Bernd Schneider, Annekatrin Löffler, Bernd Sadkowiak, Hildegard Kubsch

Deliverables Workpackage 2

D5	Seasonally resolved pCO_2 fields for the entire Baltic Sea	2	12 ←
D6	Seasonally resolved pCO_2 fields for the entire Baltic Sea: Updates	2	24
D7	Improved process parametrizations (biomass production, nitrogen fixation)	2	12 ←
D8	CO_2 gas exchange balance	2	24
D9	Concentrations of inorganic/organic carbon species in the major model sub-basins	2	12 ←
D10	Compilation of existing CO_2/carbon data	2	6 ←
D11	Trend analysis for CO_2/carbon variables	2	12 ←




D10 (month 6), Compilation of existing CO_2/carbon data:

C_T, nutrients, O_2/H_2S, T, S at BY15

March 2003 – October 2007, 4 – 5 times per year

(CT-BY15.XLS, submitted)

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D5 (month 12): Seasonally resolved pCO_2 fields for the entire Baltic Sea

1.) Mecklenburg Bight – Western Gulf of Finland:

June 2003 – September 2006 (FINNPARTNER)

since January 2008 (FINNMAID)

2.) Belt Sea/Kattegat: June/July 2008 and August/September 2009 (MERIAN)

3.) Gulf of Finland: November 1999, March 2000 (ARANDA) and June/July 2008 (MERIAN)

4.) Gulf of Riga: March 2000 (ARANDA)

5.) Gulf of Bothnia:

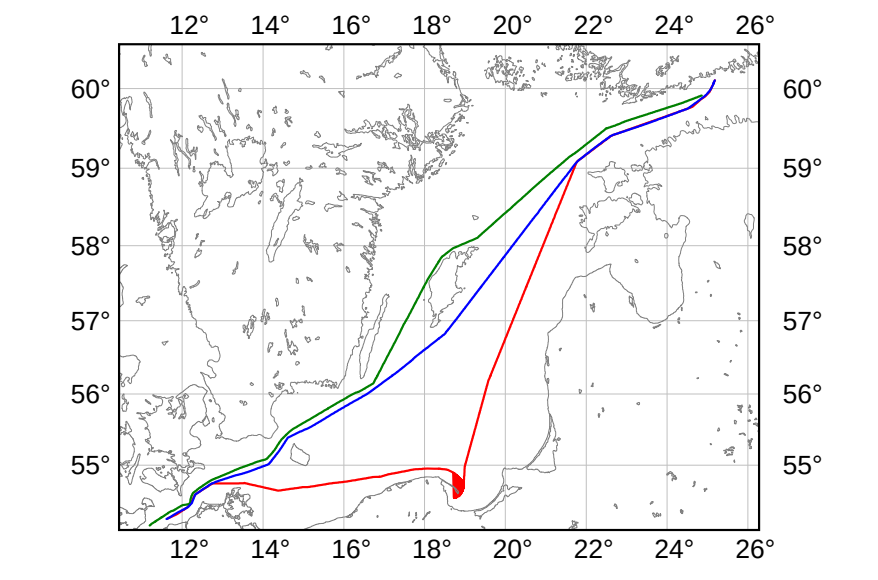
November 1999 (ARANDA)

March 2000 (ARANDA)

March 2006 (MERIAN)

June 2008 (MERIAN)

September 2009 (MERIAN)



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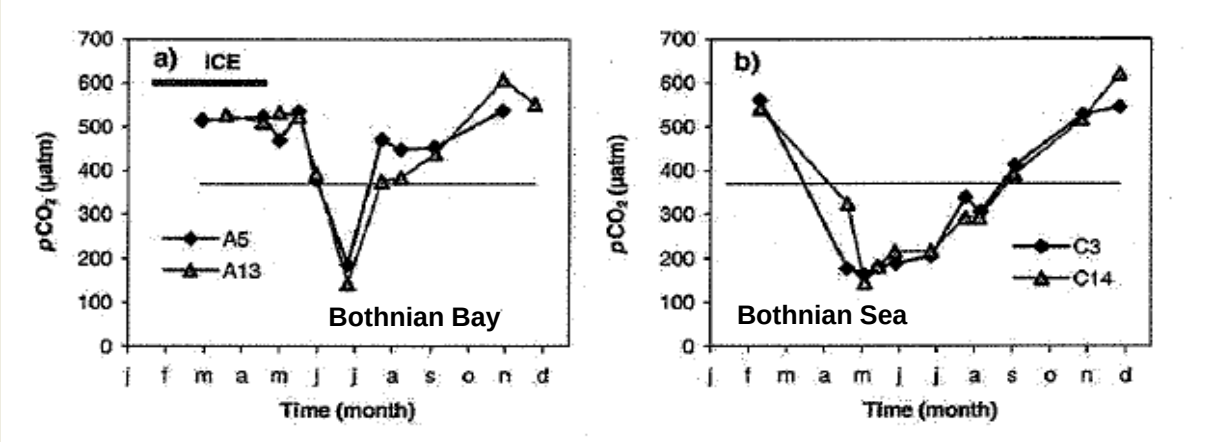
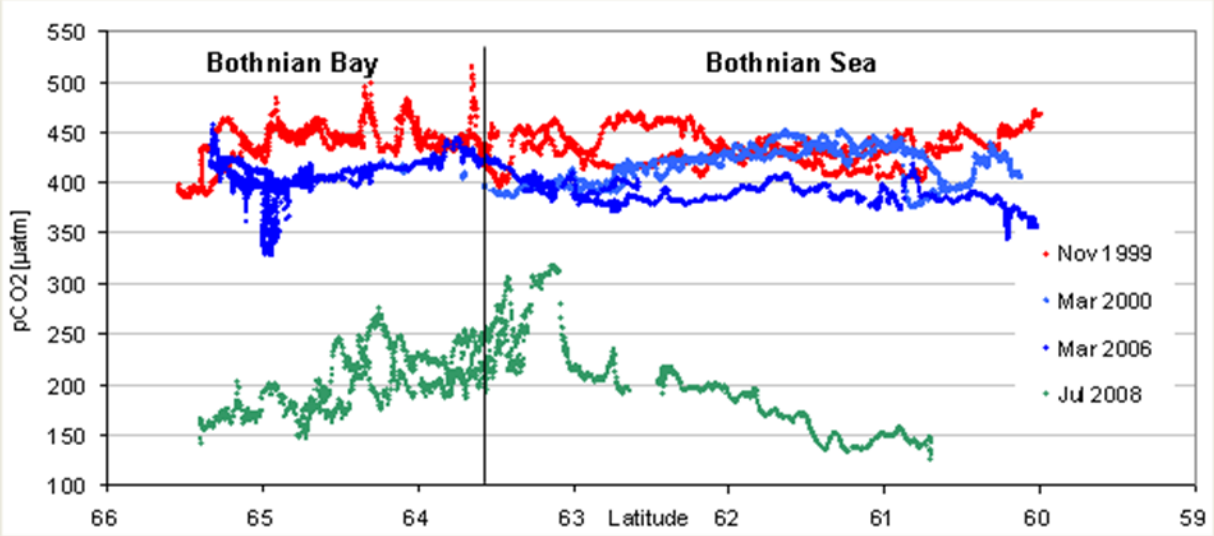
Gulf of Bothnia – a source for CO_2 to the atmosphere?

G. Algesten (2004):



ARANDA-
and MERIAN-Data
(1999-2008):



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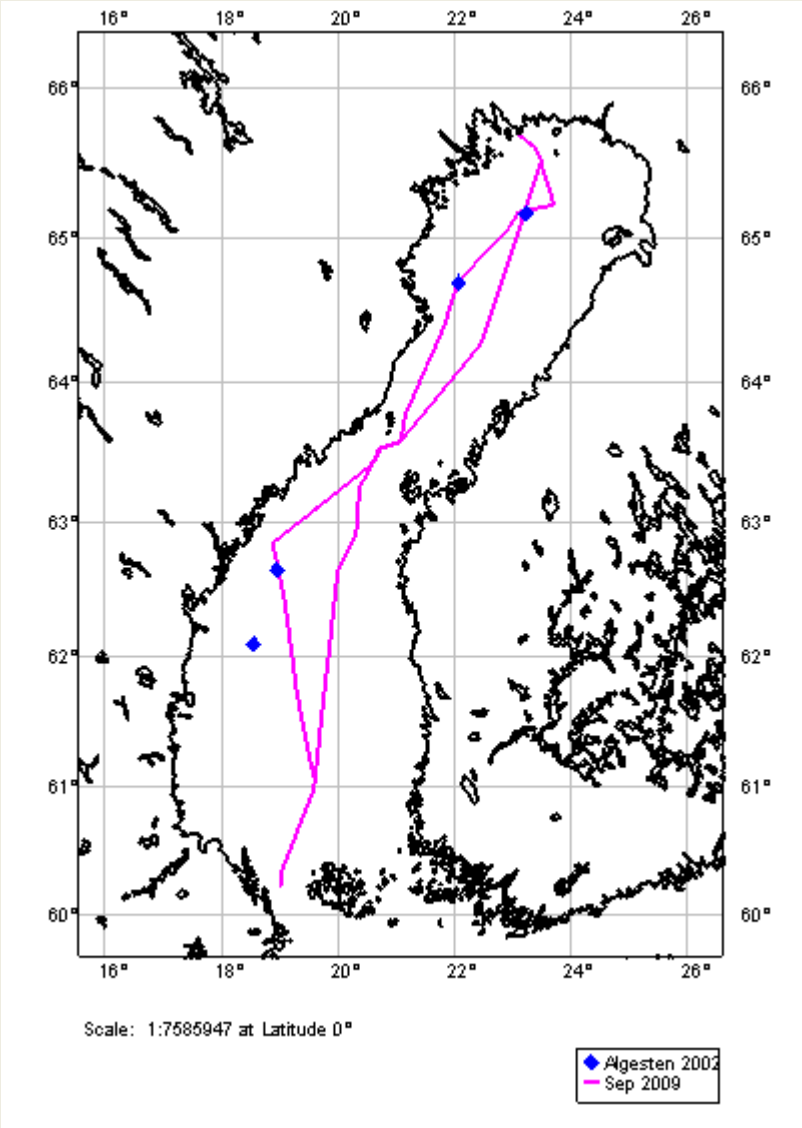
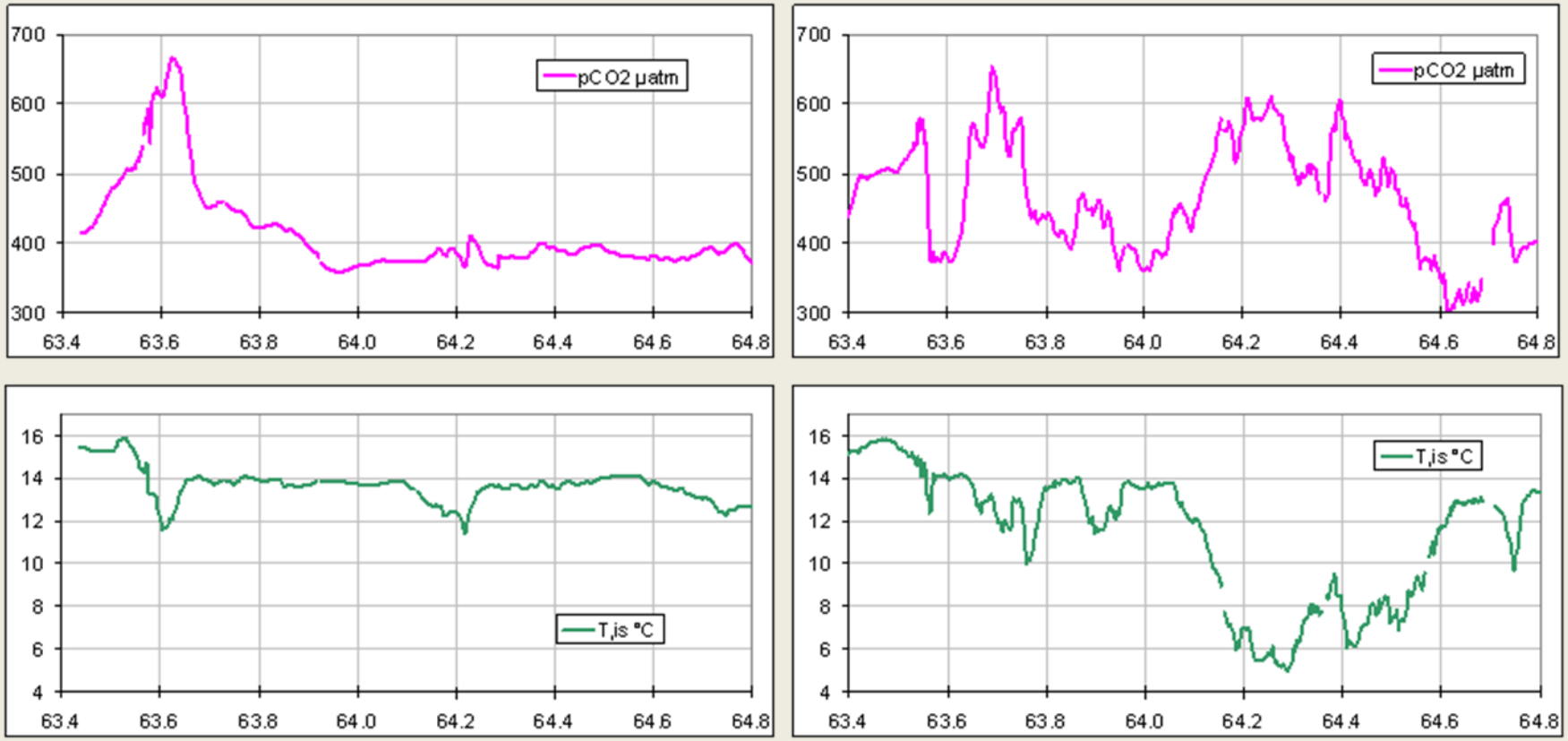
MERIAN-cruise September 2009: two transects through the Gulf of Bothnia:



MERIAN-cruise September 2009: two transects through the Gulf of Bothnia

south – north; central transect
4./5. Sep 2009
wind: 15 m/s (S)

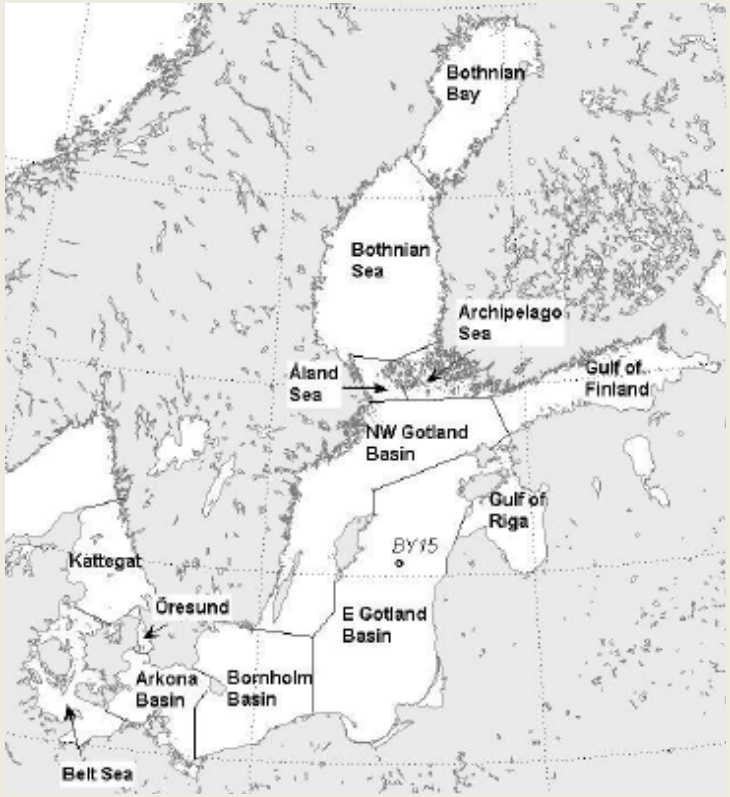
north - south; western transect
6. Sep 2009
wind: 2-6 m/s (NW)

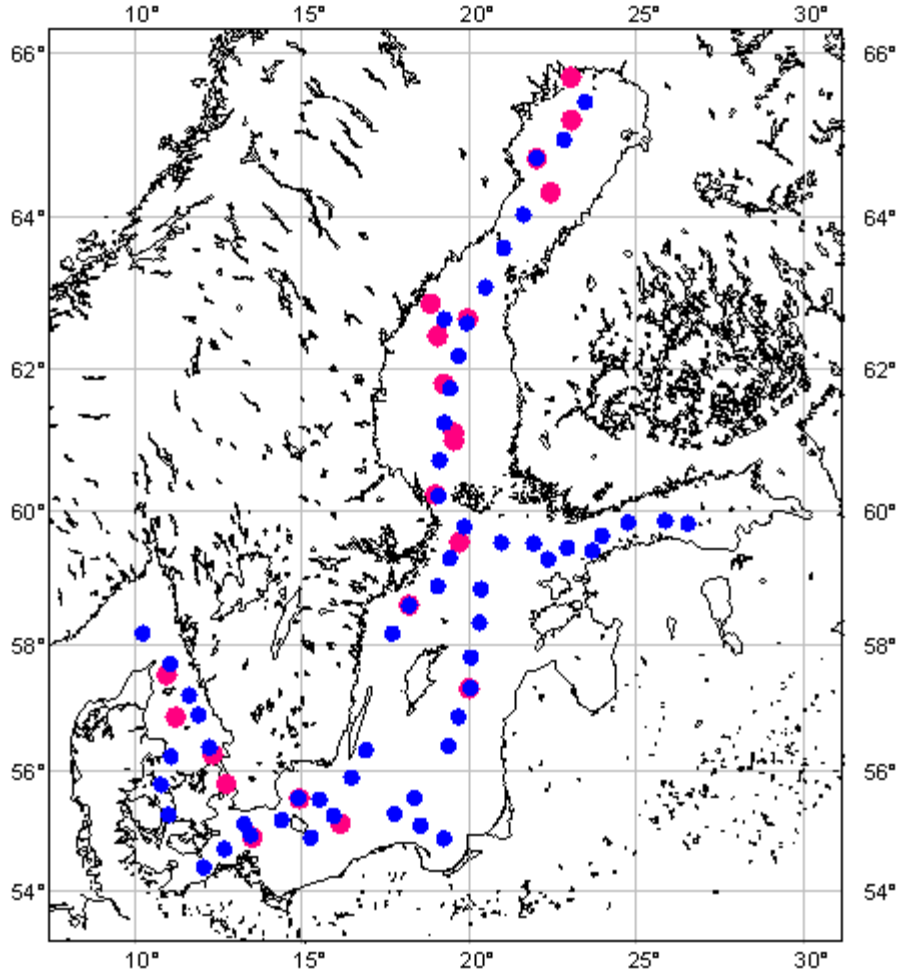


WP2: Measurements of the Baltic Sea CO_2 system and carbon inventories

Bernd Schneider, Annekatrin Löffler, Bernd Sadkowiak, Hildegard Kubsch

D9 (month 12): Concentrations of inorganic/organic carbon species in the major model sub-basins





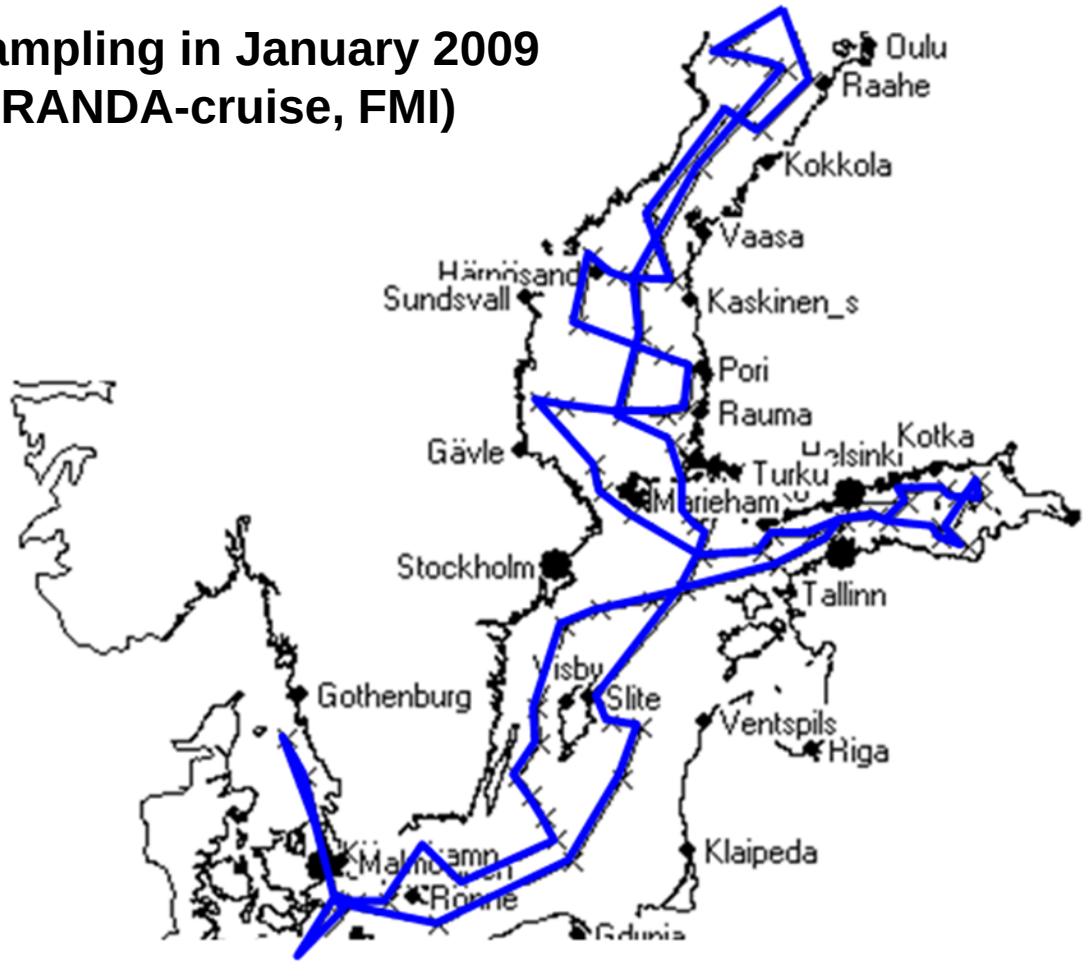
MERIAN-cruises summer 2008 and 2009:

vertical profiles of TIC, TA, O_2

WP2: Measurements of the Baltic Sea CO_2 system and carbon inventories

Bernd Schneider, Annekatrin Löffler, Bernd Sadkowiak, Hildegard Kubsch

Sampling in January 2009 (ARANDA-cruise, FMI)



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„BalticC_MarineData.xls“ – deliverable database (from FMI and IOW)

Index	Station	Date	Lon	Lat	BDepth (m)	Depth (m)	TEM	SAL	TA mmol/kg	TIC mmol/kg	pCO2 µatm
2009010052	BY15	27/01/2009	20.05003	57.32002	238	5	4.3119	7.3028	1.6430	1.5842	
2009010052	BY15	27/01/2009	20.05003	57.32002	238	20	4.4019	7.3219	1.6420	1.5822	
2009010052	BY15	27/01/2009	20.05003	57.32002	238	40	4.5262	7.3505	1.6425	1.6175	
2009010052	BY15	27/01/2009	20.05003	57.32002	238	60	4.8357	7.4079		1.6177	
2009010052	BY15	27/01/2009	20.05003	57.32002	238	70	5.0481	7.5629			
2009010052	BY15	27/01/2009	20.05003	57.32002	238	100	6.0320	10.9145	1.7857	1.9826	
2009010052	BY15	27/01/2009	20.05003	57.32002	238	125	6.3168	11.7847			
2009010052	BY15	27/01/2009	20.05003	57.32002	238	150	6.2914	12.2126			
2009010052	BY15	27/01/2009	20.05003	57.32002	238	175	6.2748	12.3497			
2009010052	BY15	27/01/2009	20.05003	57.32002	238	200	6.2809	12.4516			
2009010052	BY15	27/01/2009	20.05003	57.32002	238	225	6.3092	12.5294			
2009010052	BY15	27/01/2009	20.05003	57.32002	238	237	6.3152	12.5330			

pH	O2 µmol/l	O2 satur. %	H2S µmol/l	Fluor	NH4 µmol/l	NO3NO2 µmol/l	NO3 µmol/l	NO2 µmol/l	PO4 µmol/l	SiO4 µmol/l	totN µmol/l	totP µmol/l
8.050	360.5	93		0.1350	0.02	3.81	3.79	0.02	0.51	11.21	23.59	0.79
8.060	359.8	93		0.1246	0.01	3.75	3.72	0.03	0.49	11.29	23.50	0.78
8.051	358.7	93		0.1249	0.16	3.86	3.83	0.03	0.53	11.06	22.93	0.79
8.053	355.2	93		0.1169	0.01	3.87	3.87	0.00	0.54	10.55	22.81	0.83
8.008	254.5	67		0.1142	0.01	4.23	4.23	0.00	0.60	11.73	23.00	0.90
7.172	11.8	3		0.1002	0.01	4.88	4.88	0.00	3.03	51.20	16.52	3.39
	0.0	0	8.67	0.1037	4.17	0.08	0.08	0.00	4.01	57.86	16.51	4.32
	0.0	0	43.93	0.1121	14.51	0.06	0.06	0.00	4.93	72.24	29.79	5.14
	0.0	0	58.12	0.1162	16.55	0.07	0.07	0.00	5.01	74.49	28.92	5.84
	0.0	0	73.31	0.1193	20.06	0.07	0.07	0.00	4.71	79.49	33.50	5.92
	0.0	0	92.97	0.1238	25.48	0.08	0.08	0.00	4.98	85.81	36.74	5.94
			92.97		25.98	0.09	0.09	0.00	5.16	87.59	37.70	6.08

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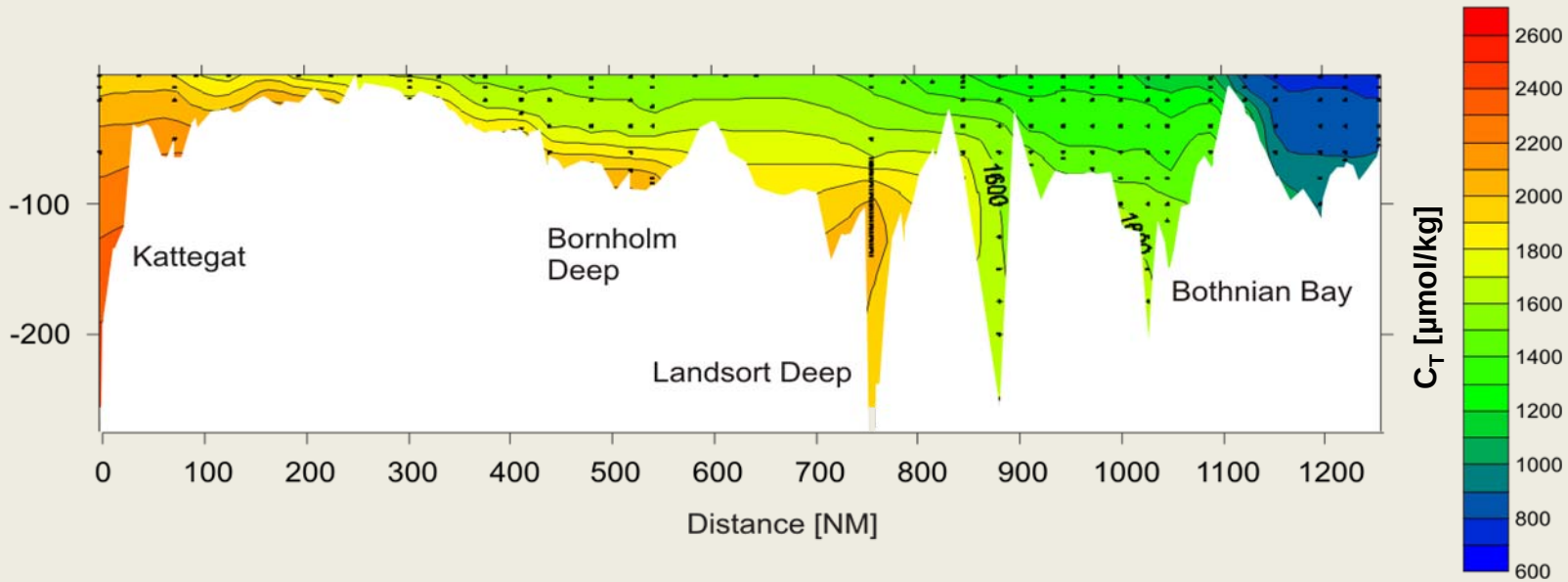
Depth distribution of total dissolved inorganic carbon (C_T) along a transect through the Baltic Sea



C_T (= $[CO_2]$ + $[HCO_3^-]$ + $[CO_3^{2-}]$) mainly depends on:

1. Alkalinity → geological structure of the catchment area (river water input)
2. Biological production / decomposition → CO_2 consumption in the euphotic zone
   → CO_2 release in deep water layers
   → CO_2 accumulation during stagnation conditions

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Alkalinity as a function of salinity with regression lines for different sub-areas of the Baltic Sea (data from FMI)

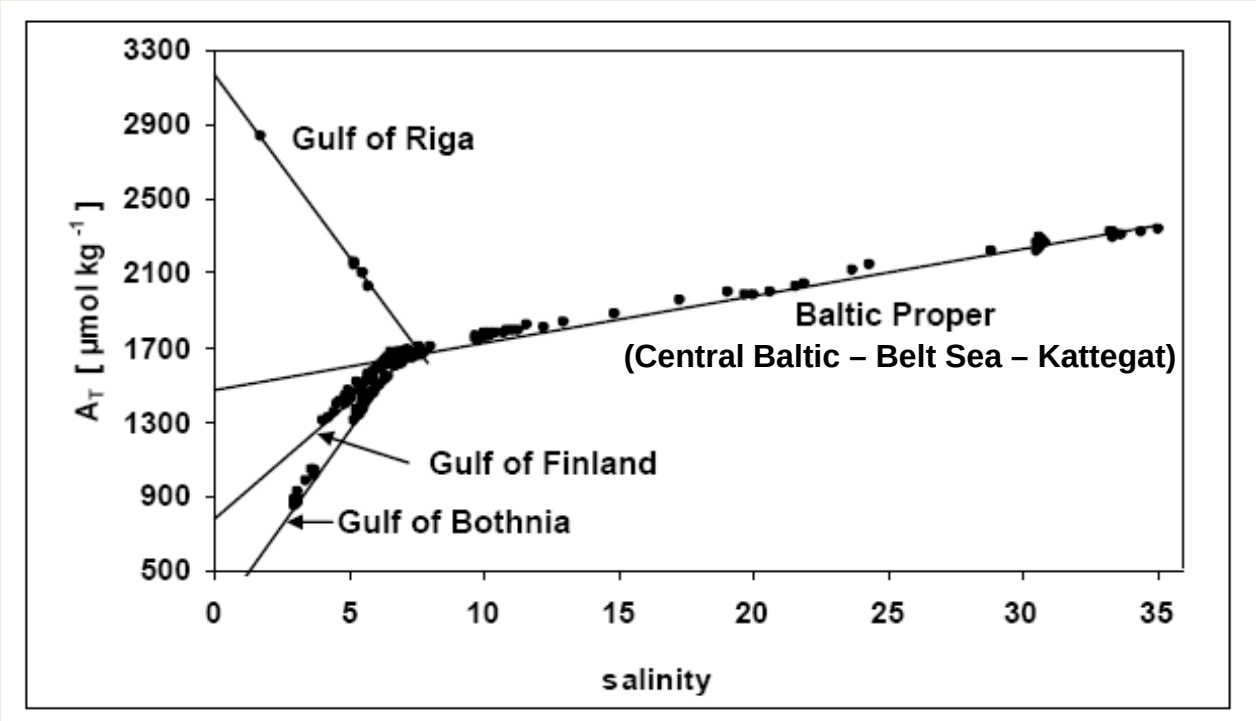
Linear $A_T(S)$ relationships (A_T in µmol kg^{-1}):

Gulf of Bothnia:
$A_T = 205 \cdot S + 229$

Gulf of Finland:
$A_T = 125 \cdot S + 786$

Gulf of Riga:
$A_T = -196 \cdot S + 3172$

Baltic Proper:
$A_T = 25.3 \cdot S + 1470$



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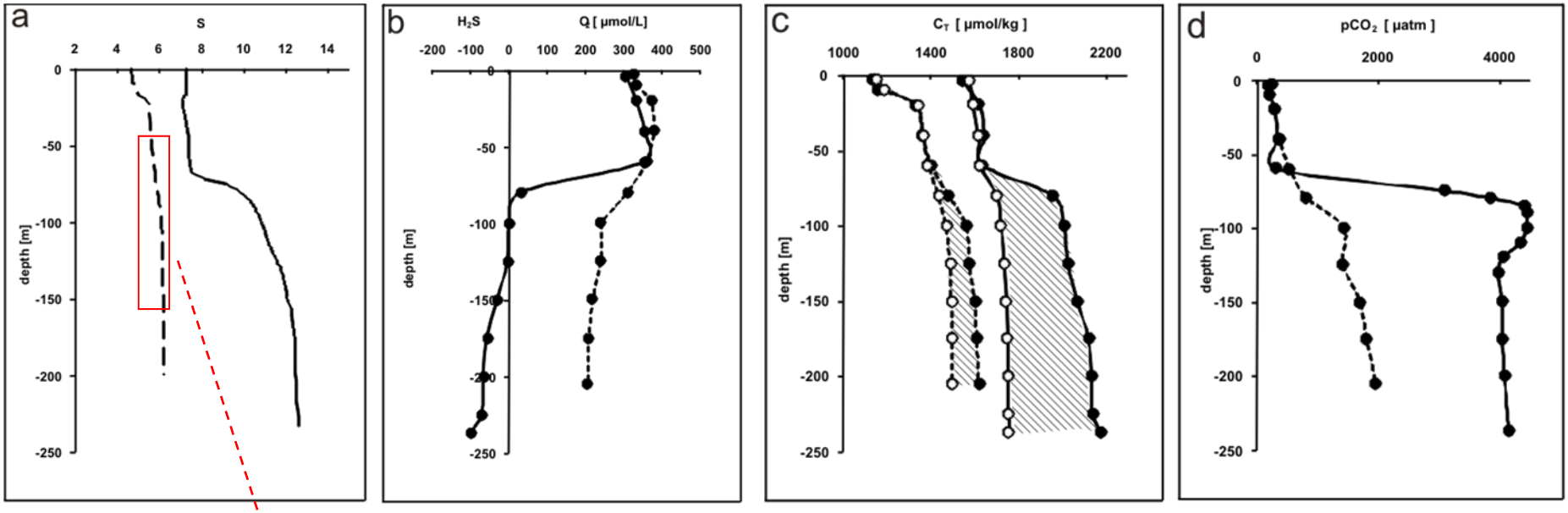
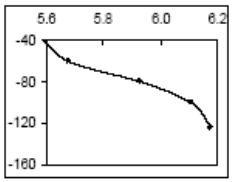
Vertical profiles of DIC (C_T) at the Bothnian Sea and the eastern Gotland Sea

– – – – – **Bothnian Sea (periodic mixed water column)**

——— **Gotland Deep (stagnation of the deep water)**



Salinity



Oxygen (µmol/l)
H_2S (µmol/l)

C_T (µmol/kg)

pCO2 (µatm)

measured values

saturation values (calculated)

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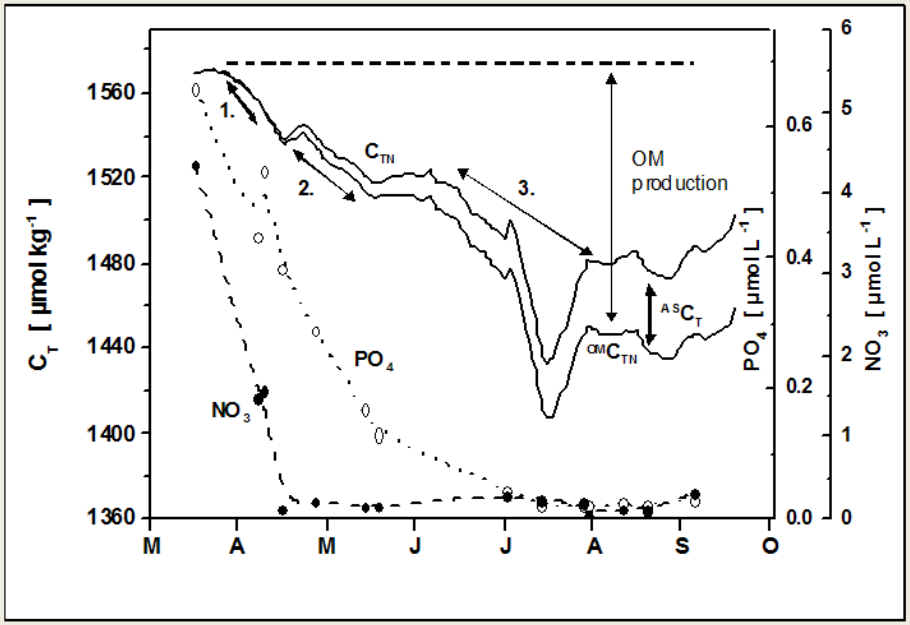
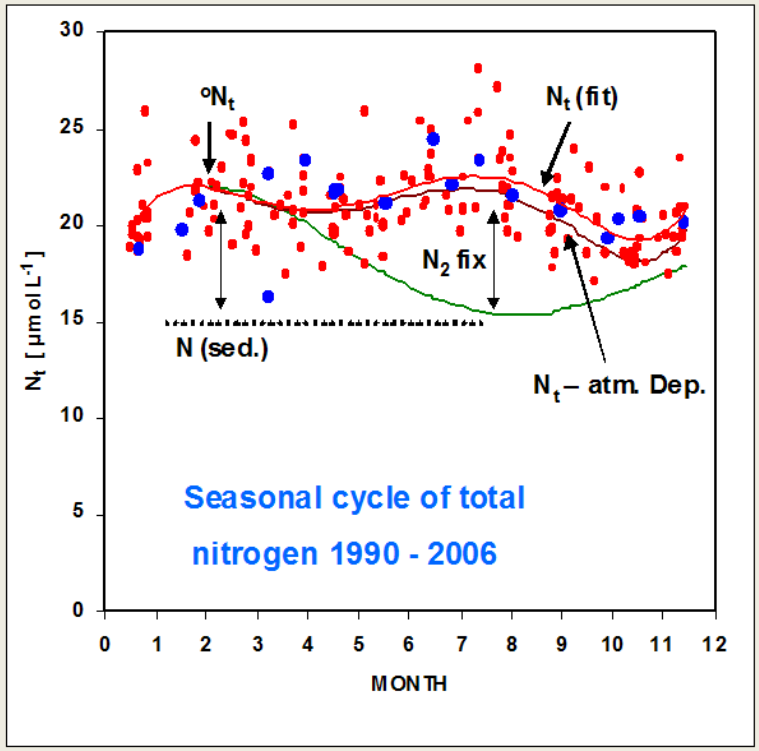
D7 (month 12), Improved process parameterizations:

1. **Nitrogen fixation starts early in April/May after the spring bloom and the exhaustion of NO_3.**

Seasonal total CO_2 and nutrient depletion (2005)





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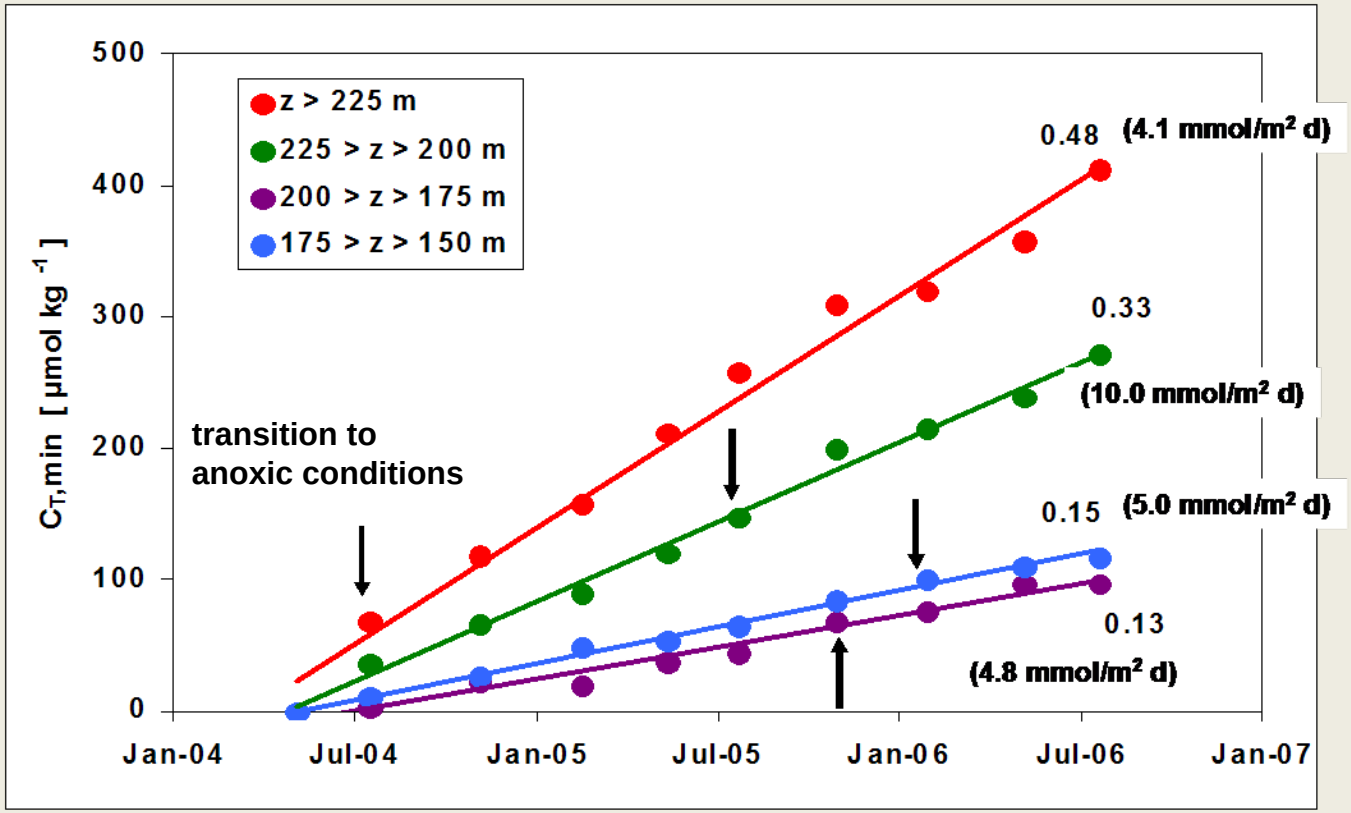
2. Mineralization rates of organic matter are independent of the redox state of the overlying water column.

Mineralization in the Gotland Sea deep water. The slope of the regression lines represent the mean mineralization rates in µmol kg^{-1} d^{-1}.



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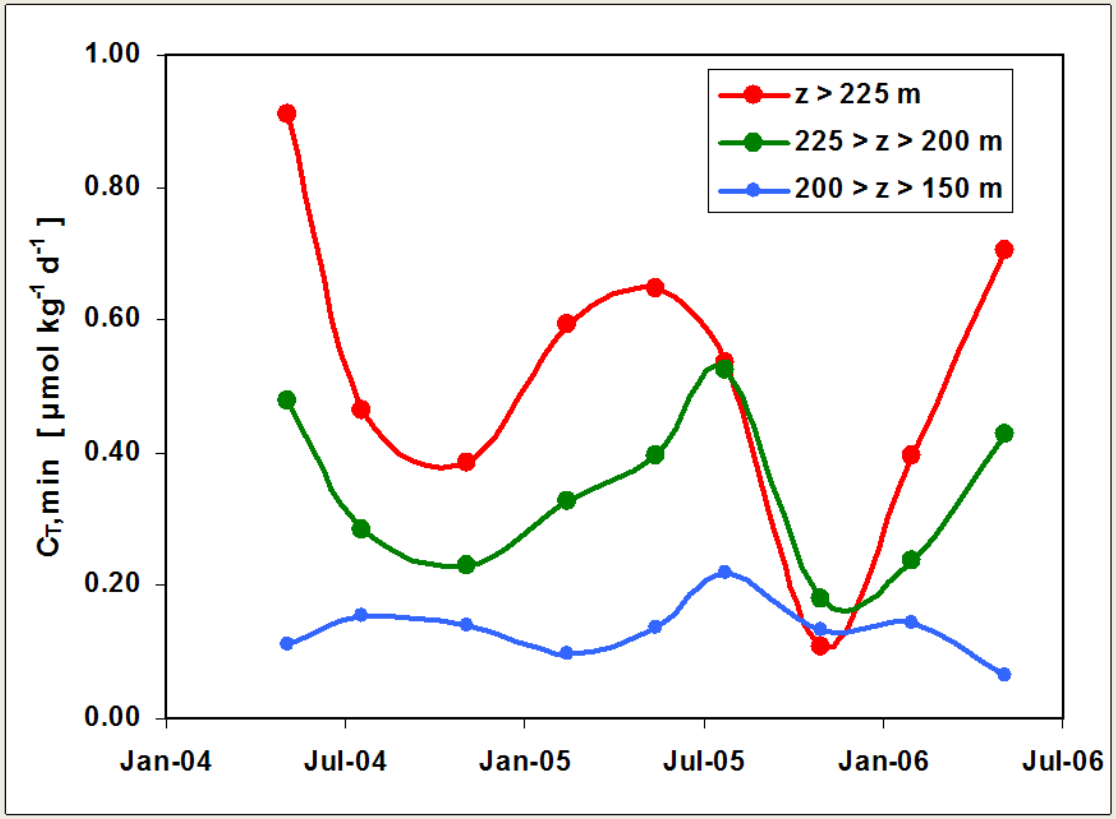
A distinct seasonality of the mineralization rates was observed only in the bottom water. This indicates that mineralization takes place mainly at the sediment surface.

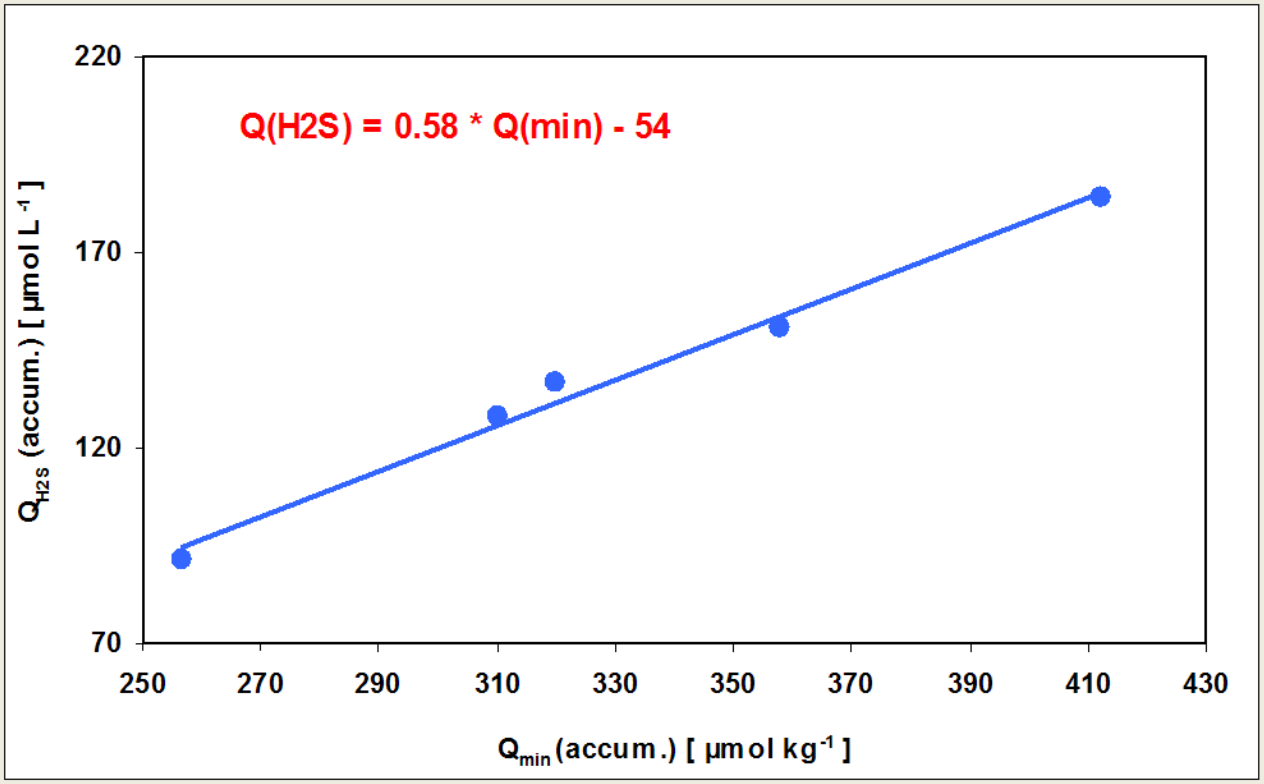
Relating the seasonality of the mineralization to the input of POC (sediment trap data) yields a mineralization rate constant of roughly 0.01 d^{-1}.

Seasonality of the mineralization rates



3. The mineralization of one mole organic carbon requires 1.16 mole oxygen equivalents.

H_2S formation as a function of the C_T production by mineralization during a period when other oxidants are not available.



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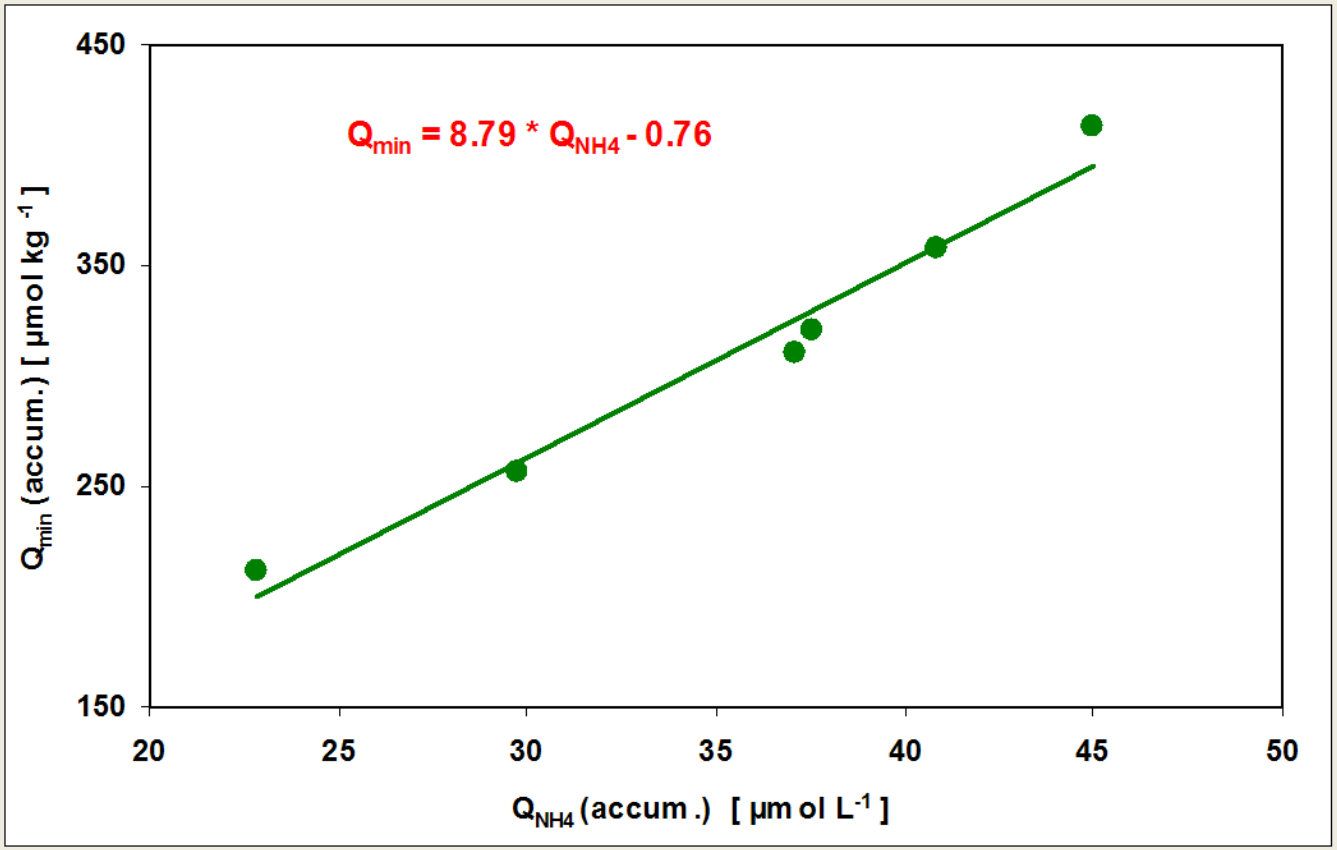
4. C/N ratio of POC in the deep water is 8.8.

Relationship between NH_4 and C_T(min) release at anoxic conditions.



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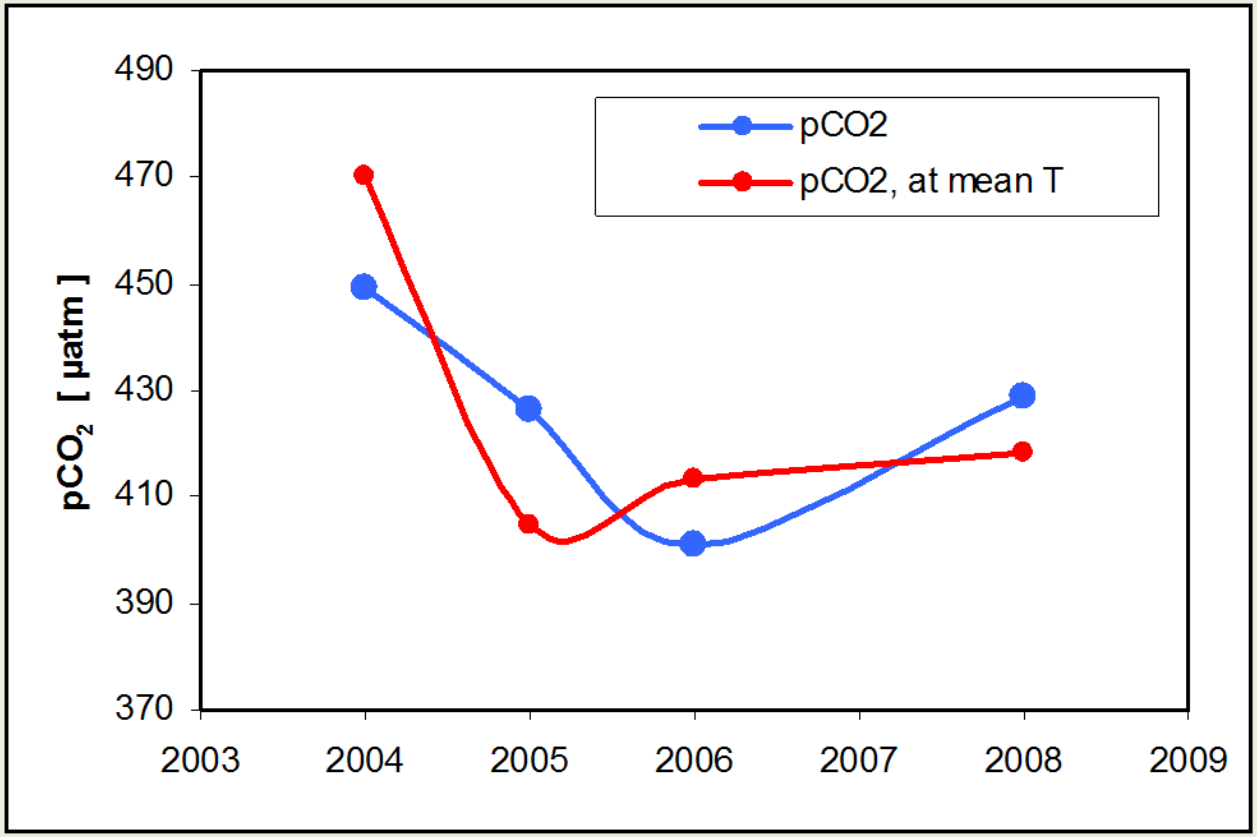
D 11 (month 12), Trend analysis for CO2/carbon variables:

First results indicate that the interannual variation of the pCO_2 exceeds the atmospheric CO_2 increase by more that one order of magnitude.



Interannual variations of the pCO_2 during February in the Northern Baltic Proper.

Publications:

Schneider, B., Kaitala, S., Raateoja, M. Sadkowiak, B. 2009:

„A nitrogen fixation estimate for the Baltic Sea based on continuous pCO_2 measurements on a cargo ship and total nitrogen data."

Cont. Shelf Res., 29, 1535 - 1540.

Schneider, B., Nausch, G., Pohl, C., 2009:

Mineralization of organic matter and nitrogen transformations in the Gotland Sea deep water.

Submitted to Mar. Chem.

Beldowski, J., Löffler, A., Schneider, B., Joensuu, L., 2009.

Distribution and biogeochemical control of total CO_2 and alkalinity in the Baltic Sea.

Submitted to J. Mar. Sys.