

Deliverables Workpackage 2

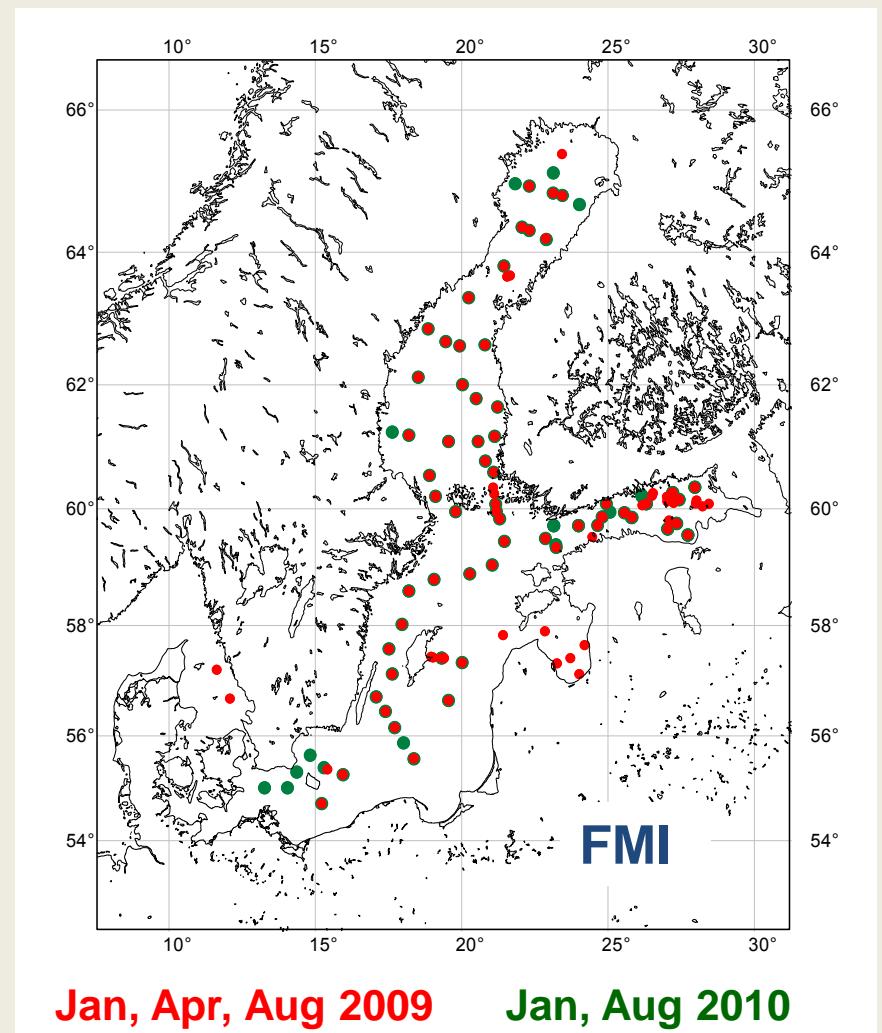
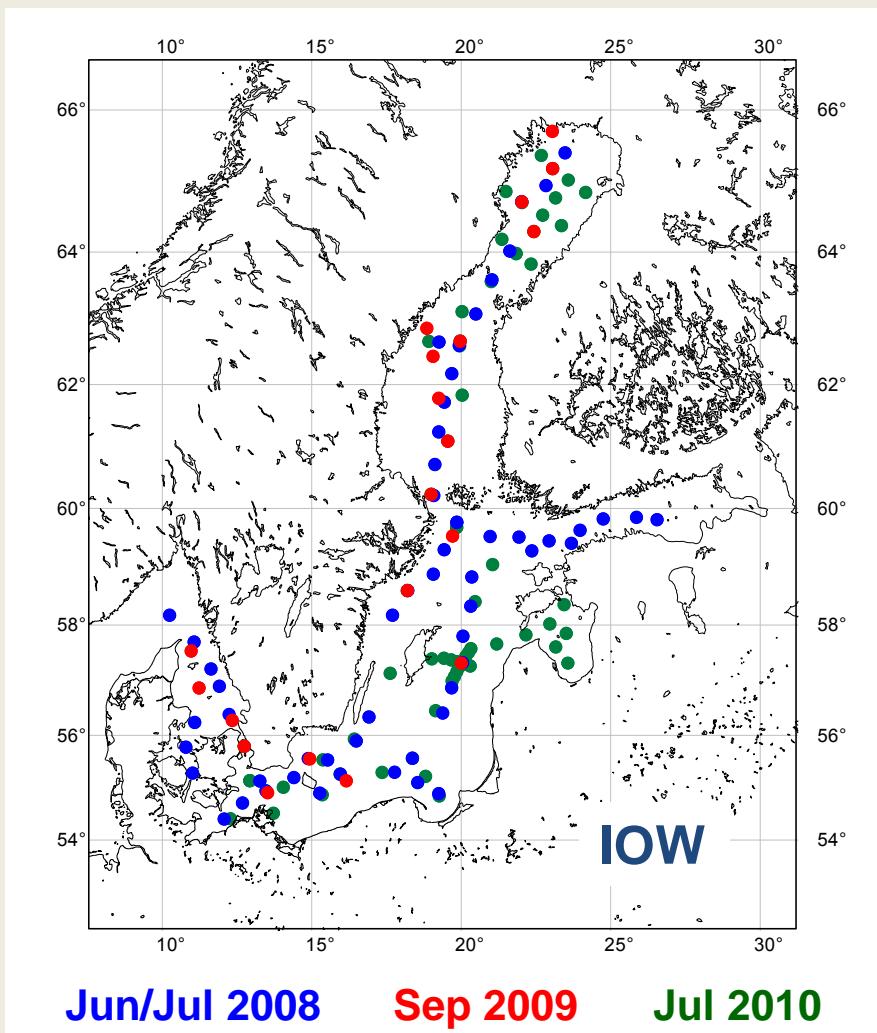
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1. Data Base

Sampling cruises in Baltic-C

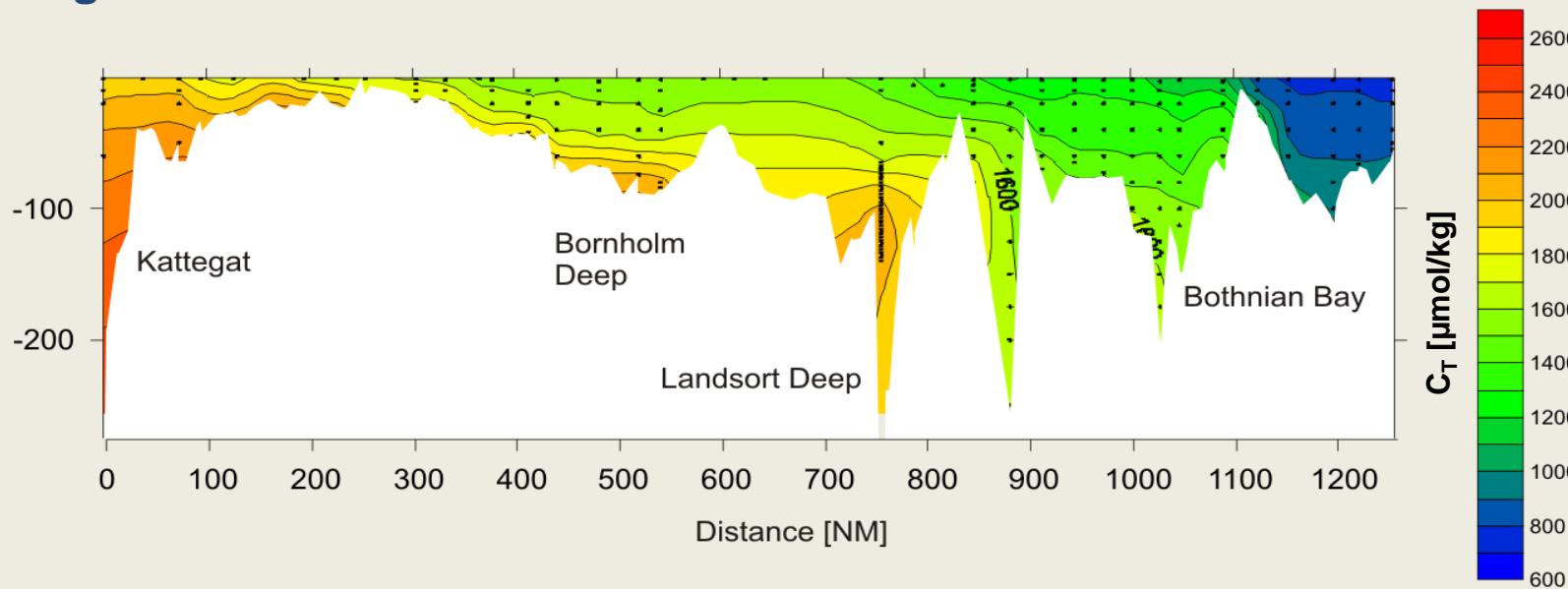


„BalticC_MarineData“ – deliverable database (from FMI and IOW)

Index	Station	Date	Lon	Lat	BDepth (m)	Depth (m)	T °C	S	AT µmol/kg	CT µmol/kg	pCO ₂ µatm
2010010001	39A	11/01/2010	24.9802	60.0668	43	1	0.09	4.35			
2010010001	39A	11/01/2010	24.9802	60.0668	43	5	0.35	4.40	1323	1179	387.8
2010010001	39A	11/01/2010	24.9802	60.0668	43	10	0.37	4.41			
2010010001	39A	11/01/2010	24.9802	60.0668	43	15	0.54	4.52			
2010010001	39A	11/01/2010	24.9802	60.0668	43	20	1.56	4.97			
2010010001	39A	11/01/2010	24.9802	60.0668	43	30	3.16	5.70			
2010010001	39A	11/01/2010	24.9802	60.0668	43	37	4.11	6.26	1538	1402	
2010010001	39A	11/01/2010	24.9802	60.0668	43	42	4.38	6.45			

pH	O ₂ µmol/l	O ₂ satur. %	H ₂ S µmol/l	Fluor	NH ₄ µmol/l	NO ₃ NO ₂ µmol/l	NO ₃ µmol/l	NO ₂ µmol/l	PO ₄ µmol/l	SiO ₄ µmol/l	totN µmol/l	totP µmol/l
7.956	379.4	86		0.1835	0.10	11.09	11.07	0.02	0.81	16.74	31.14	1.10
8.007	374.3	85		0.1784	0.09	10.94	10.91	0.03	0.84	16.93	30.91	1.09
7.986	374.9	86		0.1774	0.12	10.77	10.74	0.03	0.85	16.91	30.65	1.10
7.955	373.5	86		0.1742	0.09	10.31	10.28	0.03	0.87	17.24	30.02	1.08
7.916	357.2	85		0.1613	0.12	9.88	9.85	0.03	0.93	17.84	29.43	1.10
7.772	315.7	78		0.1371	0.10	8.98	8.95	0.03	1.11	20.30	29.04	1.30
7.641	267.2	68		0.1253			0.00					
7.519	232.3	60			0.28	9.64	9.39	0.25	1.57	27.33	28.94	1.79

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
 - CO₂ consumption in the euphotic zone
 - CO₂ release in deep water layers
 - CO₂ accumulation during stagnation conditions

Alkalinity as a function of salinity with regression lines for different sub-areas of the Baltic Sea

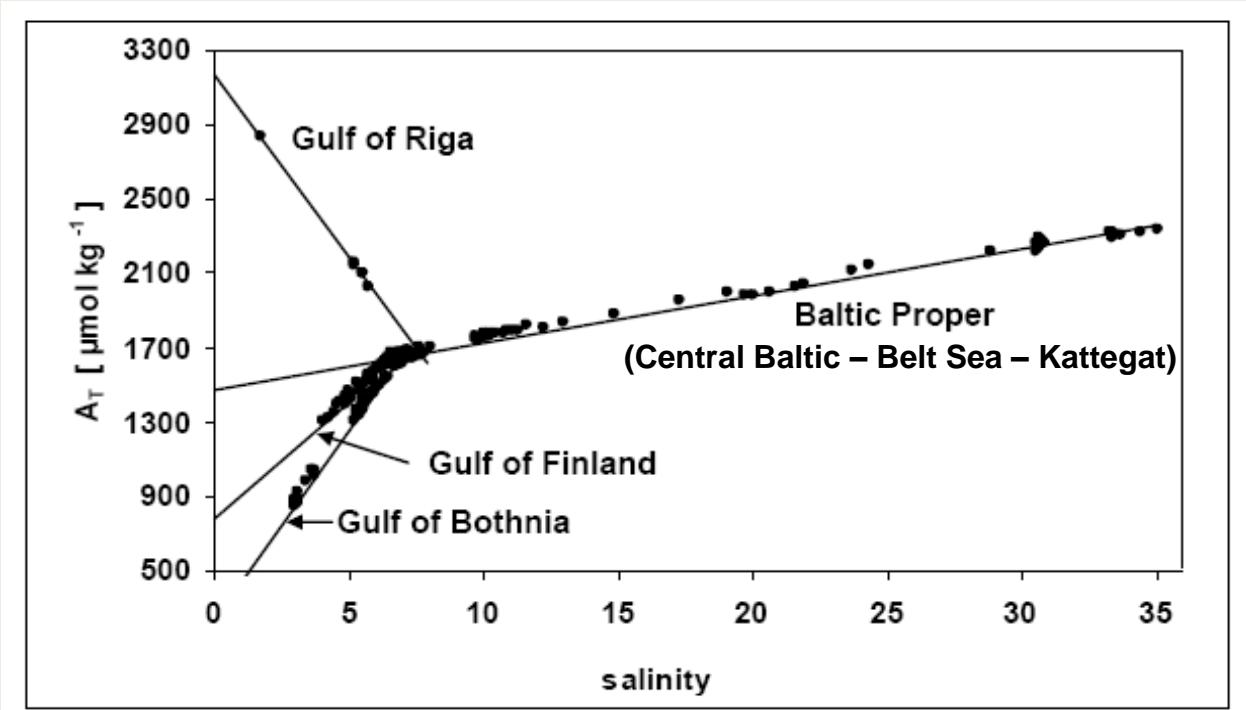
**Linear A_T(S) relationships
(A_T in $\mu\text{mol kg}^{-1}$):**

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

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

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

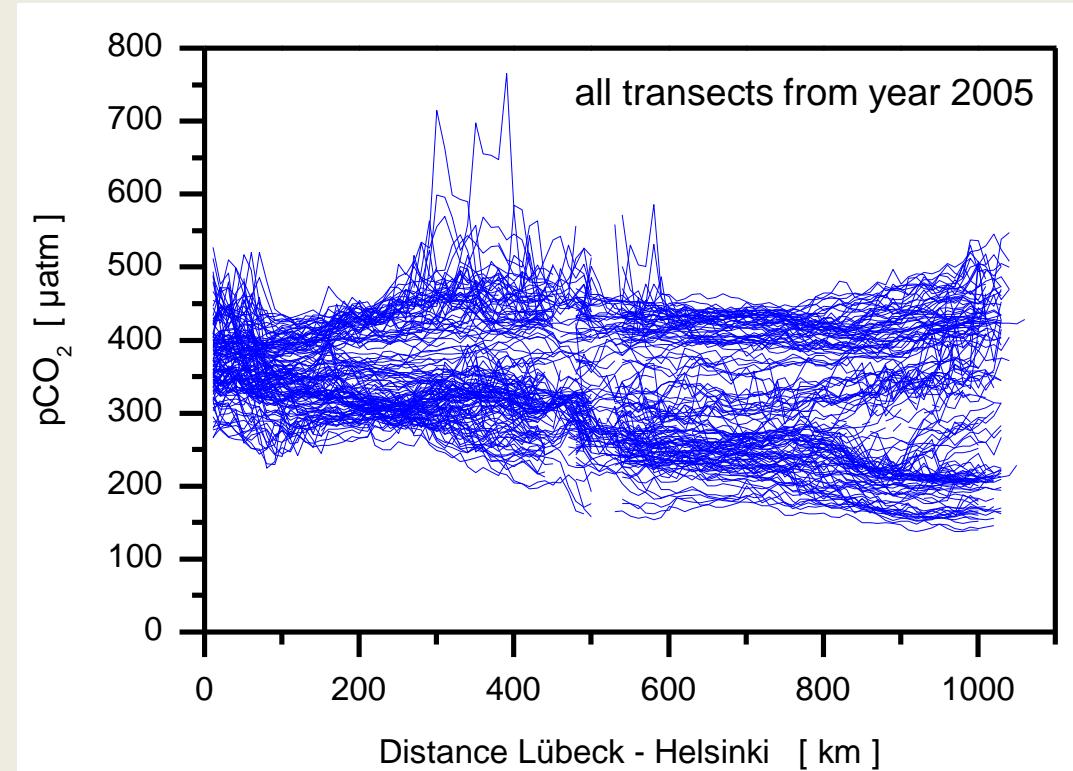
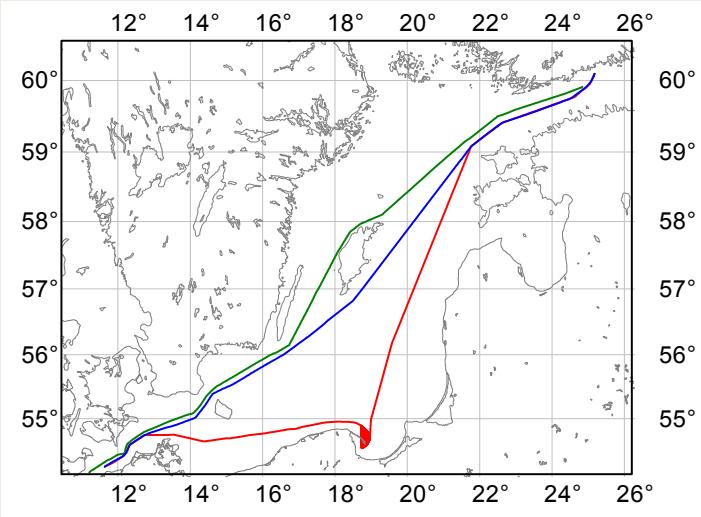
Baltic Proper:
 $A_T = 25.3 \cdot S + 1470$



Bernd Schneider, Annekatrin Löffler, Bernd Sadkowiak, Hildegard Kubsch

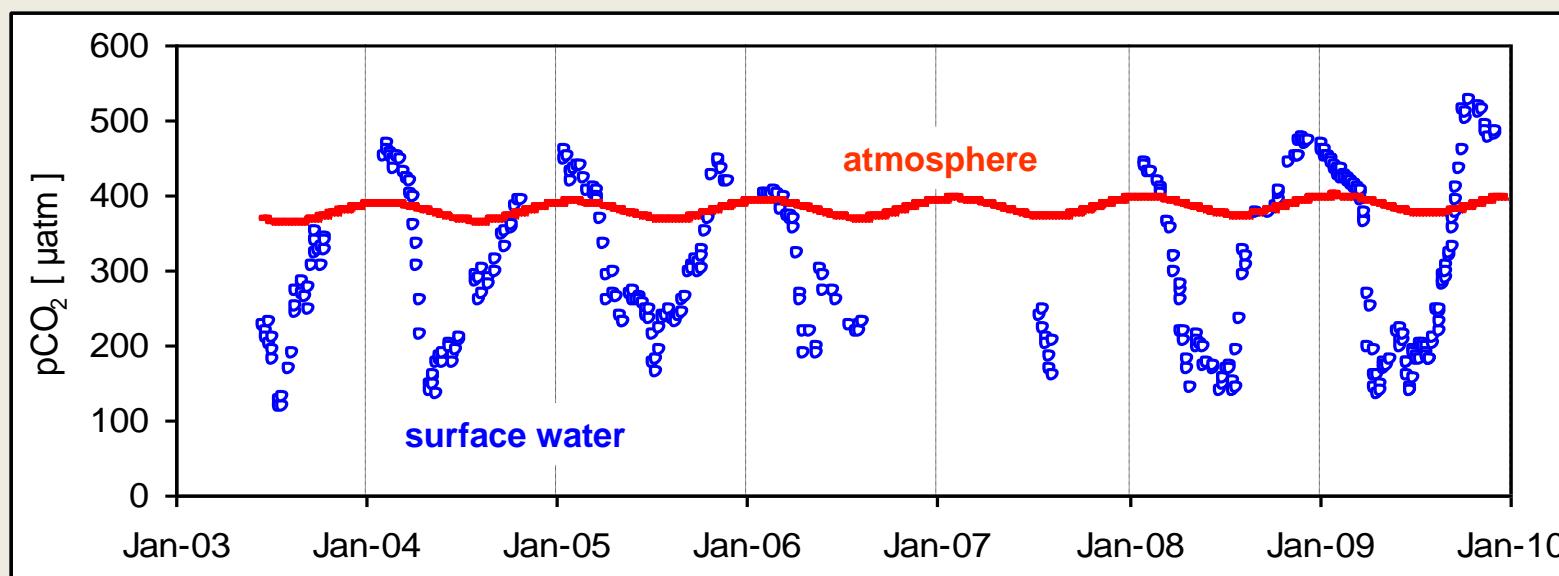
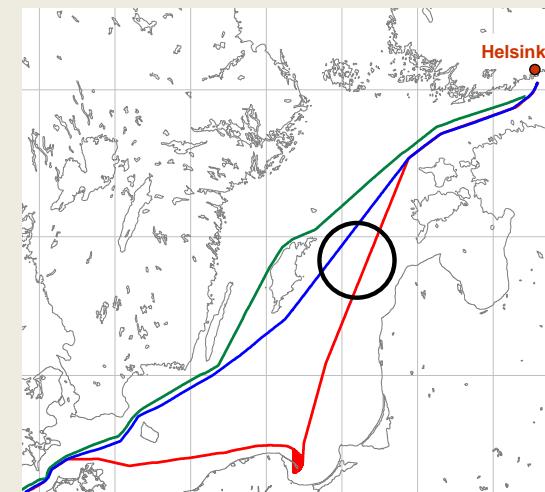
Continuous measurements of the surface water CO₂ partial pressure on a cargo ship

- start in summer 2003
- 2 - 3 transects per week
- spatial resolution 1 - 2 nautical miles



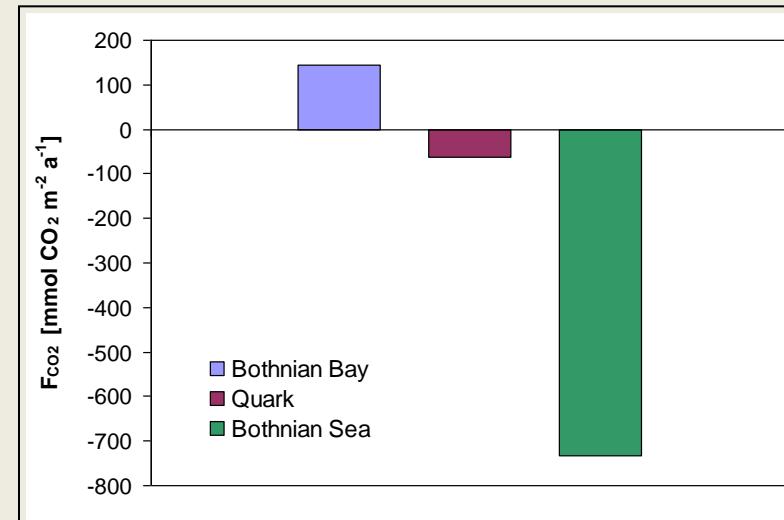
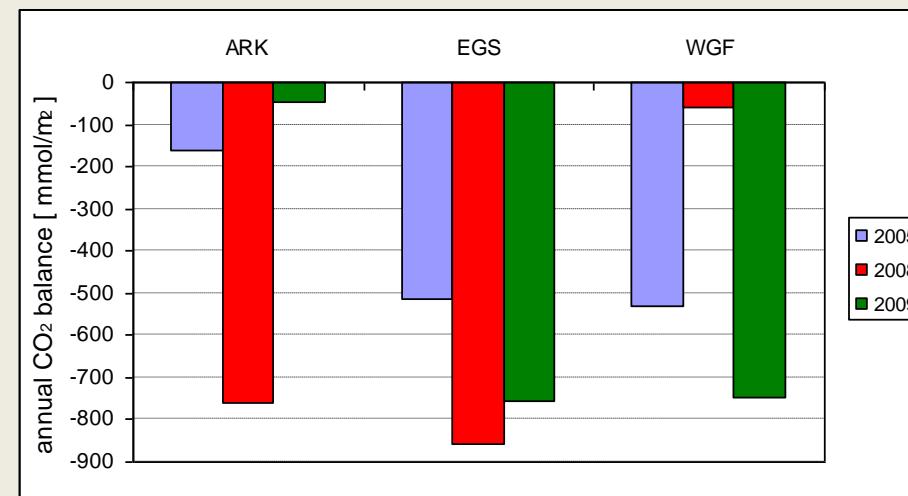
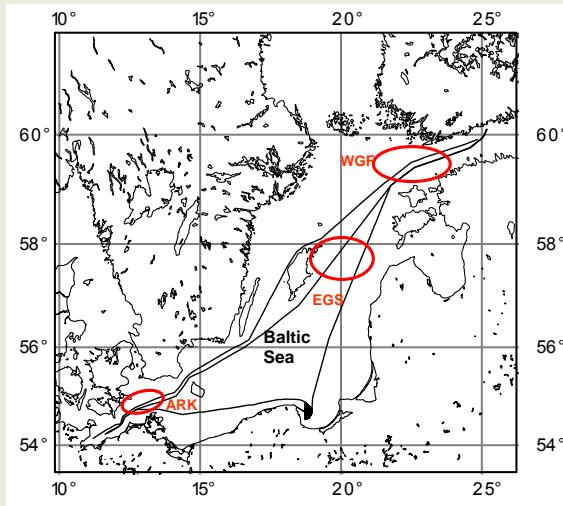
2. Process Studies

pCO₂ time series (central Baltic)

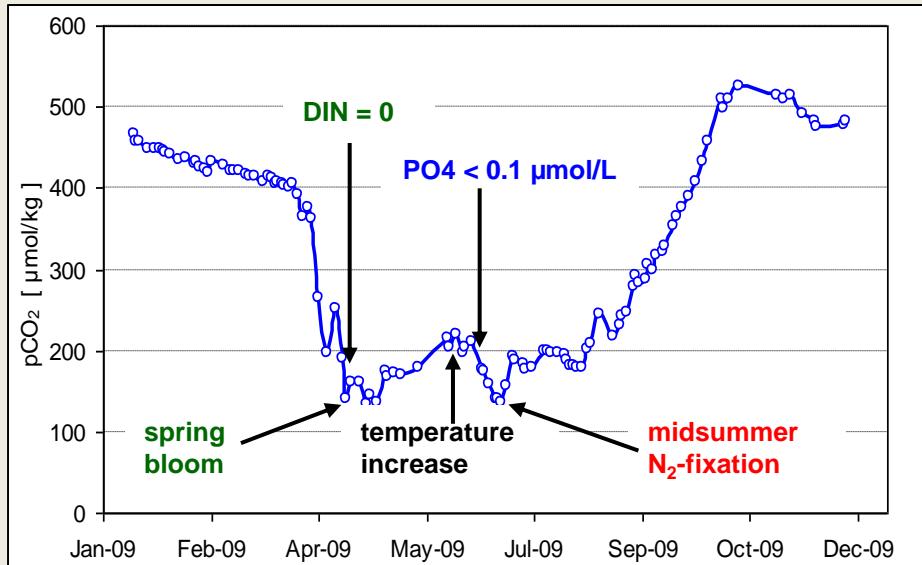


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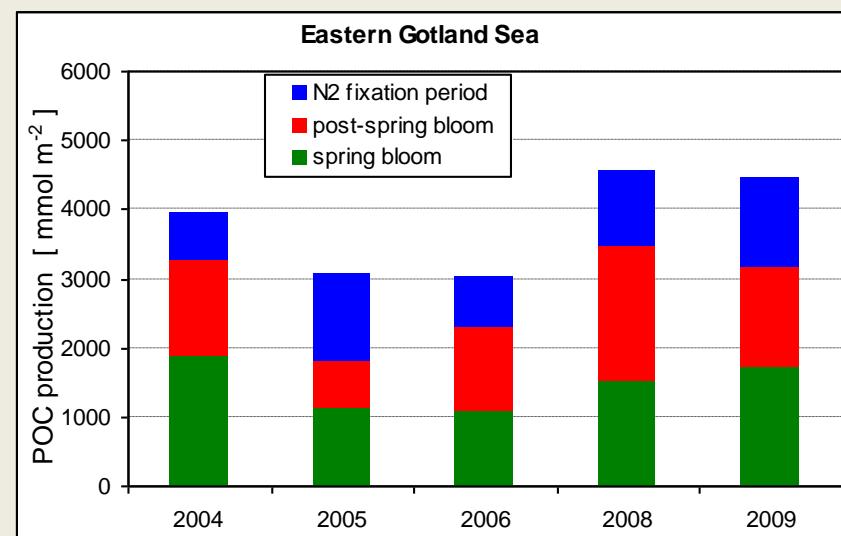
The Baltic Sea: Sink or source for atmospheric CO₂?



Calculation of the biological production



$$C_T = f(p\text{CO}_2, A_T, T, S)$$



Distinction between 3 production periods:

1. Spring bloom, limited by nitrate
2. Post spring-bloom production, limited by phosphate
3. Production based on mid-summer N₂ fixation

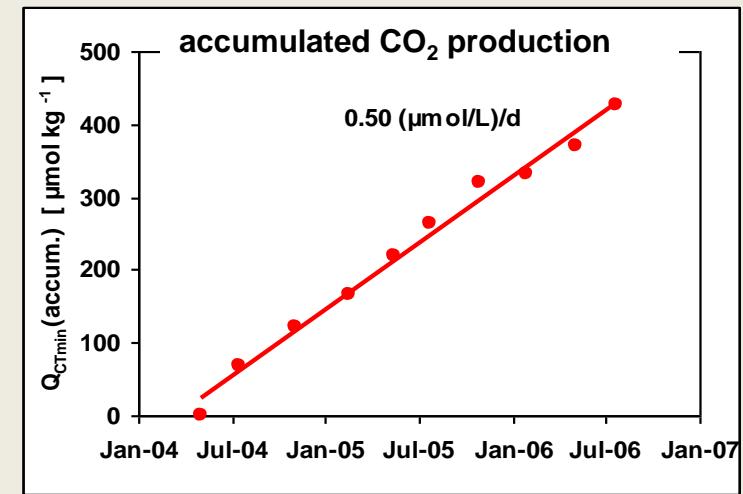
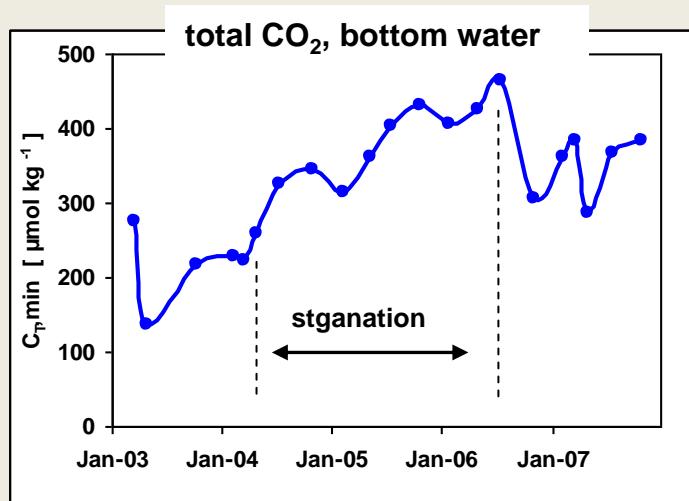
Conclusions

Measurements of the surface water pCO₂ are an efficient tool to study biogeochemical processes in the Baltic Sea.

We were able to:

- determine precisely the timing of plankton bloom events in different regions of the Baltic Sea
- quantify the net biomass production in different regions of the Baltic Sea
- estimate the nitrogen fixation
- to identify the central Baltic Sea as a (weak) sink for atmospheric CO₂

Mineralization rates of organic matter in Gotland Sea deep water from time series measurements

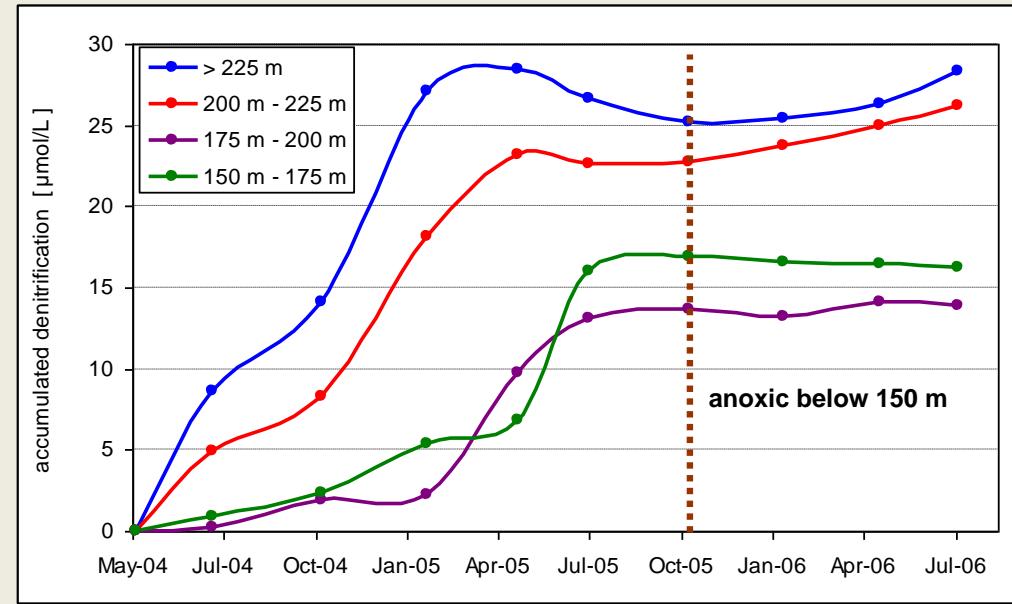


Results:

- Annual mineralization: 2.0 mol m⁻² yr⁻¹
- No difference between oxic and anoxic mineralization
- Mineralization takes place mainly at the sediment surface

Denitrification in Gotland Sea deep water during transition from oxic to anoxic conditions

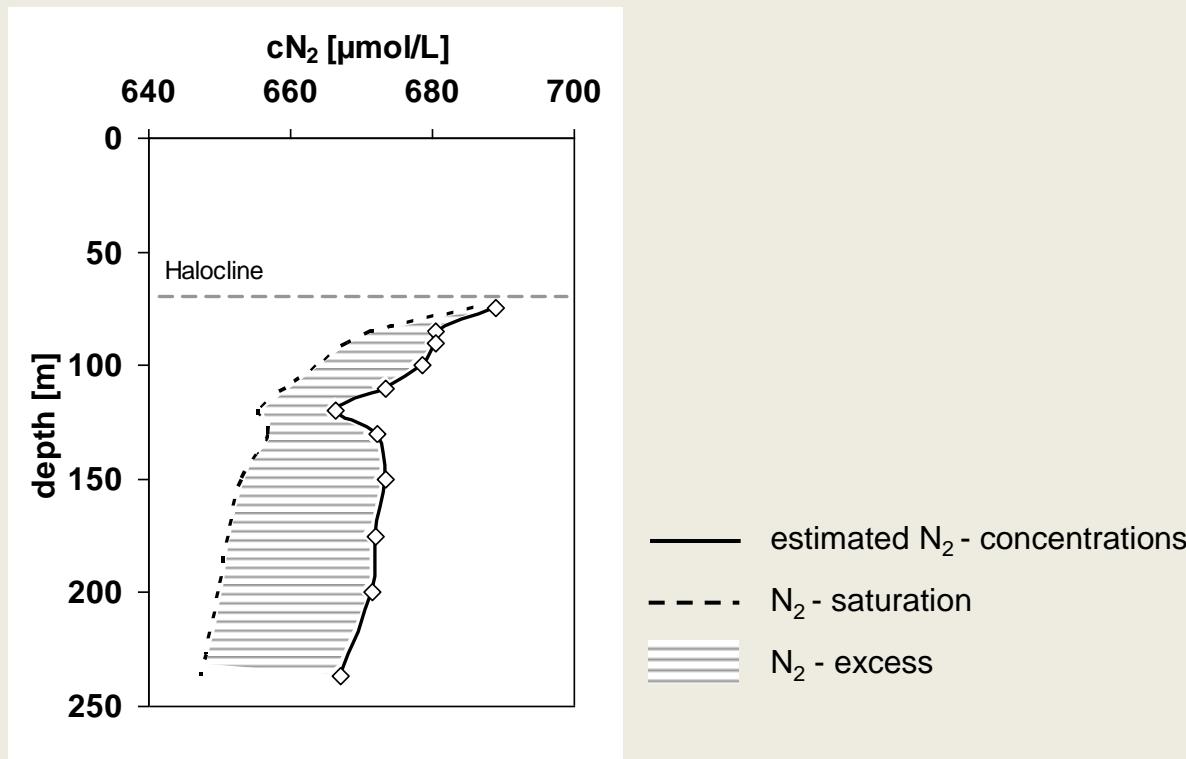
Accumulated denitrification:



Results:

- accumulated denitrification during transition from oxic to anoxic conditions was up to 30 μmol/L
- maximum rate: 0.13 (μmol/L)/d
- total denitrification during the transition from oxic to anoxic conditions: 560 mmol/m²
- anammox contribution < 5 %

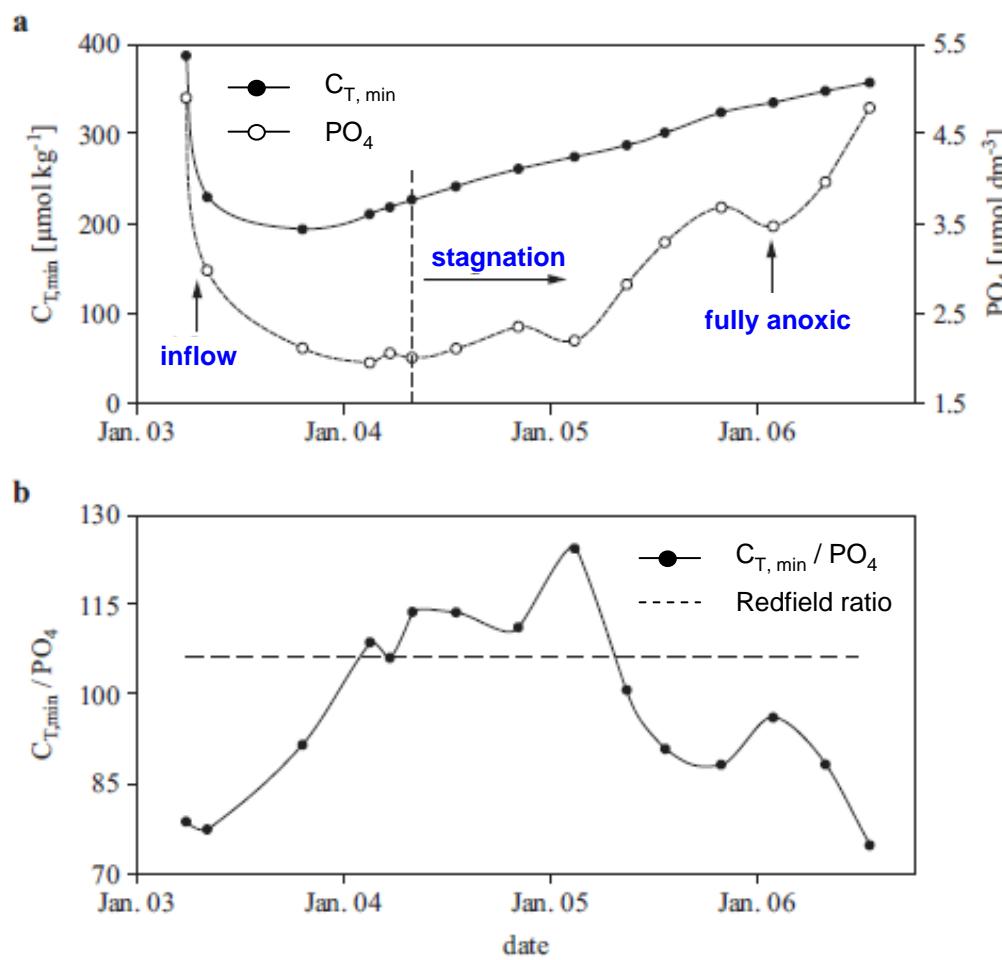
Total Denitrification in Gotland Sea deep water



Results:

- below 150 m, the N excess in the water mass was 41 $\mu\text{mol N L}^{-1}$
- integrated denitrification for the whole basin below 150 m depth was 1300 mmol m^{-2}
- half of the N_2 excess derived from denitrification outside the Gotland Basin

Phosphate release in Gotland Sea deep water



Results:

- PO₄ decrease after inflow event is to a large extent due to dilution
- formation of Fe-P is slow and occur mainly at sediment surfaces
- precipitation and dissolution of Fe-P during changing redox conditions is a closed cycle
- anoxic conditions do not generate an additional source of PO₄ from the sediments

Conclusions

Measurements of the marine CO₂ system (together with the nutrient systems) constitute an efficient tool to study biogeochemical processes in the Baltic Sea deep waters

Quantitative informations were obtained for:

- organic carbon mineralization rates and rate constants
- denitrification during the development of anoxic conditions
- the effect of anoxic conditions on the phosphate budget

Publications:

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

A nitrogen fixation estimate for the Baltic Sea based on continuous pCO₂ measurements on a cargo ship and total nitrogen data.

Continental Shelf Research 29, 1535 - 1540

Schneider, B., Nausch, G., Pohl, C., 2010:

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

Marine Chemistry 119 (1-4), 153-161

Beldowski, J., Löffler, A., Schneider, B., Joensuu, L., 2010:

Distribution and biogeochemical control of total CO₂ and alkalinity in the Baltic Sea.

Journal of Marine Systems 81, 252-259

Löffler, A., Schneider, B., Schmidt, M., Nausch, G., 2011:

Estimation of denitrification in Baltic Sea deep water from gas tension measurements.

Marine Chemistry 125, 91-100

Schneider, B., 2011:

PO₄ release at the sediment surface under anoxic conditions: a contribution to the eutrophication of the Baltic Sea?

Oceanologia 53 (Tl), 1-15

Löffler, A., Schneider, B., Perttilä, M., Rehder, G.:

Air-sea gas exchange of CO₂ in the Gulf of Bothnia, Baltic Sea.

in preparation

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Data base

Cruise	Time	Kat	Öre	Belt	Ark	Bor	EGo	NGo	Rig	Fin	Ala	Arch	BoS	BoB
Merian	Jun/Jul 2008	X	X	X	X	X	X	X		X	X		X	X
Aranda	Jan/Feb 2009	X				X	X	X		X	X	X	X	X
Aranda	Mar/Apr 2009						X		X					X
Aranda	Aug 2009									X				
Merian	Sep 2009	X	X		X	X	X	X			X		X	X
Aranda	Jan/Feb 2010				X	X	X	X		X	X	X	X	X
Alkor	Jul 2010		X		X	X	X	X	X		X		X	X
Aranda	Aug 2010									X				
Finnmaid	2003-2010				X	X	X	X		X				

Typical seasonality of the pCO₂ in the central Baltic

