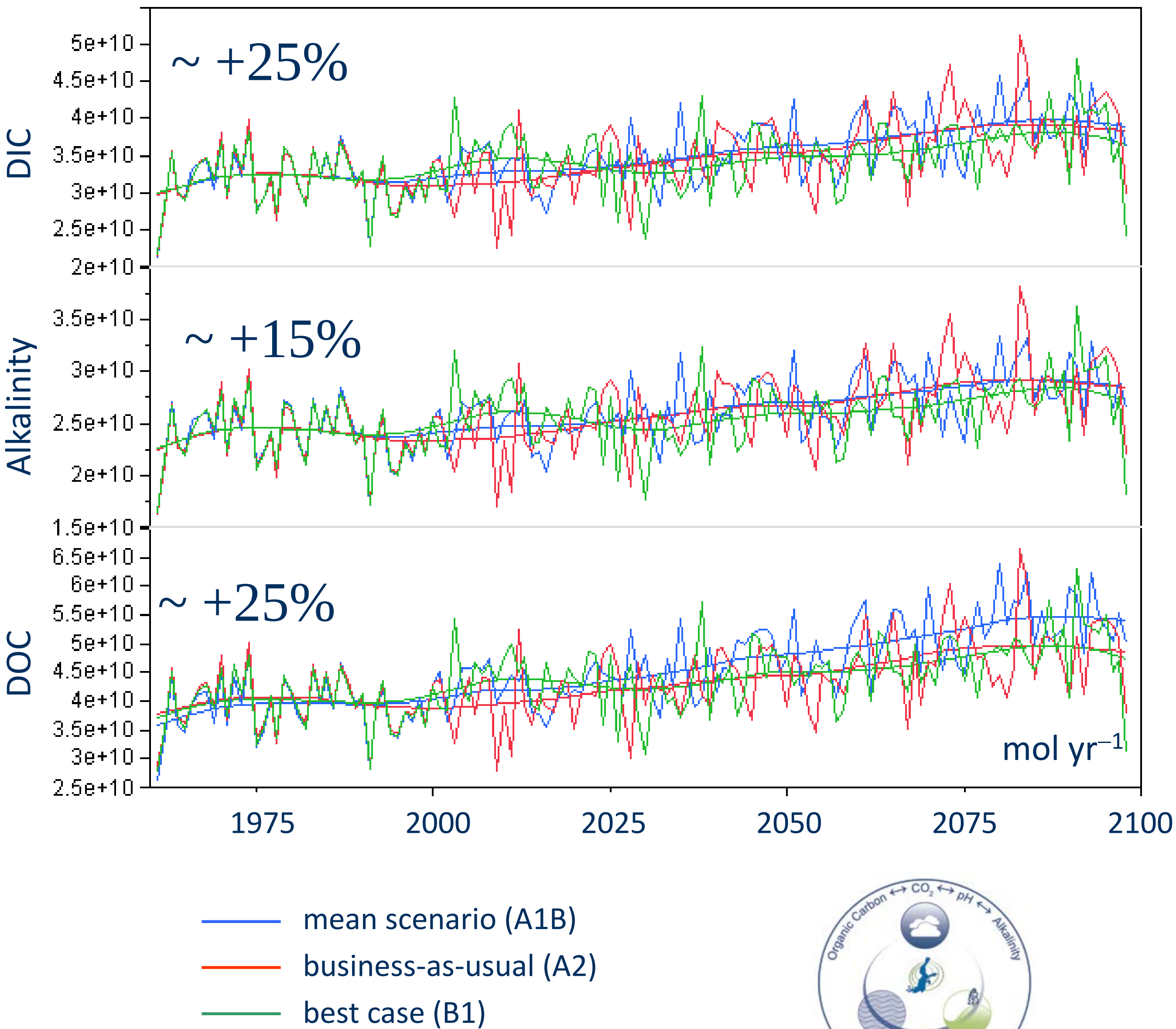
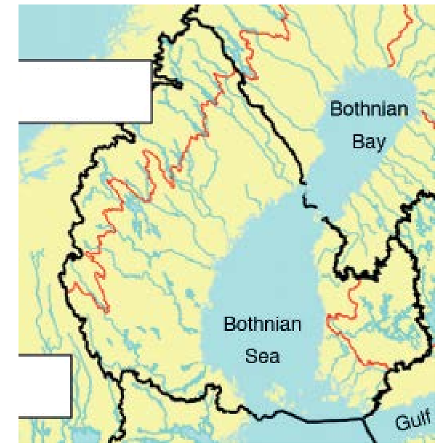
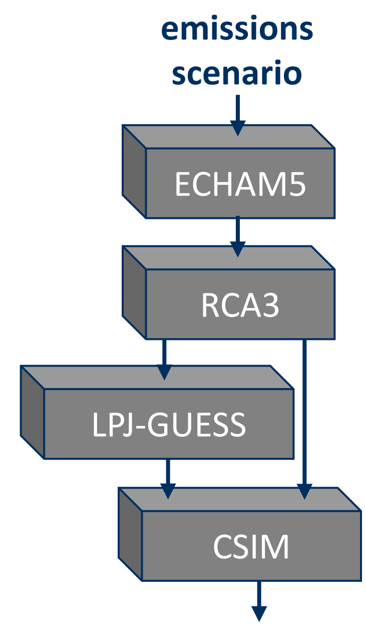
Total catchment N retention for 117 catchments draining to the Baltic Sea calculated by combining the results from the MESAW and DAISY models.

Future climate scenarios



Runoff to Bothnian Sea





Annual fluxes (Tg) of TC, DIC and DOC.
1996-2000 compared to 2090-2095

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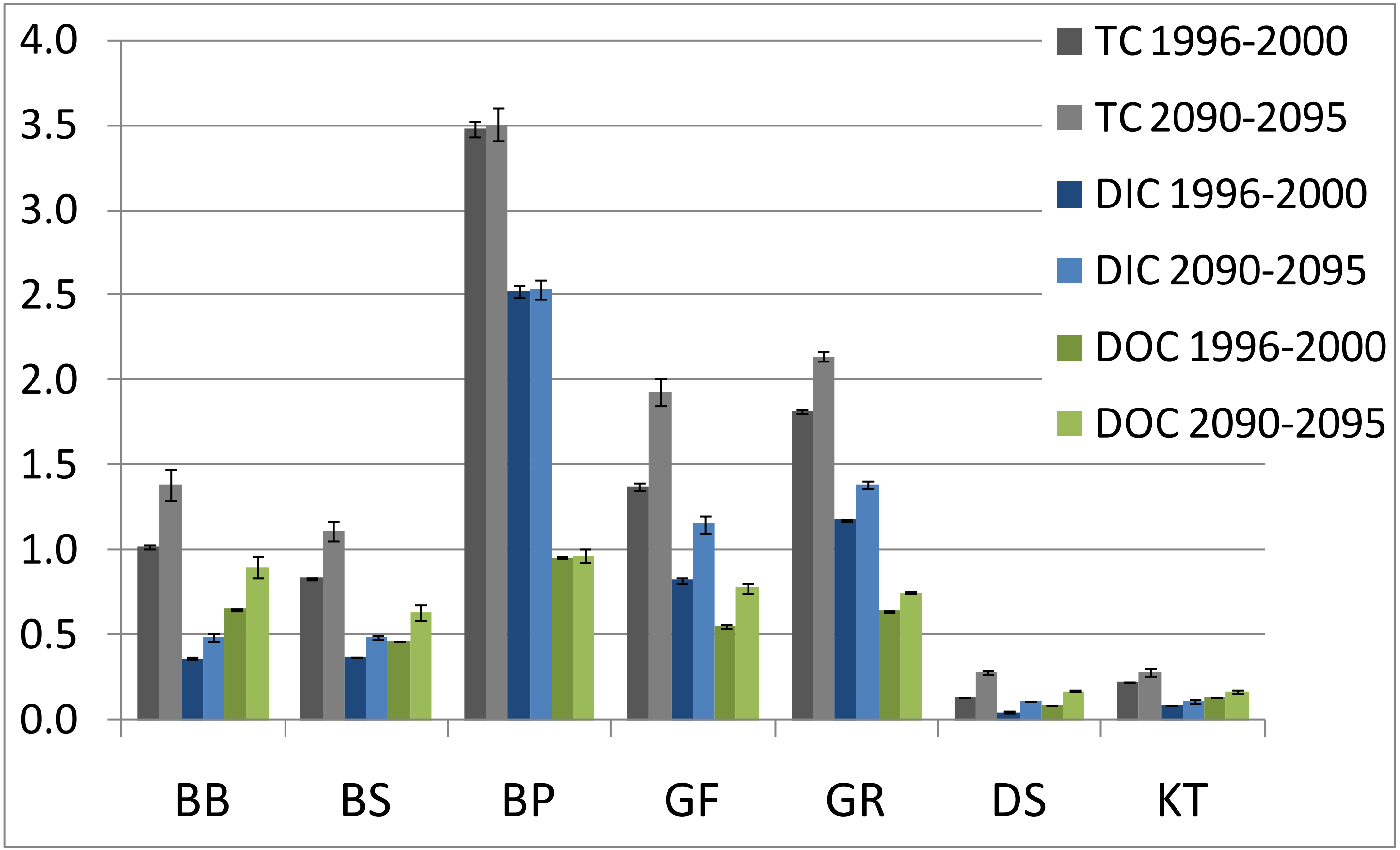

2) Challenge: Separate the terrestrial DOM from marine produced DOM

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Terrestrial source
(end member)
$\delta^{13}C$ = -28 ‰

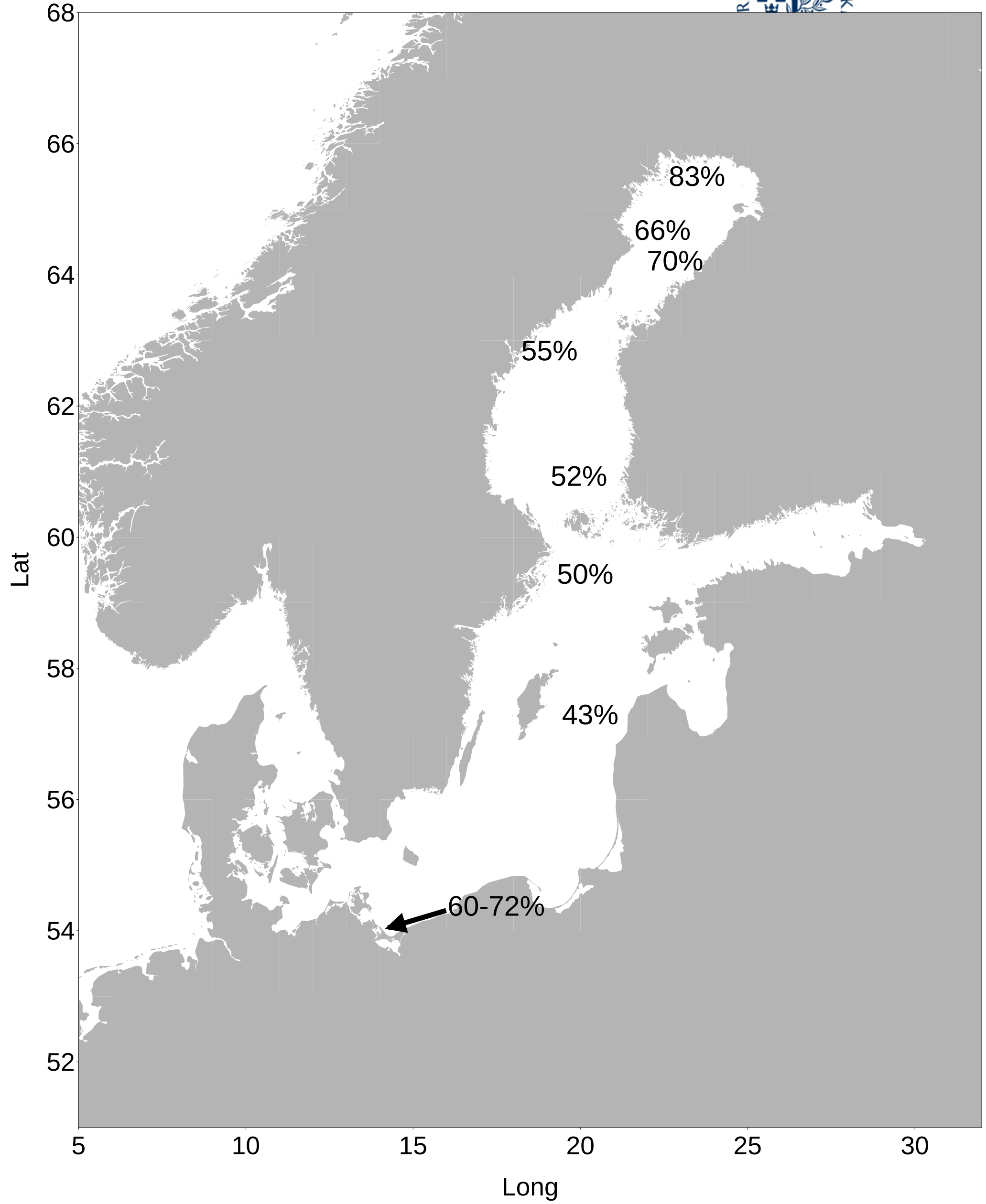
Marine source
(end member)
$\delta^{13}C$ = -21 ‰

$\delta^{13}C$ = -25 ‰ → 57 % terrestrial DOC 43 % marine

$\delta^{13}C$: (‰) -28 ... -21

Share of terrestrial DOC

Bothnian Bay:	70-83%
Bothnian Sea:	52-55%
Baltic Proper:	43-50%
Oder Bight:	60-72%



Hypotheses based on studies on DOC_{ter} inferred from isotope signatures

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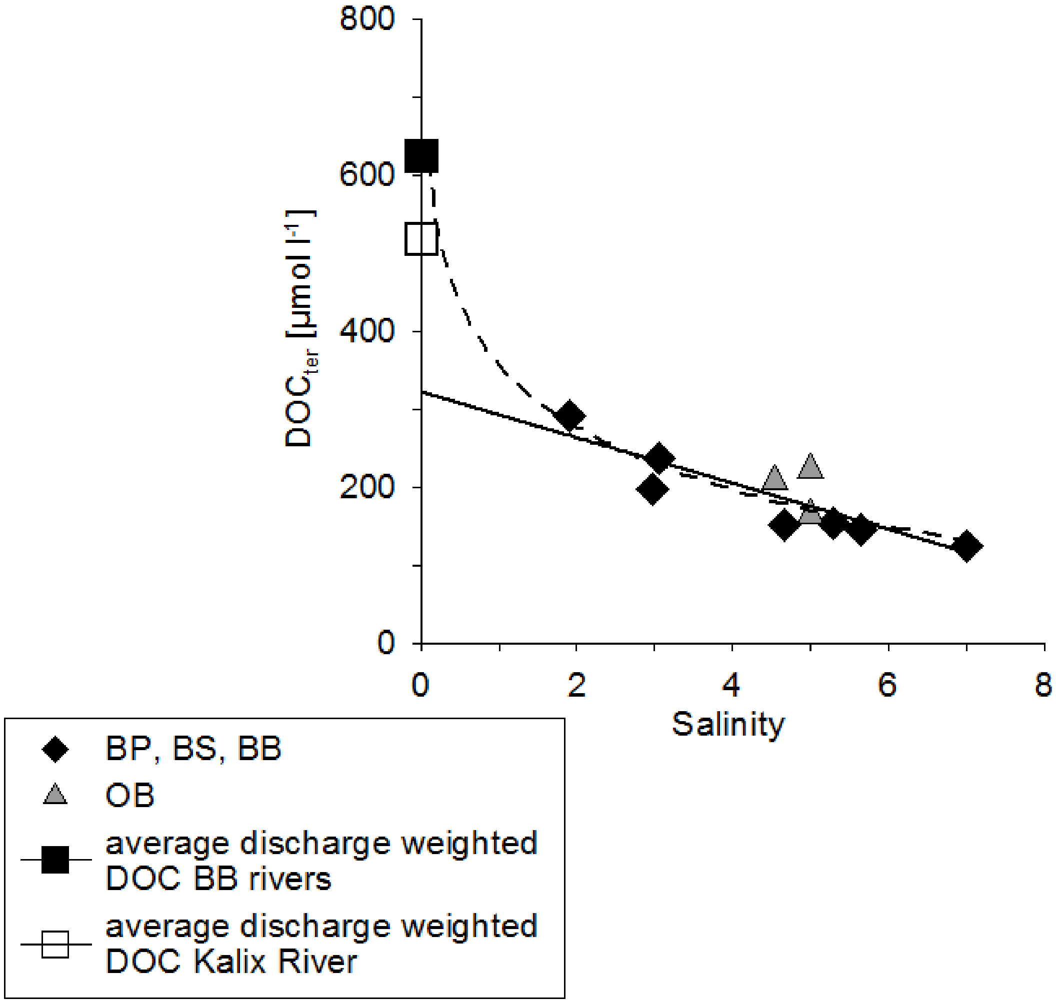
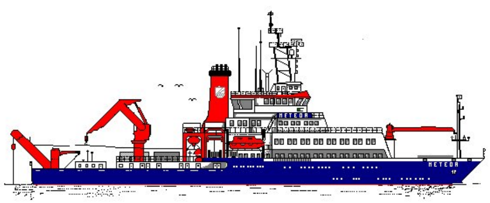
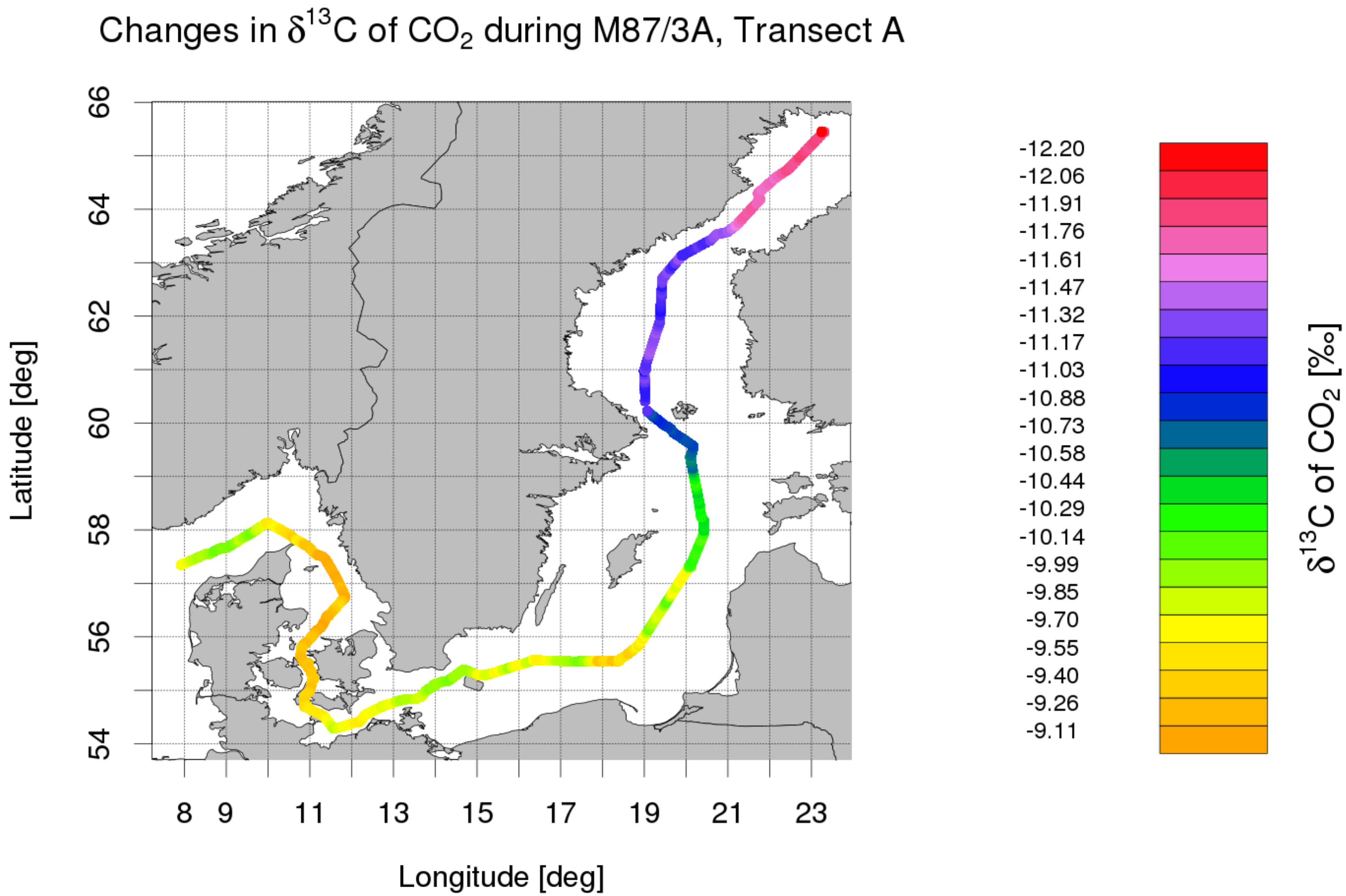
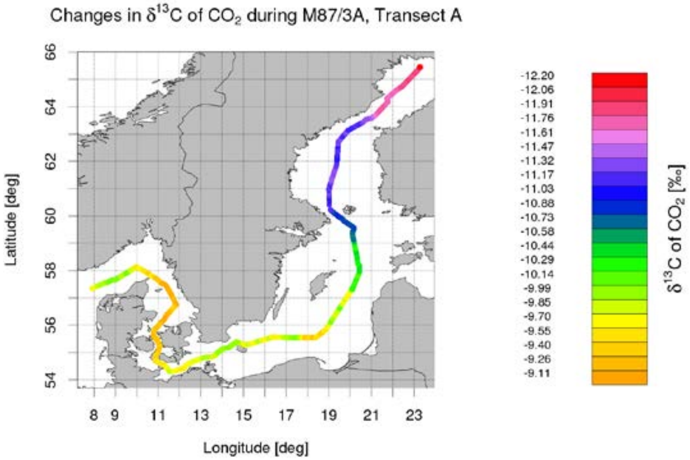


- At salinities >2 the DOC_{ter} distribution along the Baltic seems to be determined mainly by mixing.
- Most of the DOC_{ter} removal (~50%) seems to occur in the estuaries.

WEGAS on board the German research vessel METEOR 87 (May/June 2012)







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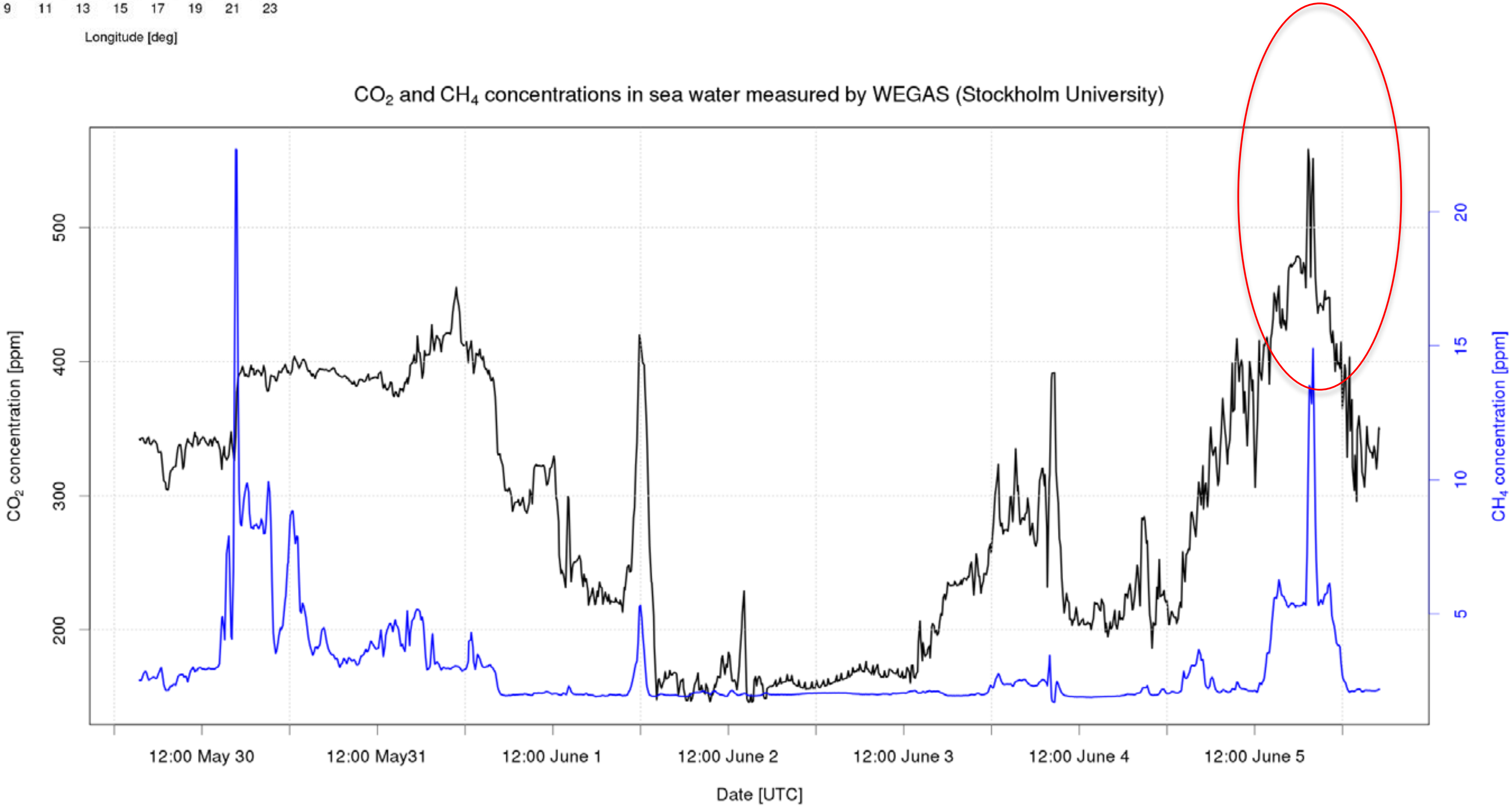

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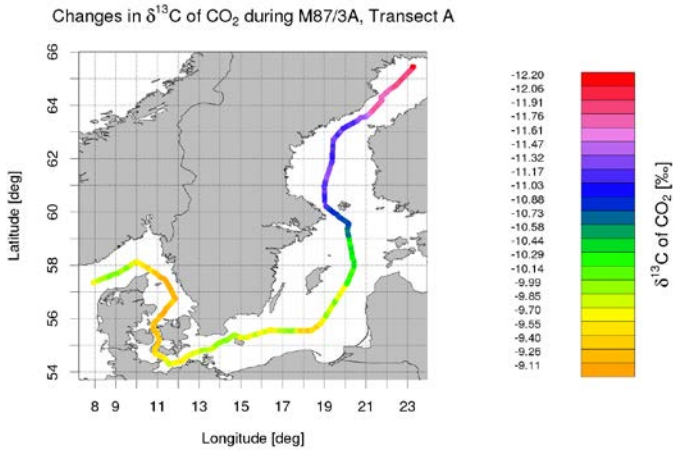
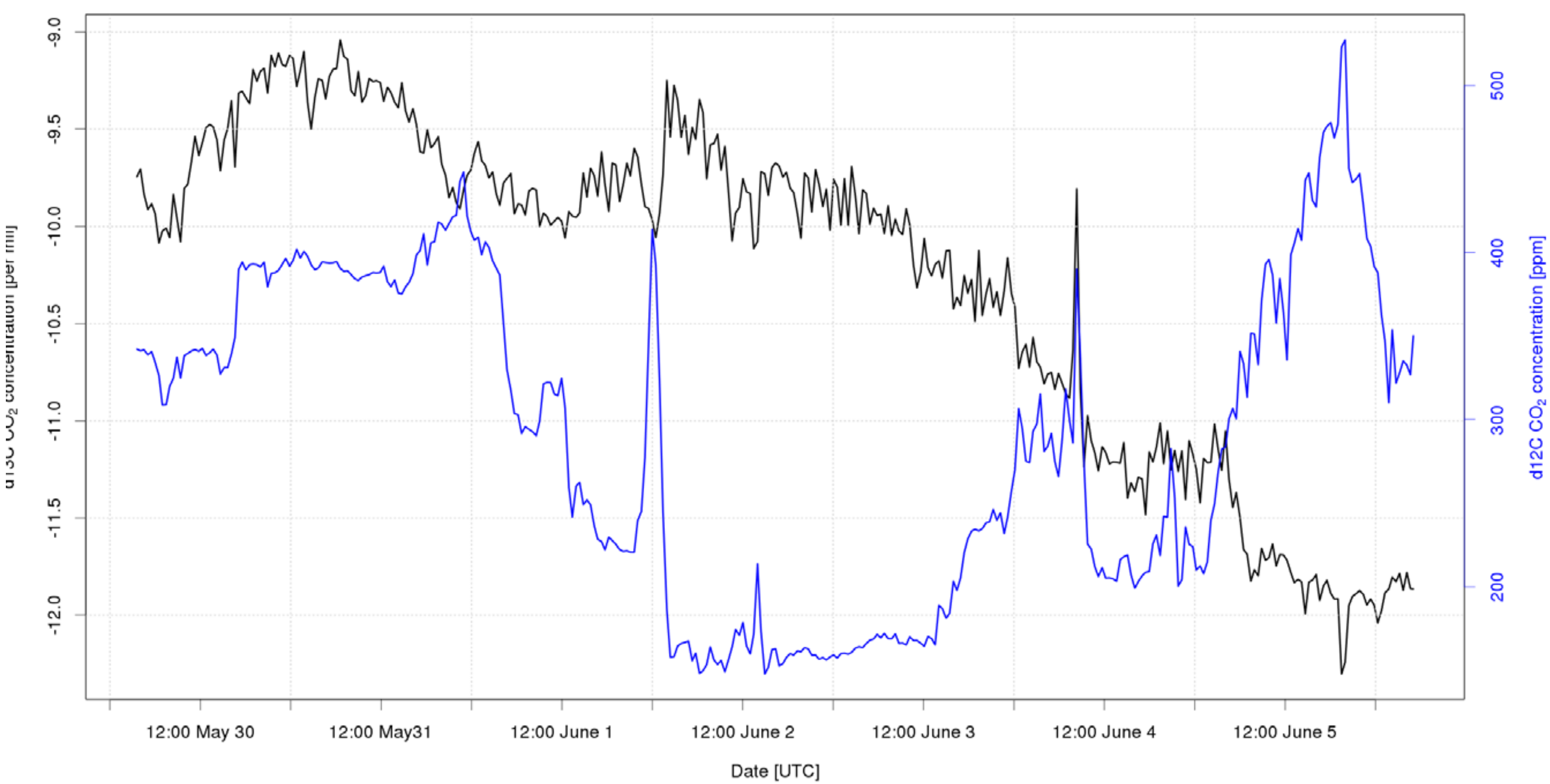
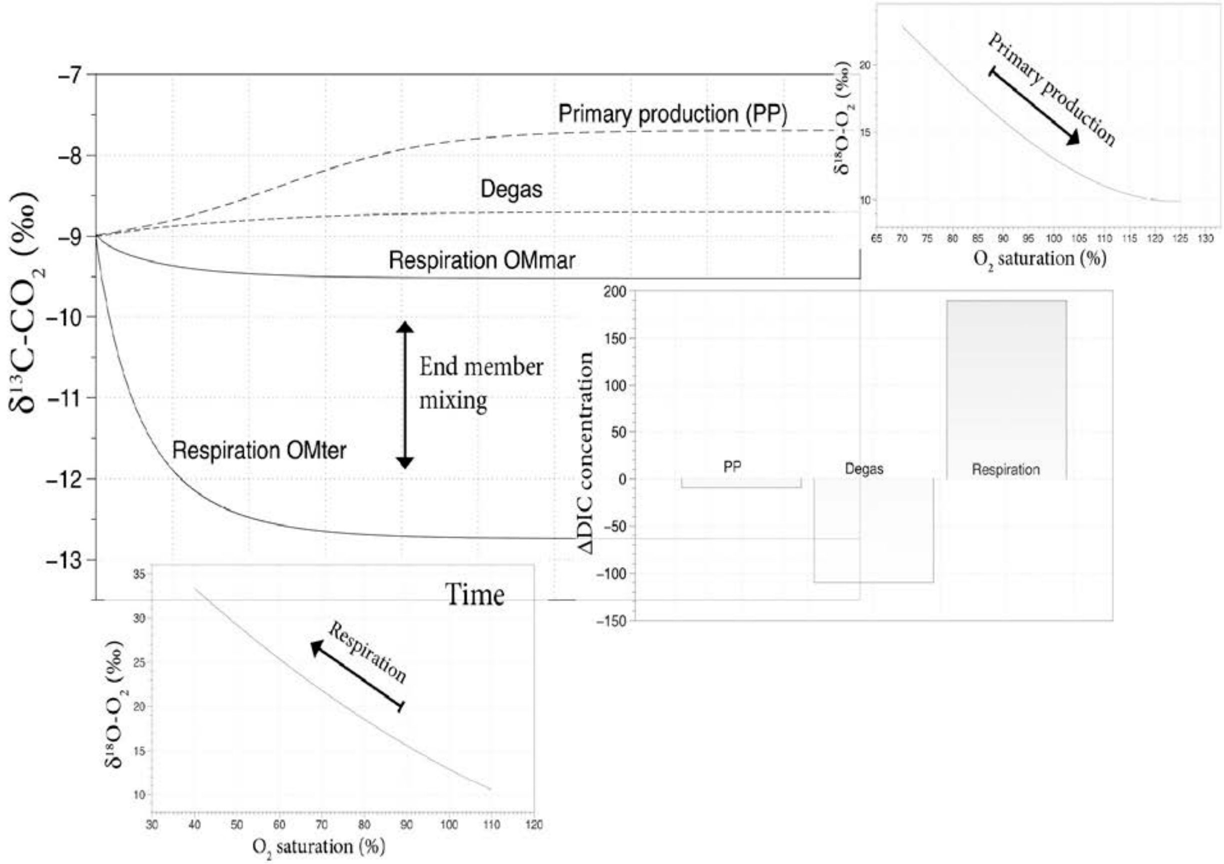


d13C CO_2 and d12C CO_2 concentrations in sea water measured by WEGAS (Stockholm University)



Conceptual model



Expected isotope patterns for **δ**13C in CO2 and **δ**18O-O2 dissolved in water as a result of the different processes that drive the fractionation of the isotopes in the different pools.

River input DOC/DIC

Salinity=0 PSU
Alk=0.21 mmol/L
DIC=0.25 mmol/L
DOC=0.5 mmol/L
PCO2=800 ppm

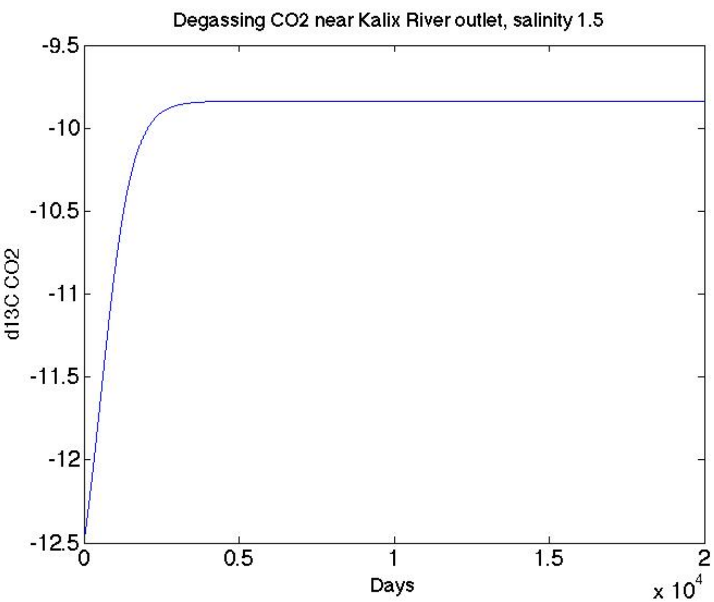
Needed respiration to maintain isotope value is ≈32 mmol m^{-2} per day

CO_2≈-12.5‰

Respiration ≈-27‰

Production, isotope fractionation -13‰

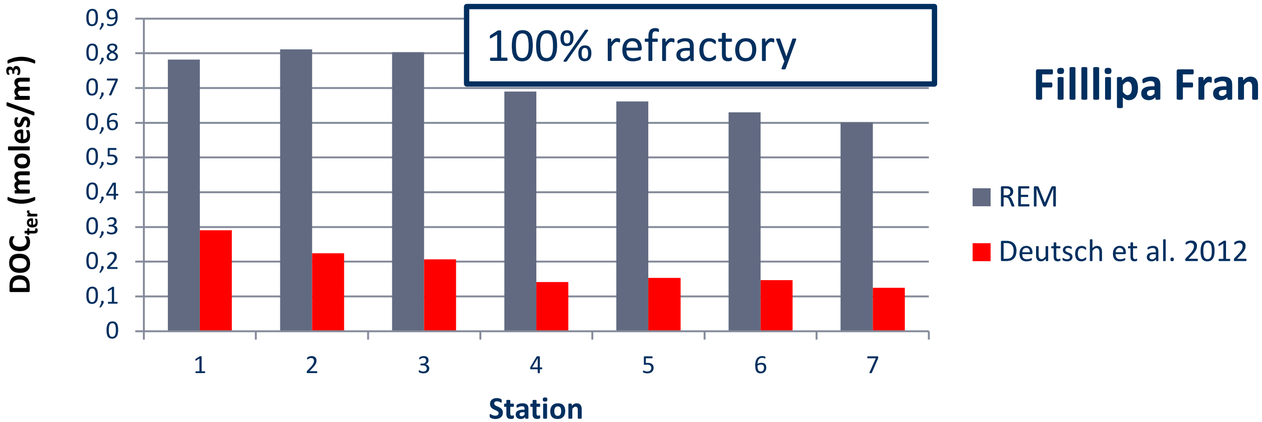
Salinity=1.5 PSU
Alk=0.62 mmol/L
DIC=0.65 mmol/L
DOC=0.4 mmol/L
PCO_2=630 ppm

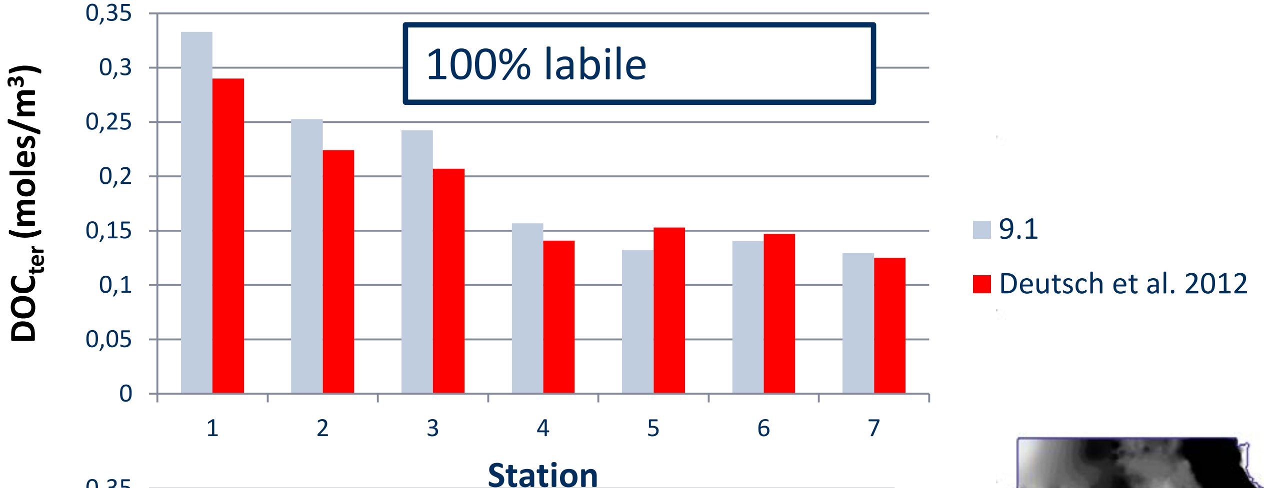


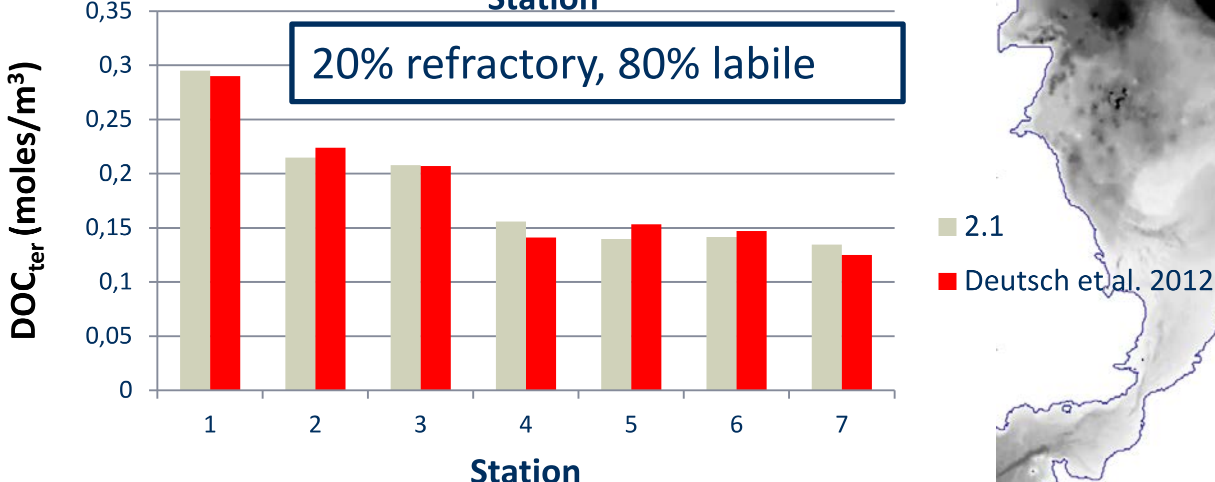
CO2sys gives air sea flux of ≈ 20 mmol m^{-2} degassing per day.

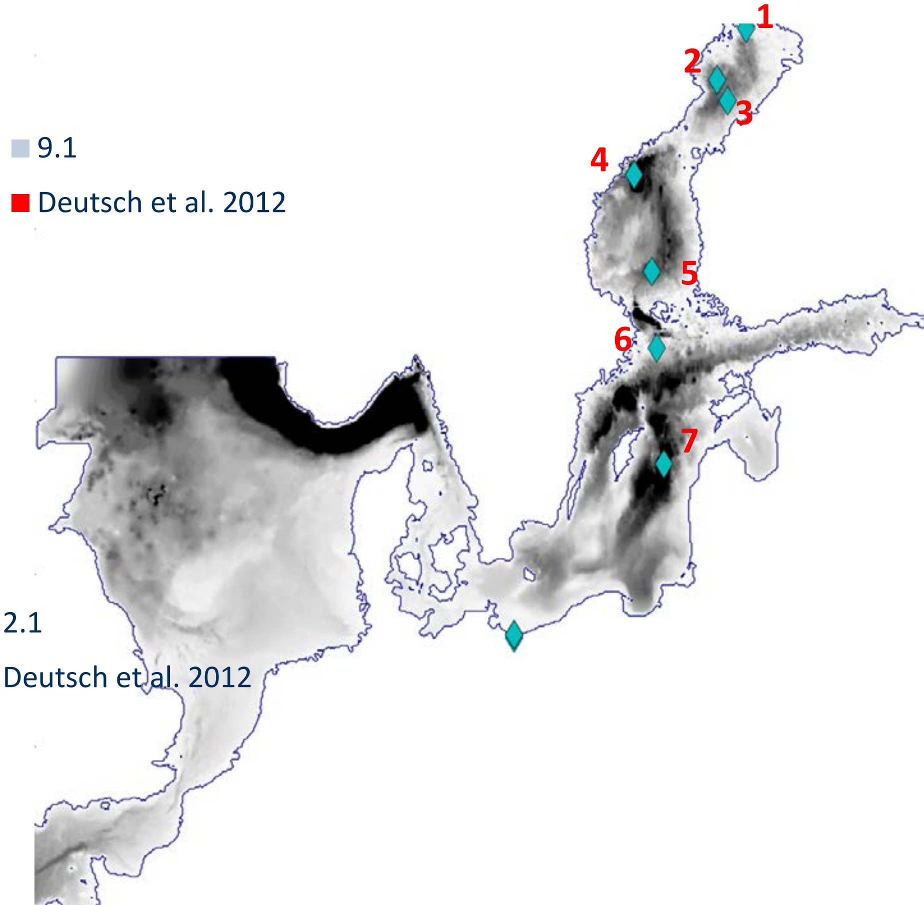
Filllipa Franser, MISU

Stockholm University

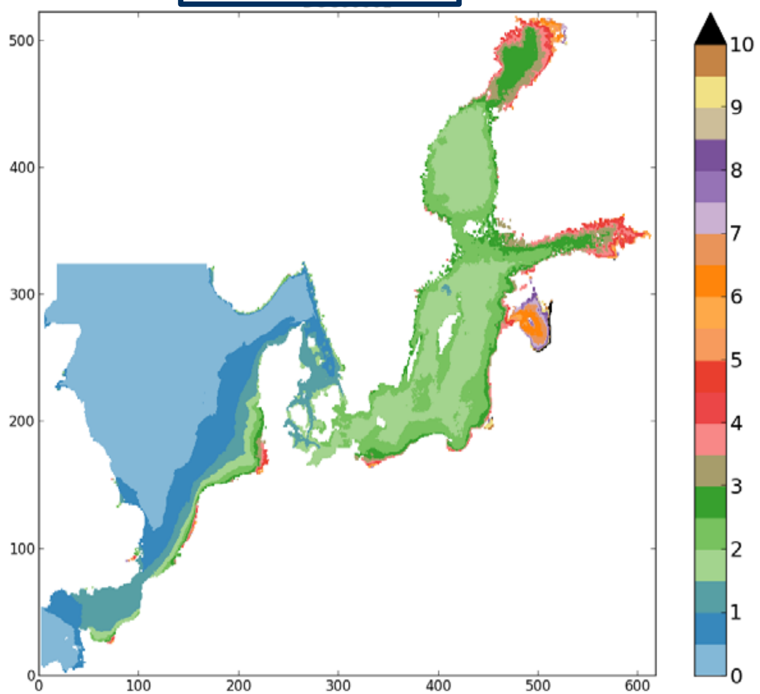




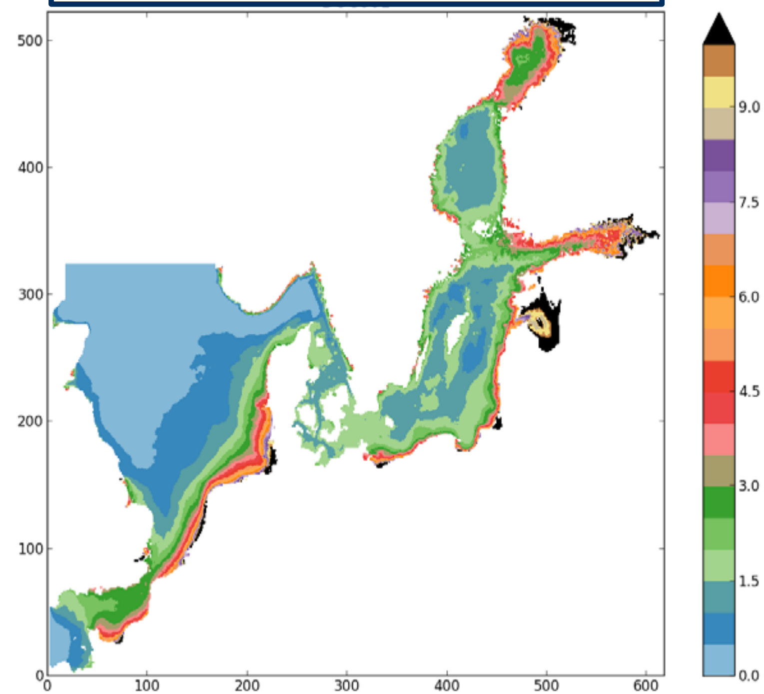




100% labile



20% refractory, 80% labile



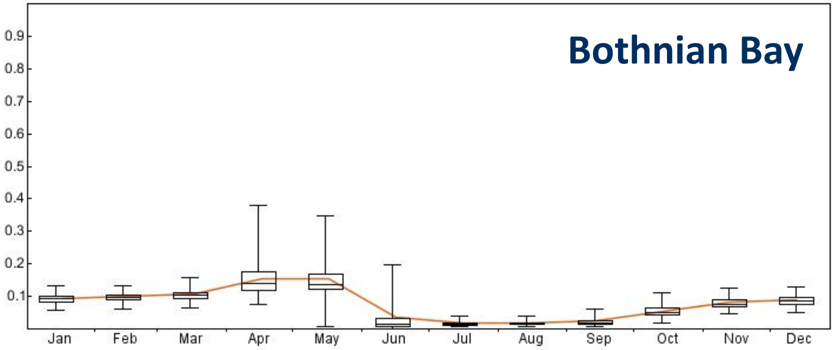
Mean (water column) removal rate in tons/year

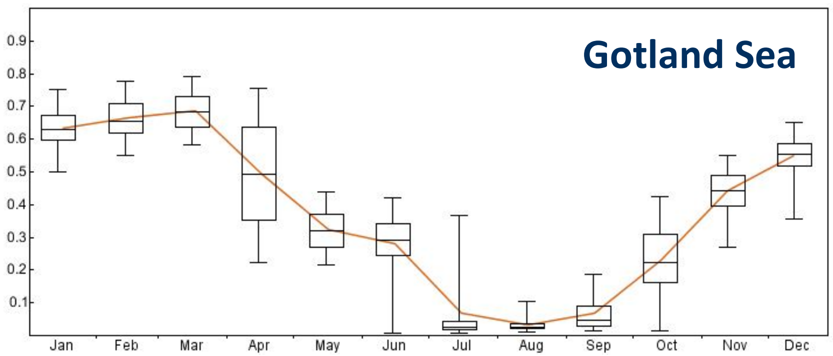
Meridional gradients of seasonal dynamics

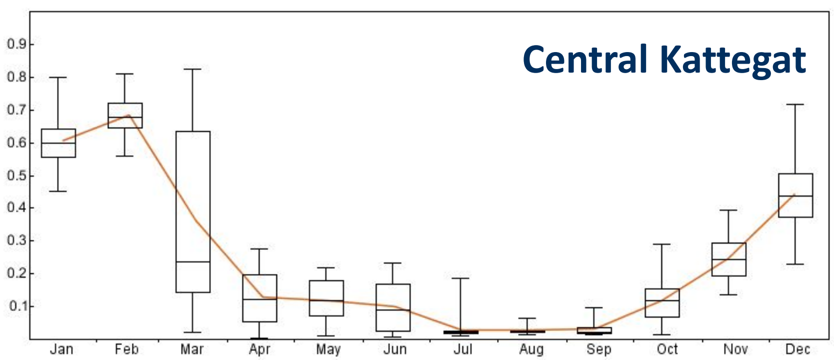
(statistics for 1970-2006)

Stockholm University

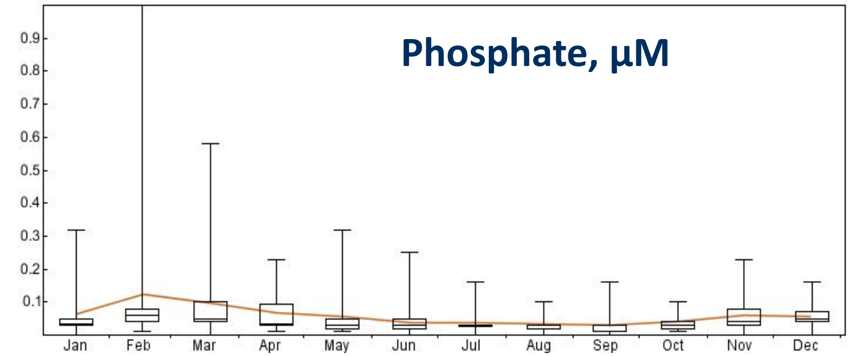
Simulation

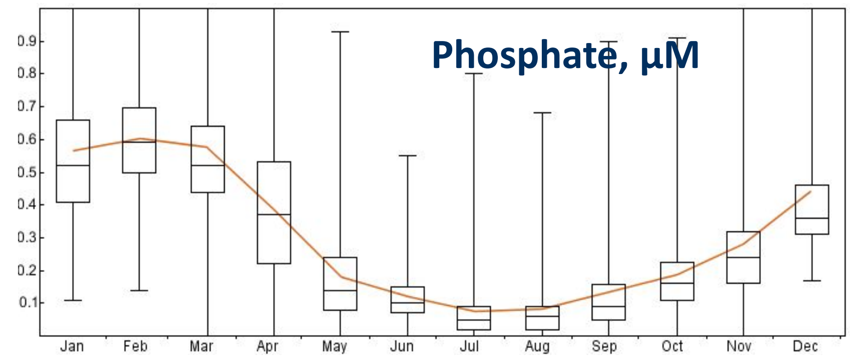


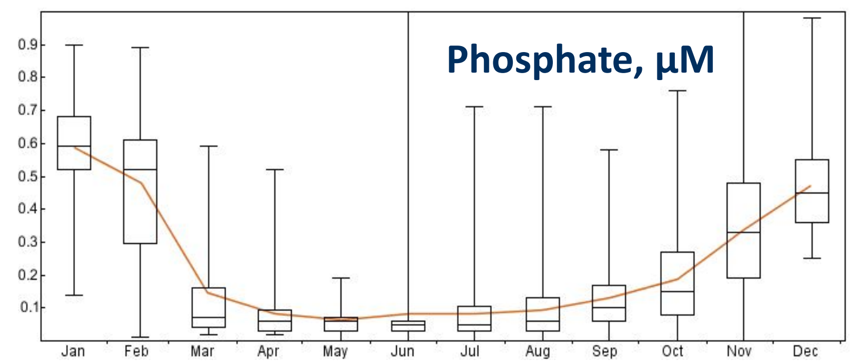




Observations





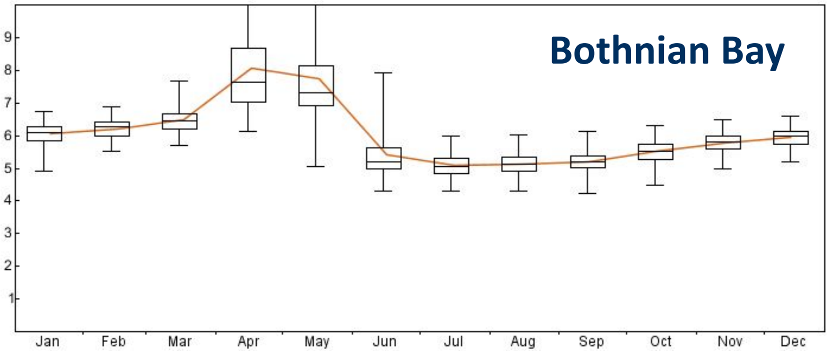


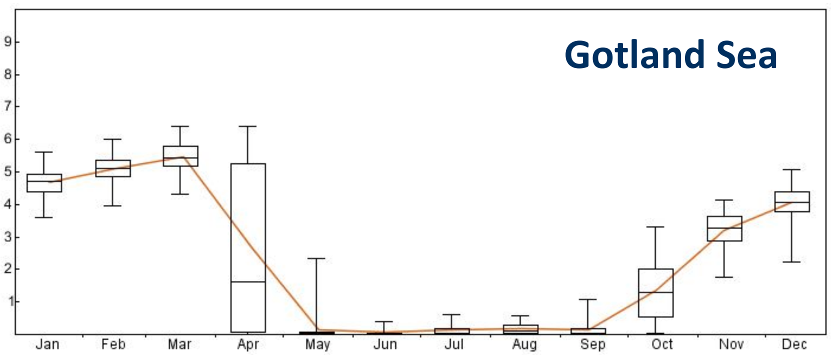
Meridional gradients of seasonal dynamics

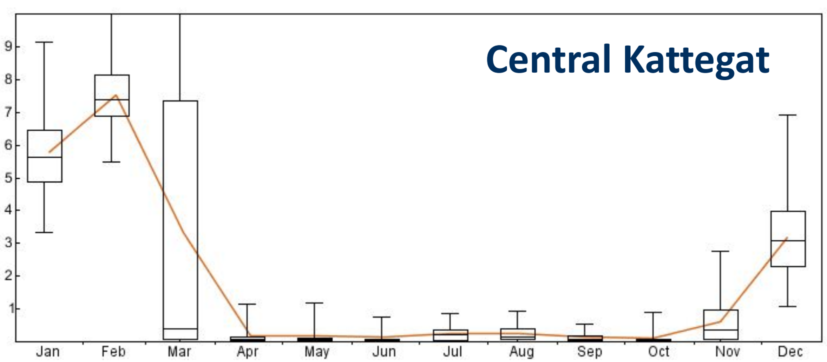
(statistics for 1970-2006)

Stockholm University

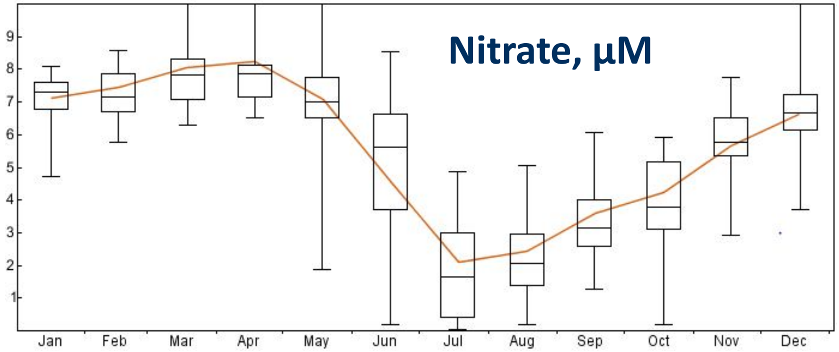
Simulation

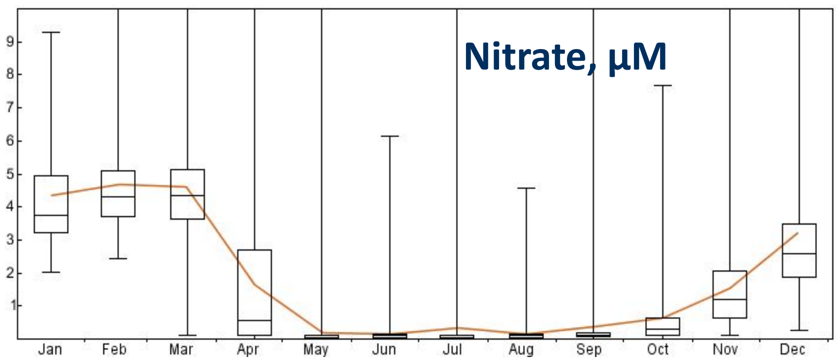


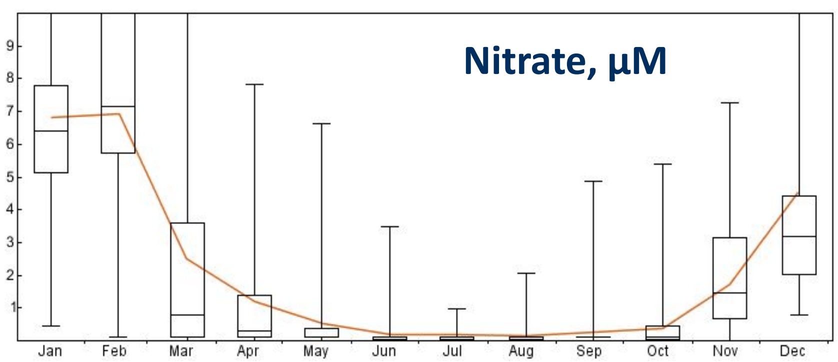




Observations







Simulated vs. observed primary production

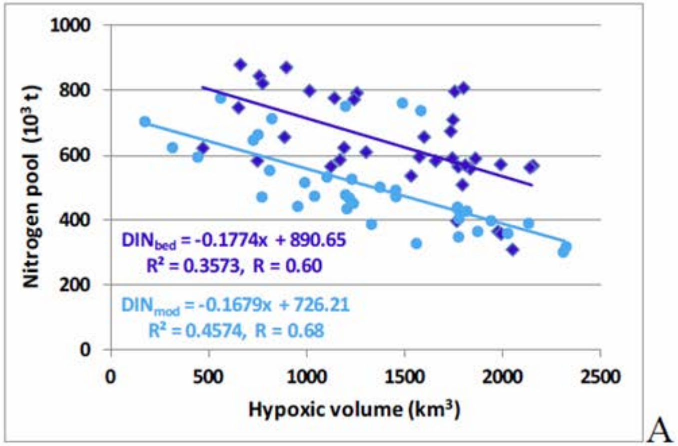
(the simulated are systematically lower)

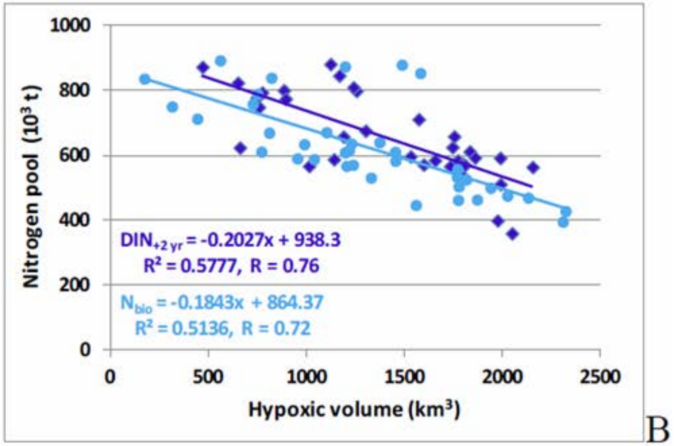
	BB	BS	BP[a]
Annual integrals (g C m^{-2} yr^{-1}) simulated over two periods (mean ± s.d.) vs. literature data			
1970/82	**4.7 ± 0.8**	**18 ± 3**	**52 ± 10**
Data	**12-20**[i]	**50-70**[i]	**40-140**[d]
1994/06	**4.6 ± 0.6**	**23 ± 3**	**98 ± 16**
Data	**16**[j] **– 17**[i]	**32**[j] **– 52**[i]	**65**[j] **– 200**[i]

Table 2 Primary production in the major Baltic Sea basins, simulated with BALTSEM and compiled from published estimates for different time intervals

[a] – aggregation weighted with basin areas; [b] – month of blooming in the model; [c] – Dahlgren *et al.*, 2010; [d] – Renk and Ochocki, 1999; [e] –Lignell, 1990; [f] – Silina, 1967; [g] – Savchuk, 2002 and references therein; [h] – Rydberg *et al.*, 2006; [i]- Wasmund *et al.*, 2001a and references therein; [j] – median value from Larsson *et al.*, 2010; [k] – Raateoja *et al.*, 2004; [l] - Carstensen *et al.*, 2003

Generally, both ERGOM and SCOBI give even lower simulated rates of PP!





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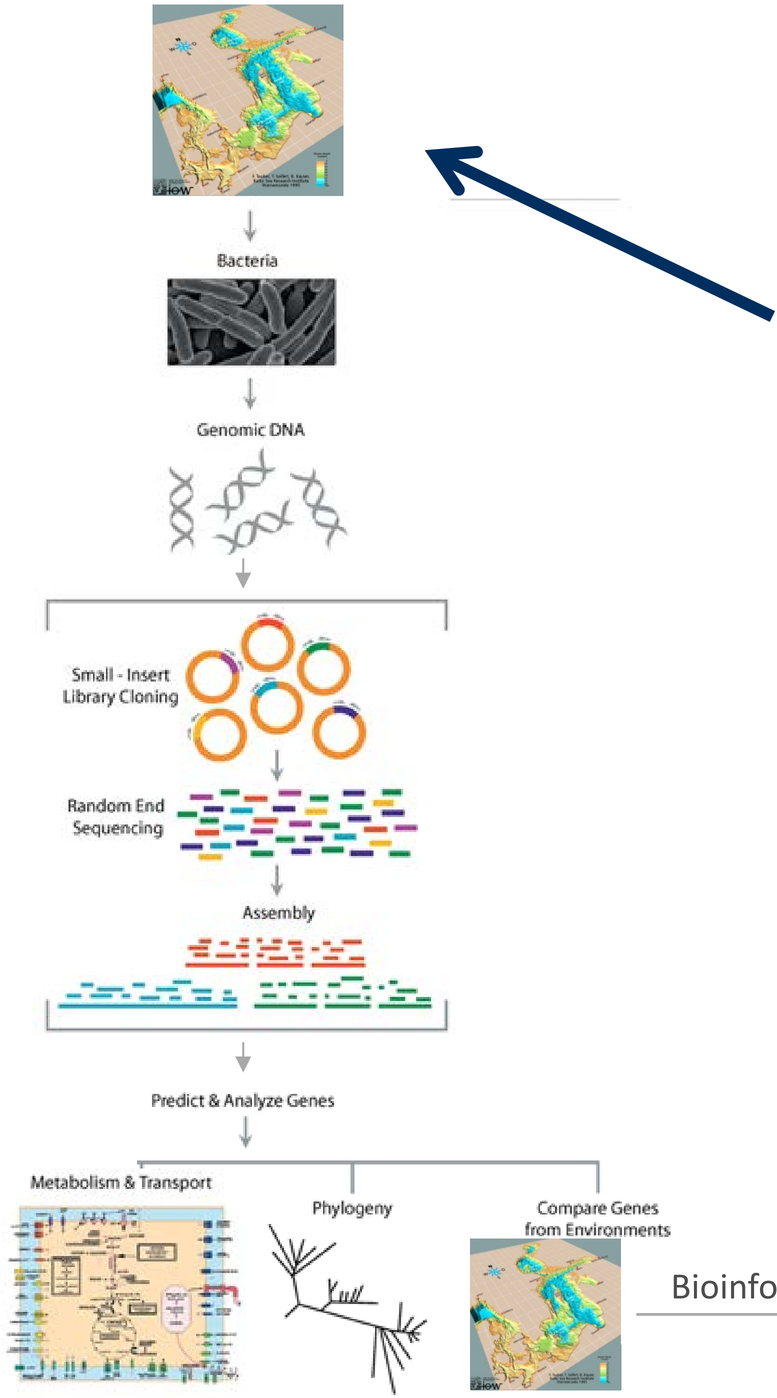
Hypoxia effects on nitrogen pool in the Baltic Proper. Relationships between annual means of simulated and reconstructed from observations hypoxic volume and DIN pool (A) or reconstructed DIN pool with a 2 year delay and simulated bioavailable nitrogen (B)

Dalsgaard et al. GCA 2013: "When extrapolated to the entire Baltic Proper (BP) denitrification in the water column was in the range of 132–547 kton N yr1 and was thus at least as important as sediment denitrification which has recently been estimated to 191 kton N yr1."

BONUS call 2012: Viable ecosystem
Project: Biological lenses using gene prints
(BLUEPRINT)

Stockholm University

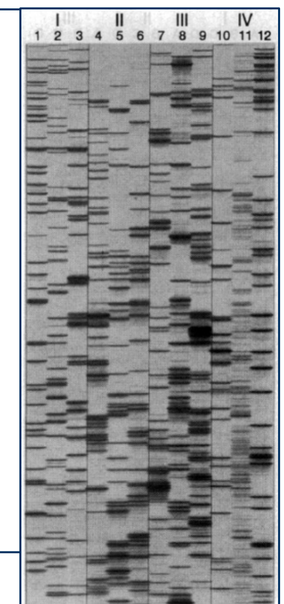


Modified from: Matthew Vaughn

Aim: Indicator development based on the generation of high-resolution functional databases throughout the Baltic Sea based on metagenomics.

Outcome: A publicly available resource with the capacity to deduce environmental status and dominant biogeochemical pathways from the biodiversity and genetic functional profiles of microbes, the blueprint, in a seawater sample.

Bioinformatic evaluation



Chial, H. (2008)

Indicative blueprints

WP5: Incorporation of BLUEPRINT in biogeochemical modeling

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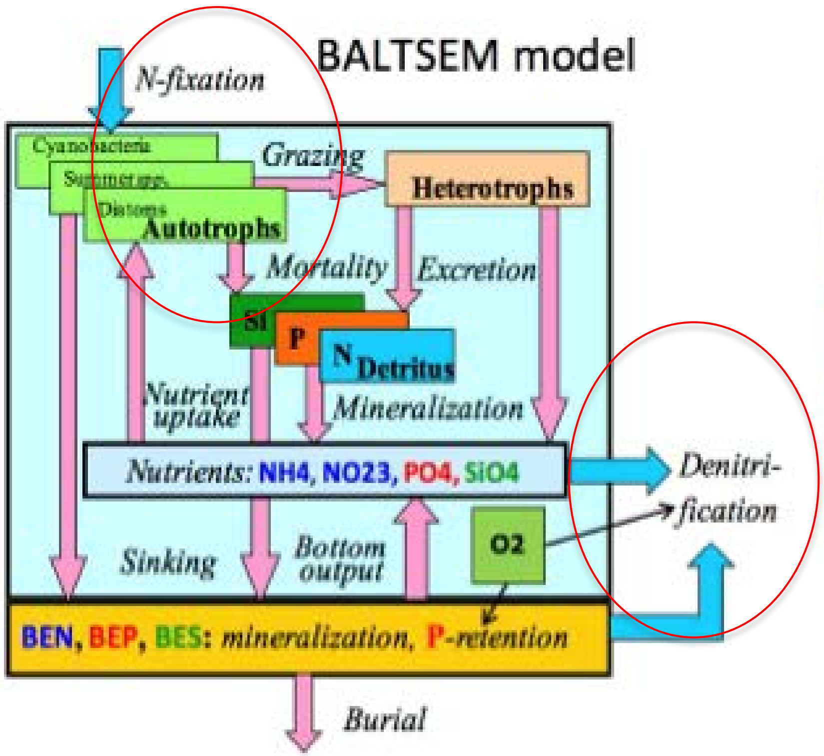
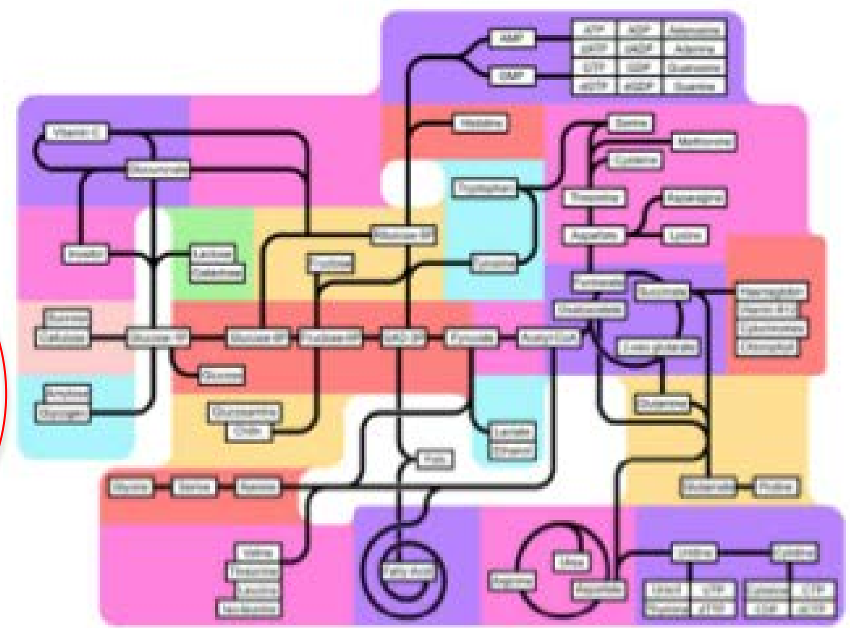
BALTSEM model



Metabolic chart



Outlook

Develop more realistic catchment (hydrological and land surface) models -> DOM and nutrient retention are the big unknowns!

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Coastal degradation processes appear significant-> how much reaches the open Baltic?

To develop a general model to quantitatively link CO_2 and CH_4 fluxes from aquatic ecosystems to primary productivity, degradation and outgassing using new isotope techniques –>how much of the terrestrial respiration actually occurs in the sea?

Shed light on DOM dynamics in the Baltic Sea-> how it contributes to nutrient dynamics and PP?

DOM dynamics along the estuarine gradient in the Baltic play a similar important role as dissolved nutrient dymanamics but is poorly parameterized in the models -> new microbiological tools needed?