

Budget approach to carbon cycling in the Baltic sea

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Outline

- Budget
- Sediments
- Acronim

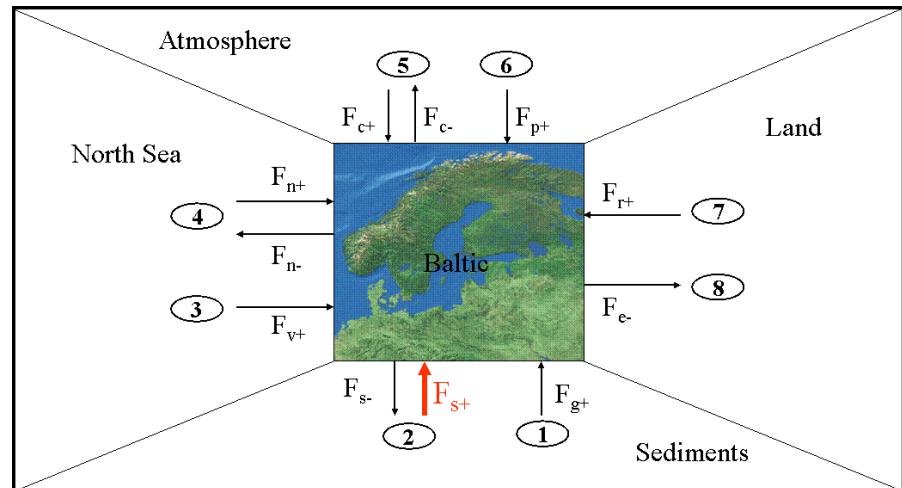
f- material flow (water,sediment....)

c_z - concentration of component z in material

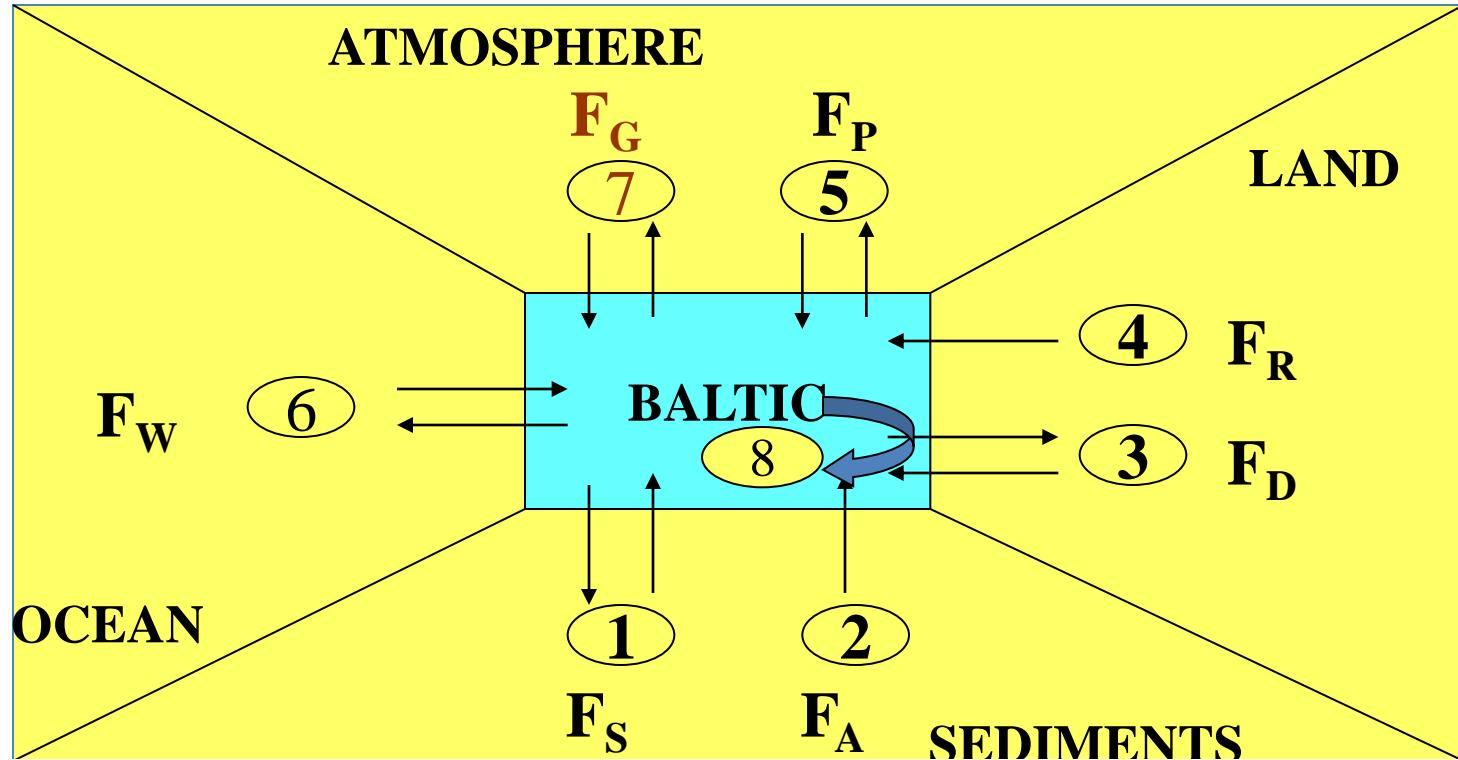
$$f \times c_z = F_z$$

F_z - material flux of component z

S Fluxes = Budget



MATERIAL FLUXES



- | | |
|-----|--------------------------------|
| (1) | Sedimentation / diffusion |
| (2) | Ground water seepage |
| (3) | Direct discharges / extraction |
| (4) | Run-off |
| (5) | Precipitation / aerosol |
| (6) | Water Inflow / outflow |
| (7) | Net gas absorption |
| (8) | Net primary production |

$F_1 (F_S)$

$F_2 (F_A)$

$F_3 (F_D)$

$F_4 (F_R)$

$F_5 (F_P)$

$F_6 (F_W)$

$F_7 (F_G)$

$F_8 (F_N)$

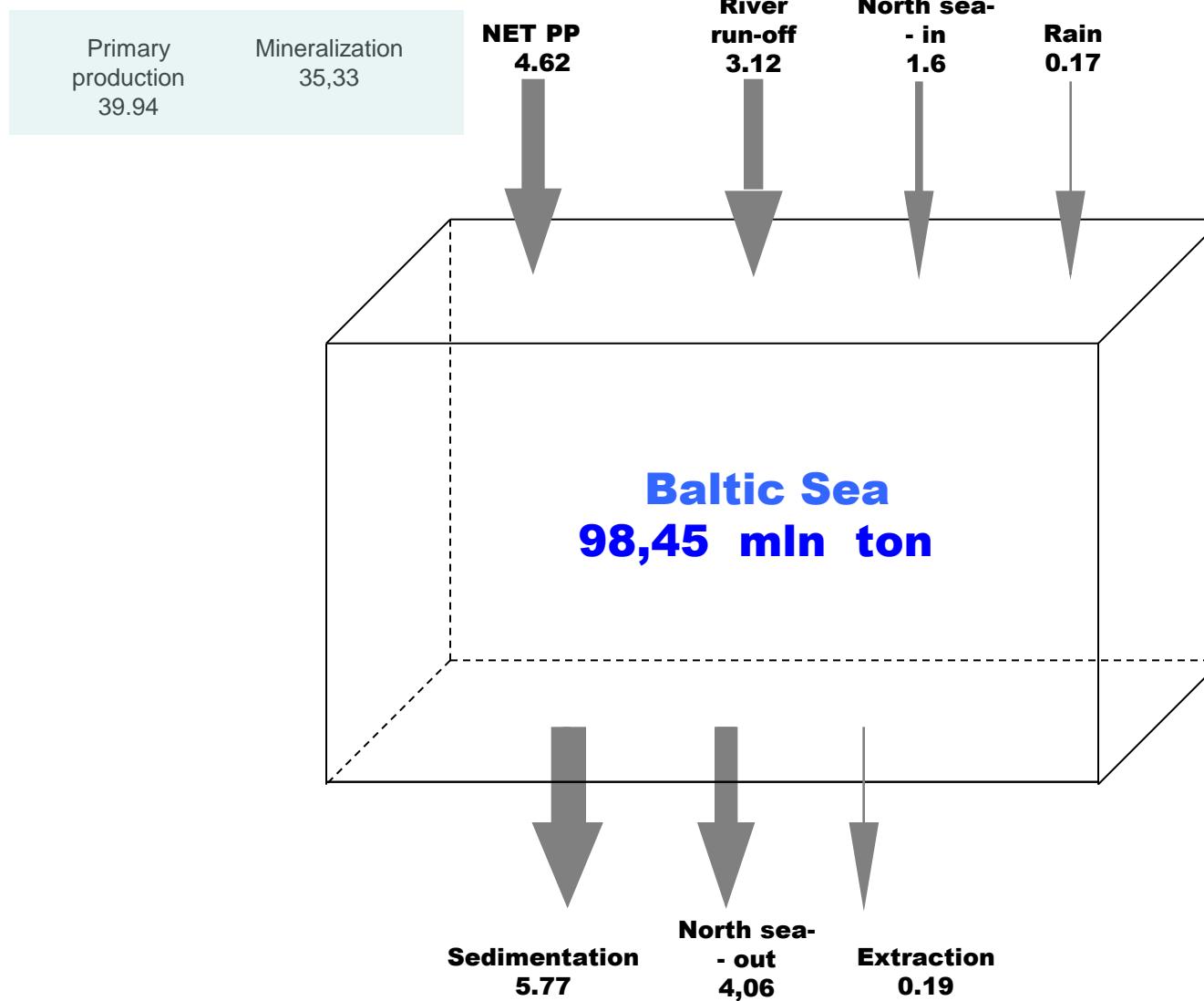
$$SF_W = F_{IW} + F_{OW}$$

$$= F_{iWo} + F_{iWi} + F_{oWo} + F_{oWi}$$

$$SF_W = 0 \text{ (steady state)}$$

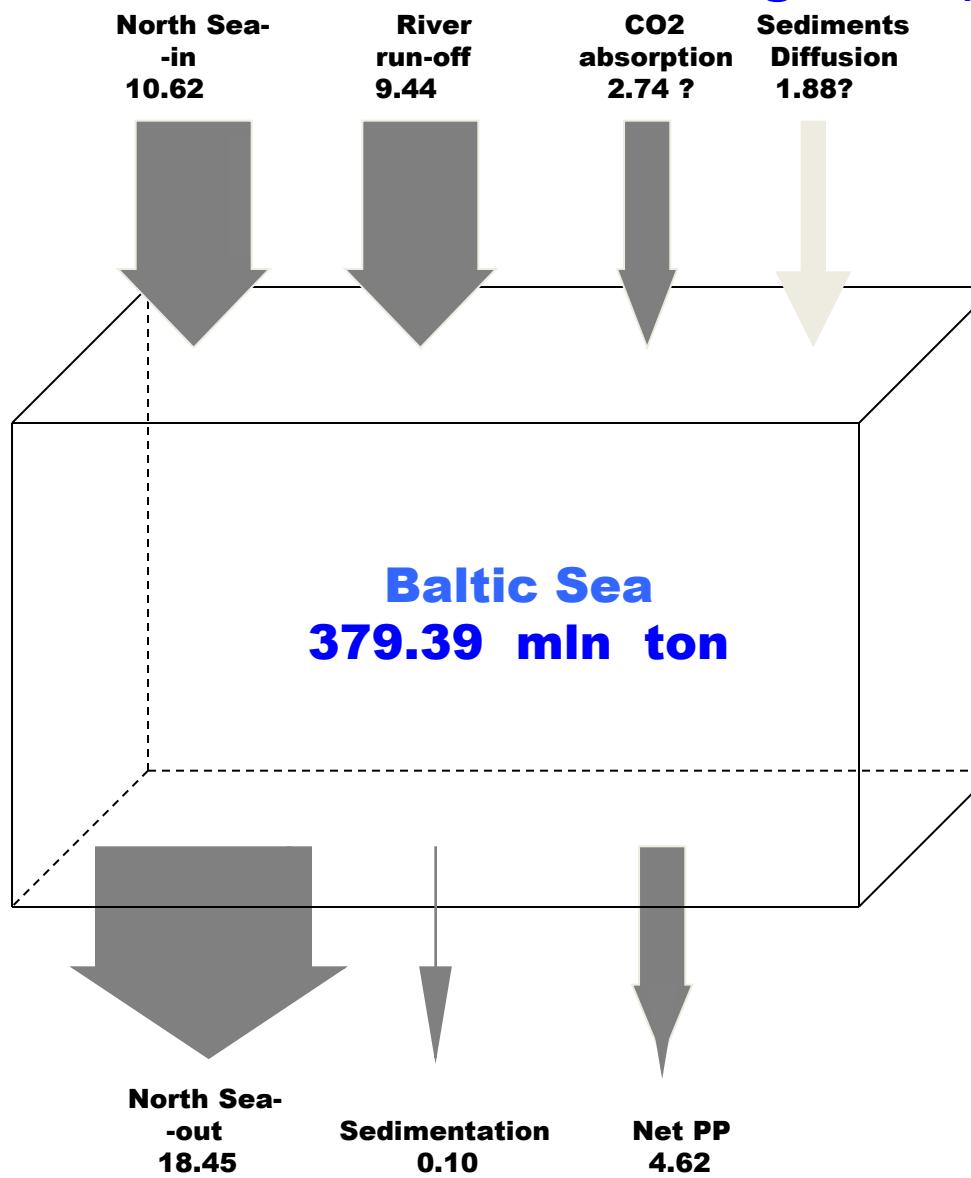
Organic carbon in the Baltic -

**yearly fluxes (10⁶ ton/year)
standing stock (10⁶ ton/year)**



Inorganic carbon in the Baltic -

**yearly fluxes (10^6 ton/year)
standing stock(10^6 ton)**



Budget – is it good for anything?

- Standing stock
- Residence time
 - Corg ~10years
 - Cinorg ~40yers
- Major sinks/sources
- Sensitivity to changes

Sediments

- serve as sink of carbon (C_o - organic)
- the sink term is poorly quantified
- rough estimates indicate that sediments
 1. receive ~50% of organic carbon leaving the Baltic
 2. (~20% of tot carbon)
- sediments are likely to be
 1. a source of ~8% inorg carbon to the Baltic
 2. (~6% of total carbon)

Establishing return flux of carbon from the Baltic bottom sediments to sea-water.

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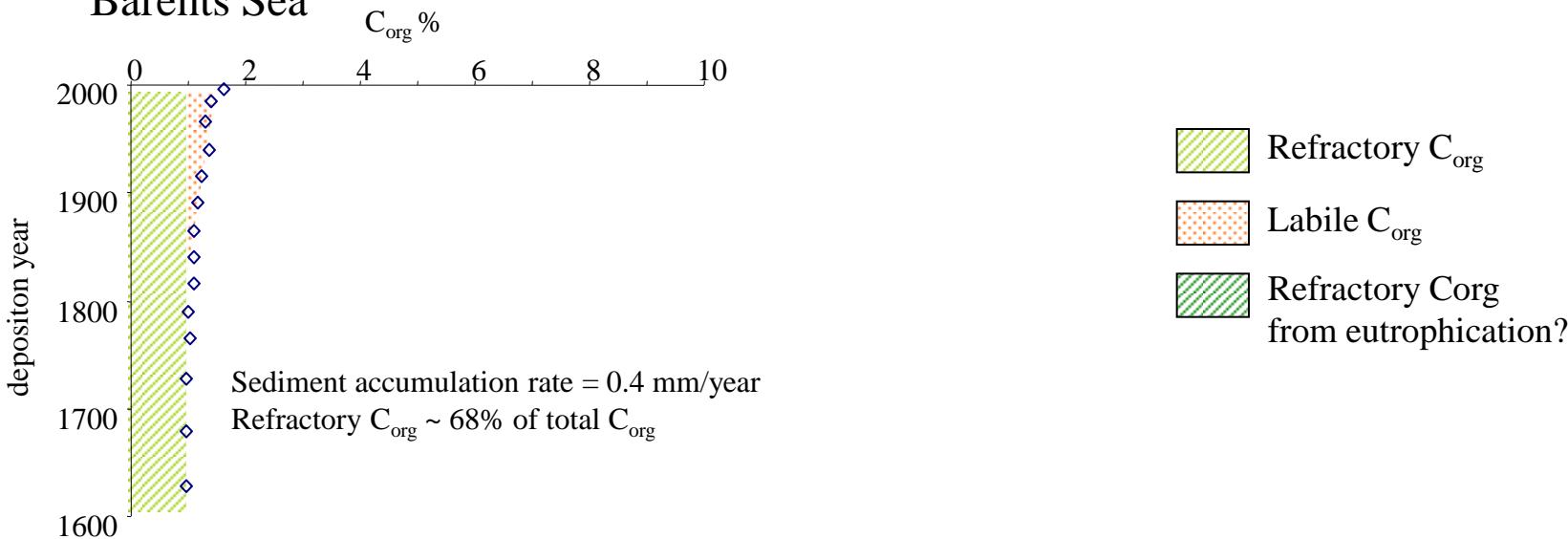
Outline

- why carbon?
- problem
- methods proposed



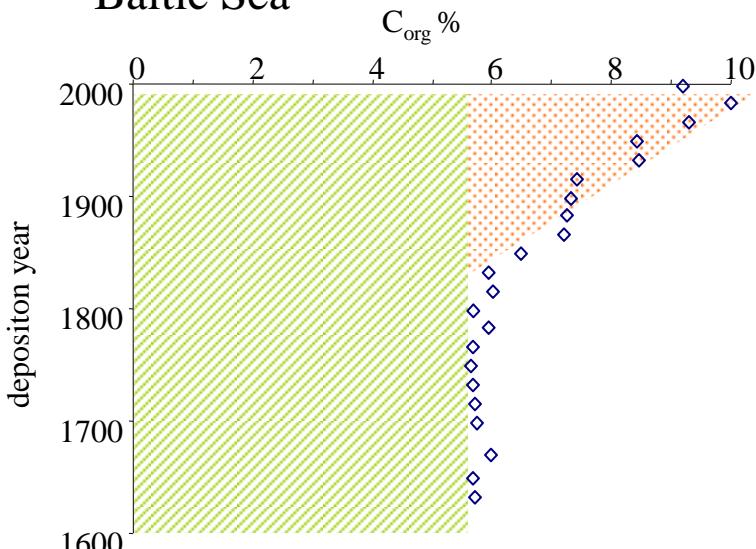
Fresh o.m. production impact to sedimentary organic carbon

Barents Sea

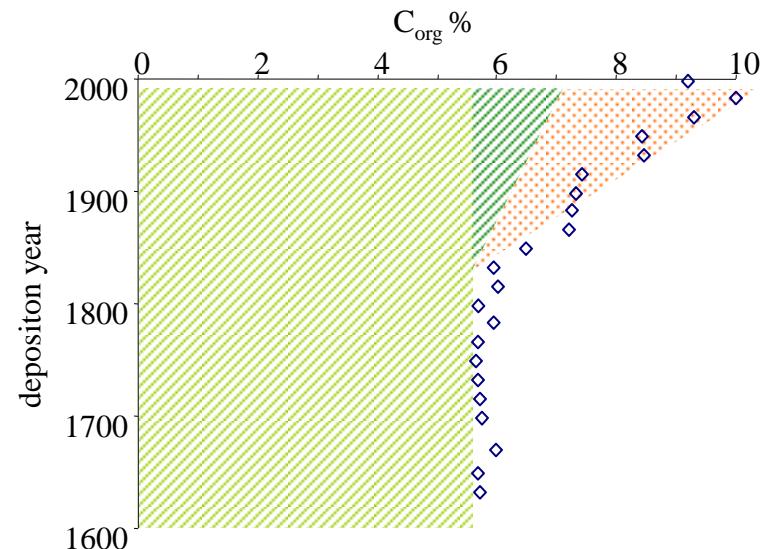


Baltic Sea

no-eutrophication scenario

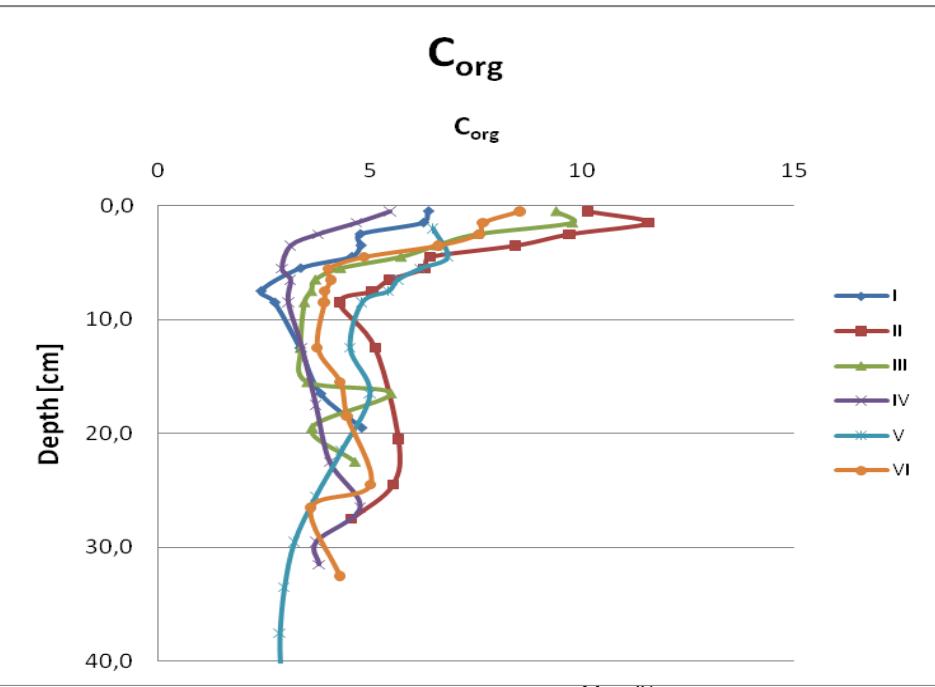
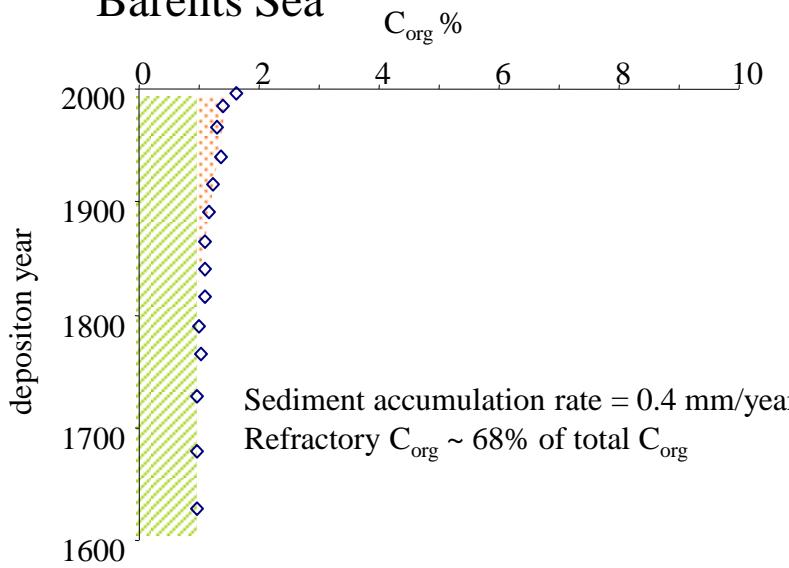


eutrophication scenario

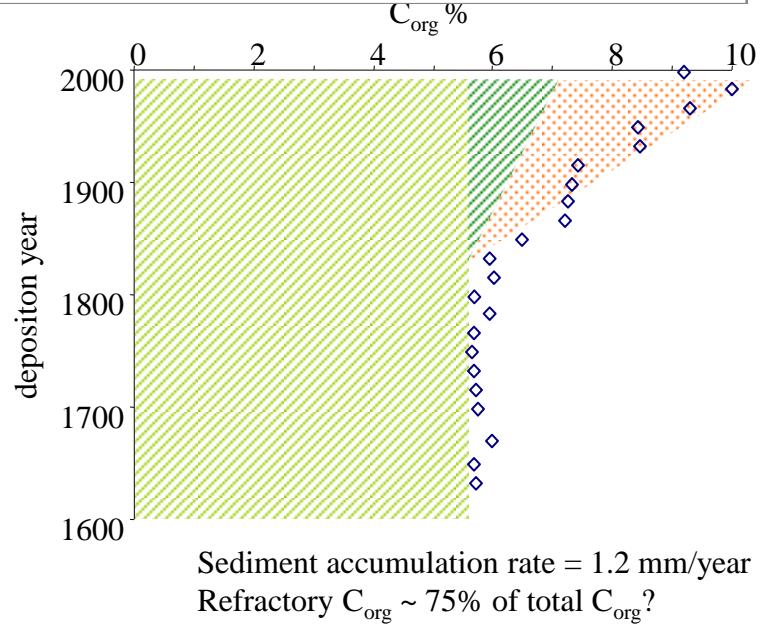
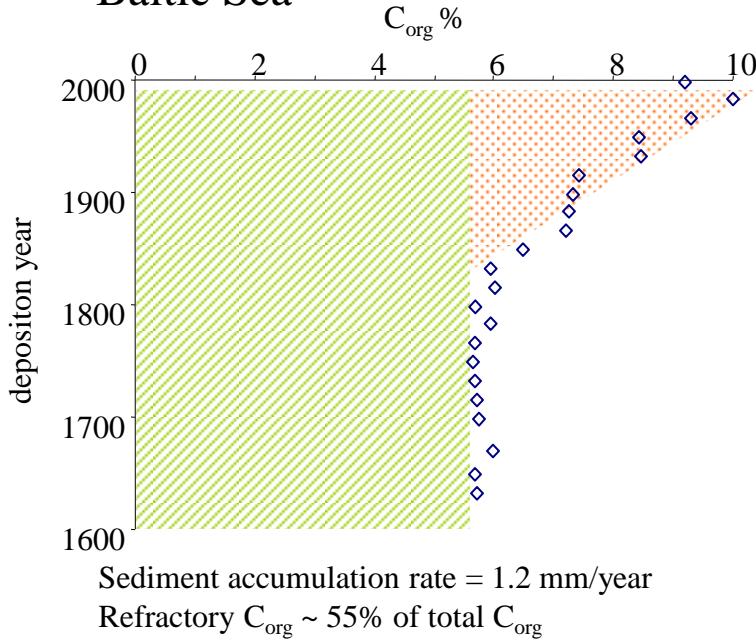


Fresh o.m. production impact to sedimentary organic carbon

Barents Sea



Baltic Sea



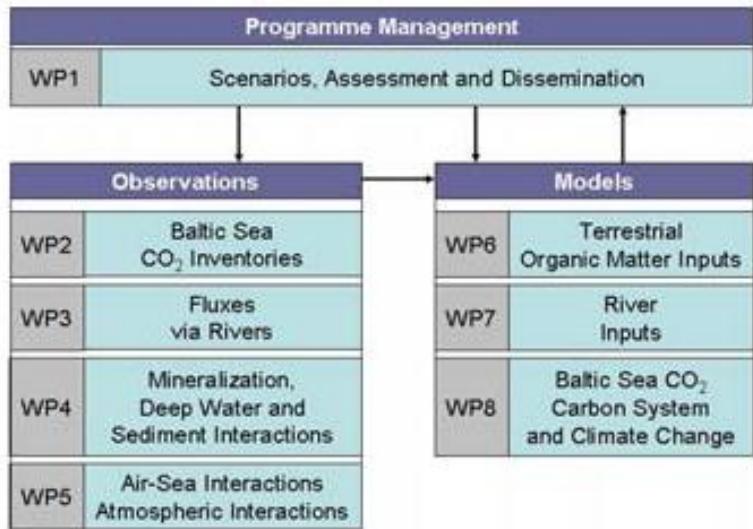


Figure 1. Basic problem addressed in **Baltic-C** (a), and programme structure (b).

WP4. Mineralization of organic material, deepwater–sediment interaction

- a) Quantification of carbon species fluxes through sediment-water interface
- b) C org mineralization in deep water and sediments. Process parametrization and model validation

(Janusz Pempkowiak, Institute of Oceanology Polish Academy of Sciences, Poland)

Mineralization rates of organic carbon in the Baltic Sea sediments

Karol Kuliński, Aleksandra Szczepańska, Anna Maciejewska,
Janusz Pempkowiak

Institute of Oceanology Polish Academy of Sciences, Sopot, Poland



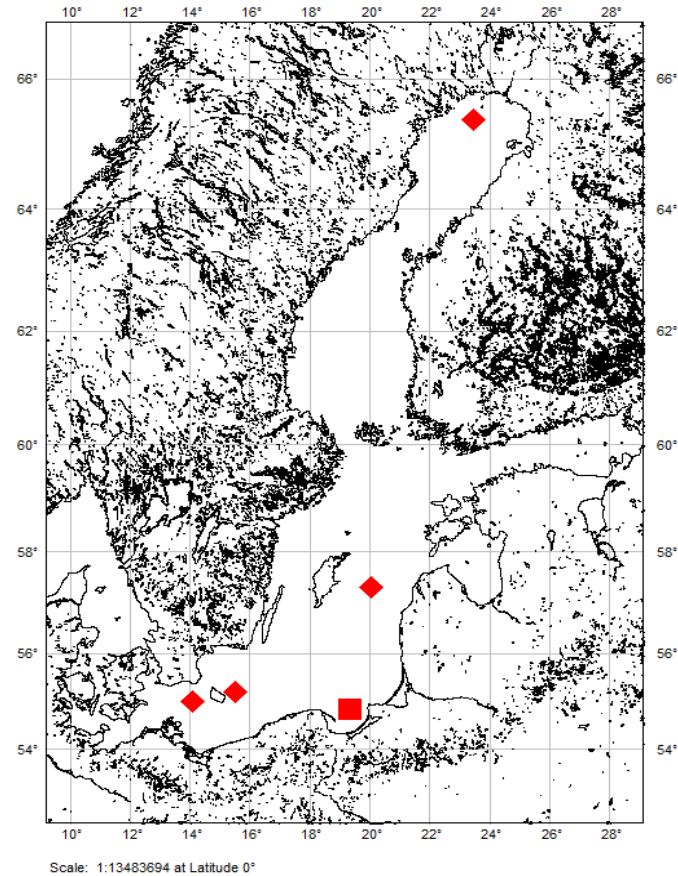
Methods of the carbon return flux estimation from the bottom sediments

1. DIC and DOC concentration in the pore waters

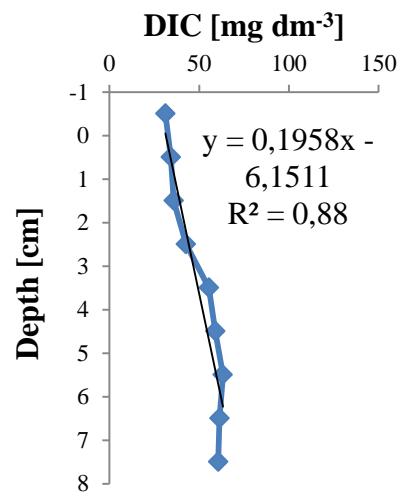
2. „Time Capsule”

Incubation condition:

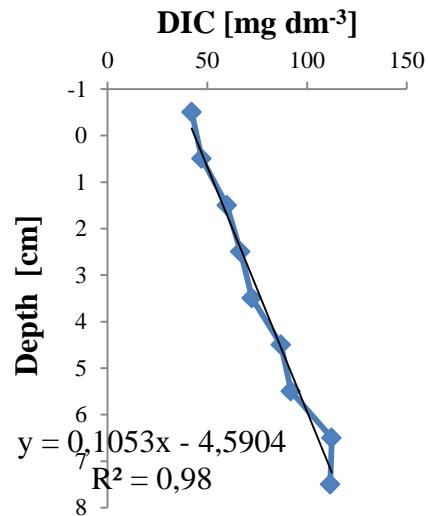
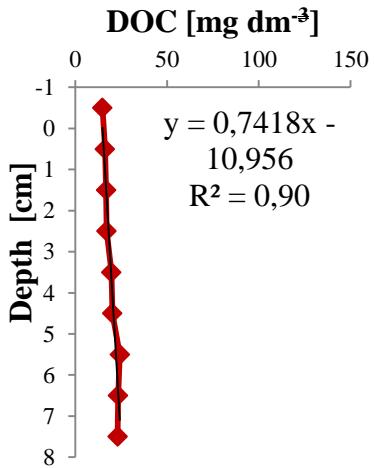
- $19^{\circ}\text{C} \pm 1$
- darkness
- Ar atmosphere



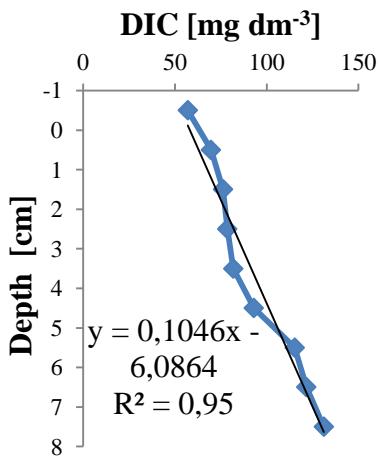
Profiles of DOC and DIC concentration in the pore waters



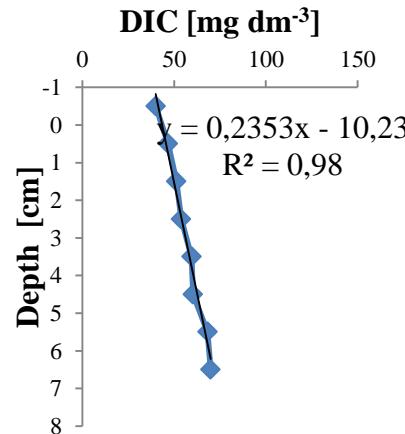
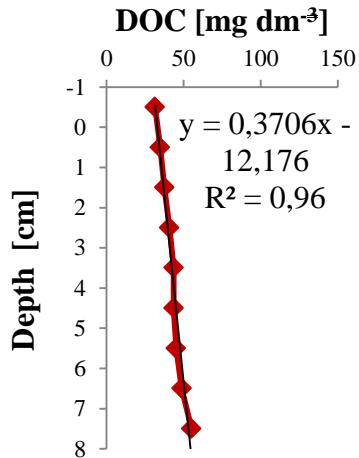
Arcona Basin



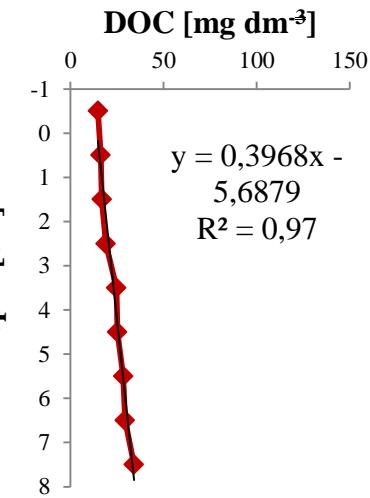
Bornholm Deep



Gdansk Deep



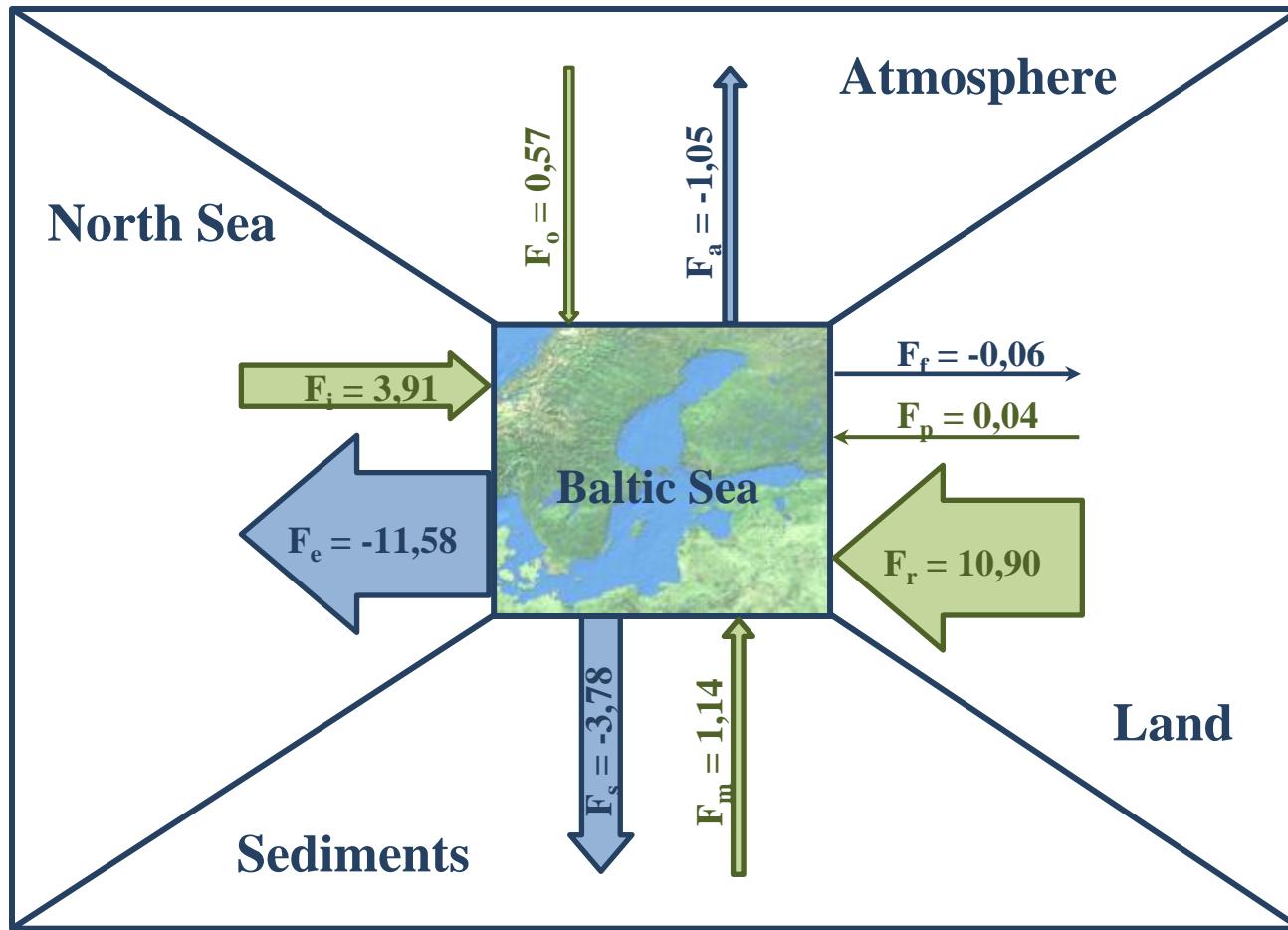
Gotland Deep



Summary

Area of deposition	Carbon return flux from the sediments [g C m ⁻² year ⁻¹]		Return flux % of deposition	Labile carbon [%]
	DIC and DOC profiles	„Time Capsule”	DOC/DIC profiles	„Time Capsule”
Arcona Basin	10,2		51,0	
Bornholm Deep	18,9	-	32,0	
Gdansk Deep	19,1	35,5	32,0	19,9
Gotland Deep	9,5	-	25,0	
Gulf of Riga	9,5	-	25,0	
Gulf of Finland	9,5	-	25,0	
Gulf of Bothnia	8,0	-	33,0	

The carbon budget of the Baltic Sea



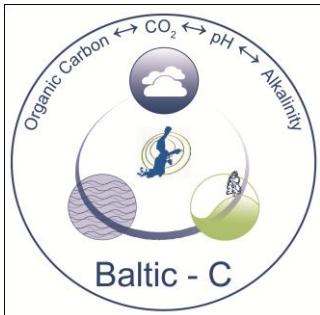
Values are in Tg (10^{12} g) C yr⁻¹

River run-off
IC: 62%
OC: 38%

Import from the North Sea
IC: 95%
OC: 5%

Export to the North Sea
IC: 83%
OC: 17%

Return flux from the sediments
IC: 91%
OC: 9%



Baltic_C bussiness

Baltic-C: Building predictive capability regarding the Baltic Sea organic/inorganic carbon and oxygen systems



WP 4:

Quantification of carbon species fluxes through sediment-water interface. 463136

Organic matter in the Baltic sediments

- deposition rates
- remineralization rates
- burial rates

Baltic_C Meeting; Lund, 2010

Methods of the carbon return flux estimation from the bottom sediments/3

- Determination of the labile carbon fraction in the surface sediments

Incubation

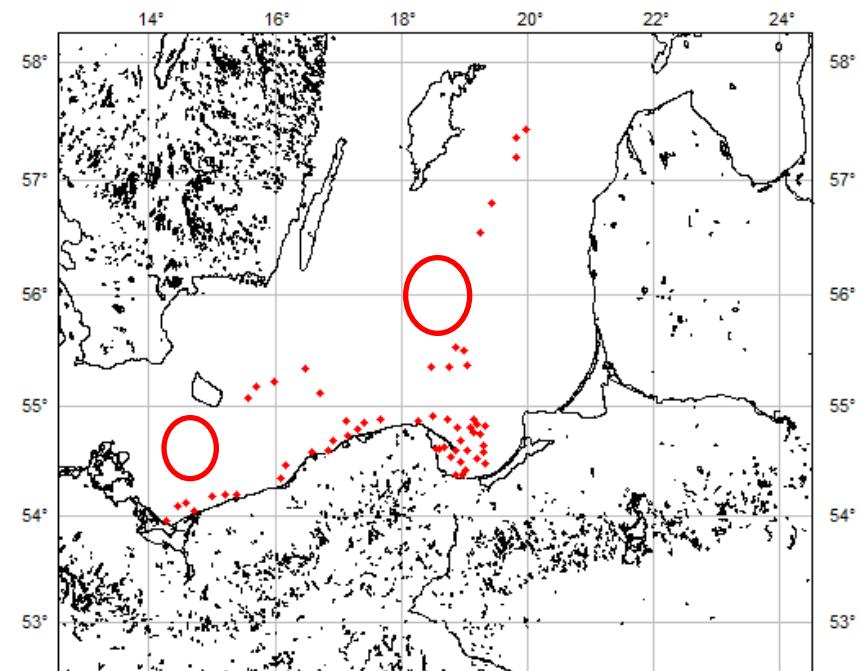
$$v = dC/dt = k C_0$$

v – decomposition rate [$\text{mg C g}^{-1} \text{ d.m. day}^{-1}$]

dC/dt – carbon concentration gradient [$\text{mg C g}^{-1} \text{ d.m. day}^{-1}$]

k – decomposition constant [day^{-1}]

C_0 – concentration in „time 0” [$\text{mg C g}^{-1} \text{ d.m.}$]



Scale: 1:8088729 at Latitude 0°

Conclusions

Source	Number of samples	Average deposition [g C m ⁻² yr ⁻¹]	Average return flux [g C m ⁻² yr ⁻¹]	Return flux % of deposition
Karol Kuliński	8 muddy sediment cores	40	12	30%
Aleksandra Szczepańska	7 muddy sediment cores	38	10	26%
	~30 sandy sediments (in progress)	-	-	Estimated 45%



No burial□just temporary deposition/storage

Sandy sediments as a source of carbon□less than 4% of fluxes from muddy sediments

Deliverables

WP4 Most pressing deliverables_ Uppsala 2009

D.14 Calculate remineralization rates of organic matter basing on existing data	M 6
D.15 New stratified sediment samples collected	M12
D.16 Mineralization rates at the sediment water interface and in the deep water	M12
D.17 Mineralization rates for different environmental conditions	M18

- D.14 Karol Kuliński will talk about remineralization rates
Aleksandra Szczepańska will show results of 'data mining'
- D.15 Sediment cores collected (Aranda, Oceania), Anna Maciejewska
- D.16 Bernd Schneider (?)

WP4 Most pressing deliverables_Lund 2010

D.18	Collected cores analysed	M18
D.19	Mineralization rates established for a range of environmental conditions	M18
D.20	Deposition loads and return flux	M24
D.21	Carbon burial rates established	M30

- D.21 Karol Kuliński will talk about burial rates (**dep.-6.9%, burial-4.7% ;of PP**)
- D.18 Aleksandra Szczepańska has doubled no of analysed cores
- D.20 Calculated for the newly analysed cores; in progress for surface sediments
- D.19 In progress

Deliverables List			
Del. No.	Deliverable Name	WP no.	Delivery date (month)
D1	Estimating environmental costs of change in the acid-base balance (pH).	1	12
D2	Assessment of Baltic Sea CO ₂ system.	1	36
D3	The Baltic-C data base.	1	36
D4	Lecture and notes on the Baltic Sea CO ₂ system under climate change.	1	12
D5	Seasonally resolved pCO ₂ fields for the entire Baltic Sea.	2	12
D6	Seasonally resolved pCO ₂ fields for the entire Baltic Sea: Update.	2	24
D7	Improved process parameterizations (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
D12	River inflow of: alkalinity, pH, total organic carbon, total inorganic carbon, and calcium: Initial database.	3	6
D13	River inflow of: alkalinity, pH, total organic carbon, total inorganic carbon, and calcium: Updated database.	3	18
D14	Calculate remineralisation rates of organic matter based on existing data.	4	6
D15	New stratified sediment samples collected covering Arkona Deep, Bornholm Deep, Gotland Deep, Coastal areas.	4	12
D16	Mineralization rates at the sediment water interface and in the deep water.	4	12
D17	Mineralization rate at different redox conditions.	4	12
D18	Collected cores analyzed.	4	18
D19	Mineralization rates established for a range of environmental conditions.	4	18
D20	Loads of carbon deposited to sediments and return flux of carbon from sediments for the entire Baltic Sea established.	4	24
D21	Carbon burial rates in the Baltic sediments established.	4	30

Deliverables List			
Del. No.	Deliverable Name	WP no.	Delivery date (month)
D22	Data base consisting of C _T depth profiles measured in the central Gotland Sea.	4	36
D23	Report concerning mechanisms of carbon flux to the Baltic sediments.	4	36
D24	Improved parameterisation of the gas exchange transfer velocity.	5	18
D25	Measurements from the first 12 month of the project taken at the Östergarnsholm station.	5	18
D26	Acidic deposition for the Baltic Sea drainage basin.	5	8
D27	Compiled present and future scenario land use data for the Baltic Sea drainage basin.	5	12
D28	Set up and validation of the vegetation model with implementation of DOC export algorithm and coupling to river runoff model.	6	18
D29	Modelling present and past changes in vegetation, CO ₂ exchange and DOC production on watershed basis for the Baltic Sea drainage basins.	6	18
D30	Modelling future changes in vegetation, CO ₂ exchange and DOC production on watershed basis for the Baltic Sea drainage basis	6	24
D31	Data set on A _T , C _T , Ca and C _{org} inputs to the Baltic Sea.	7	6
D32	Model describing A _T , C _T , Ca and C _{org} inputs from 83 major watersheds for the period 1990-2000.	7	12
D33	Model runs and data set A _T , C _T , Ca and C _{org} fluxes from 83 watersheds as a function of land cover changes.	7	24
D34	Model runs and data set on N and P fluxes from 83 watersheds as a function of land cover changes.	7	24
D35	Model runs and data on N and P fluxes from 83 watersheds as a function land use changes.	7	24
D36	Modelling present and past changes of Baltic Sea CO ₂ system.	8	18
D37	Modelling possible future changes in the Baltic Sea CO ₂ system.	8	24

D23

Report concerning mechanism of carbon flux to the Baltic sediments

M36

D.16

Mineralization rates at the sediment water interface and in the deep water (B.Schneider) M12

D.22

Report concerning mechanism of carbon flux to the Baltic sediments (B.Schneider)

M36



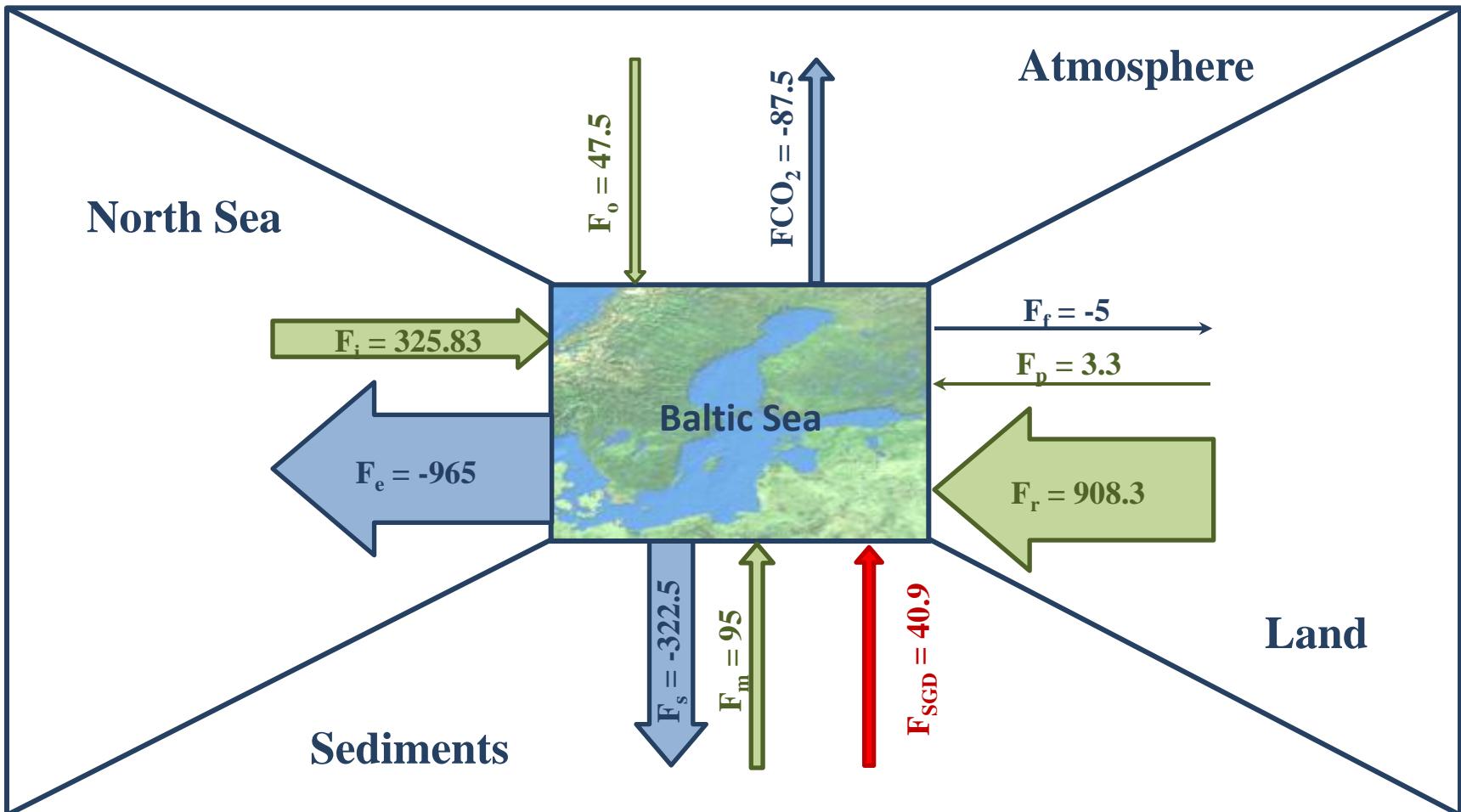
DIC and DOC fluxes to the Baltic Sea -originating from the Submarine Groundwater Discharge (SGD).

Extrapolation based on the Bay of Puck study.



Beata Szymczycza,
Anna Maciejewska, Karol Kuliński, Janusz Pempkowiak
The Institute of Oceanology of the Polish Academy of Sciences

The quantitative carbon circulation for Baltic Sea



(modified after Kuliński, 2010).

POC and DOC **DYNAMICS** in the southern Baltic Sea - model and experimental approach.

Contents:

- POC/DOC introduction
- POC/DOC model
- POC/DOC model verification



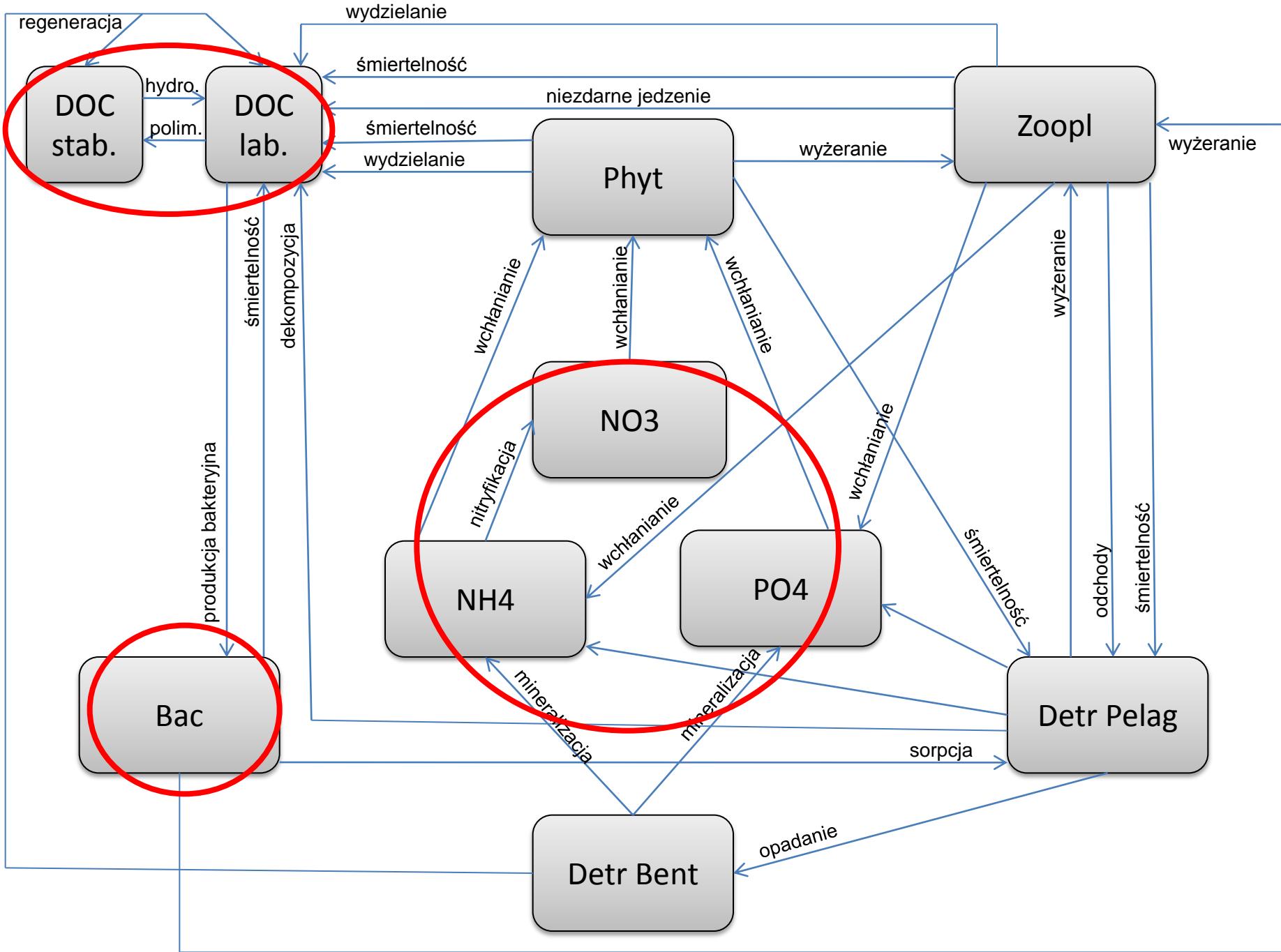
Anna Maciejewska

Lidia Dzierzbicka-Głowacka, Karol Kuliński, Aleksandra Szczepańska,
Janusz Pempkowiak

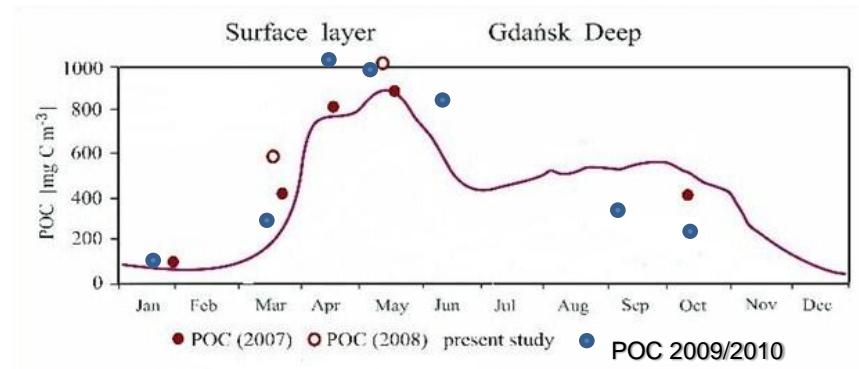
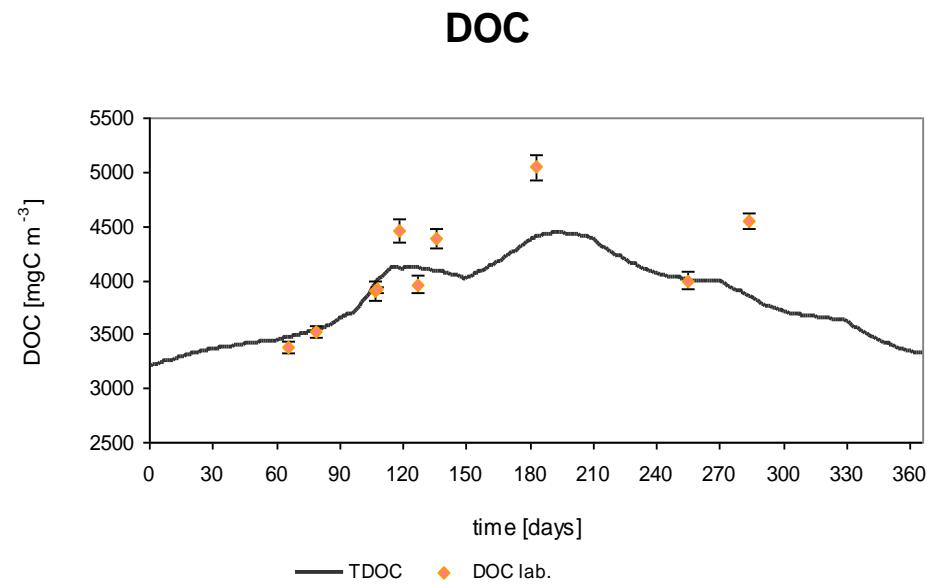
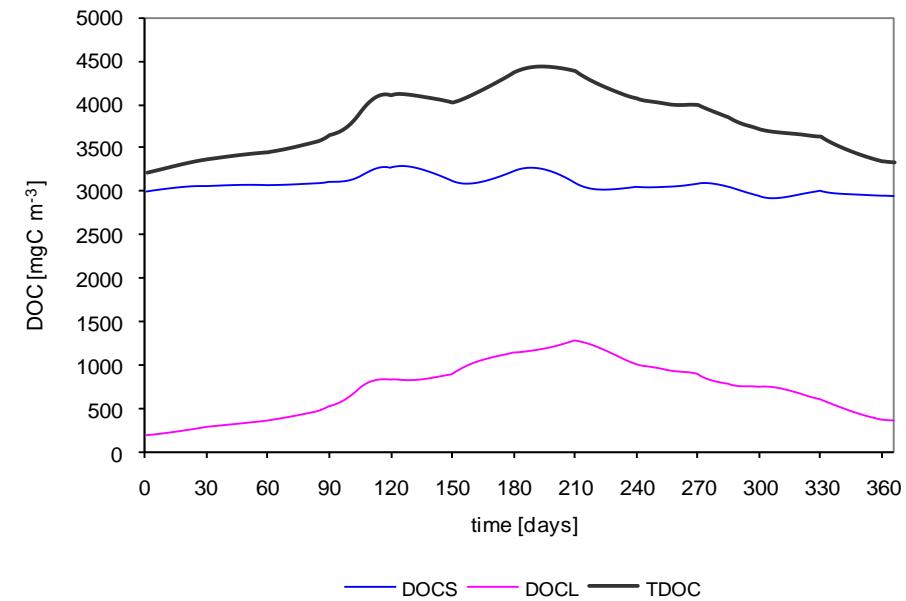
Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland

Extensive measurements for model validation

	POC [mgC/l]			DOC [mgC/l]		
Deep/Month	Gdansk	Gotland	Bornholm	Gdansk	Gotland	Bornholm
January		surface - 0,15 w. column - 0,09			surface - 3,22 w. column - 2,78	
February				surface - 3,93		
March	surface - 0,28 w. column - 0,15	surface - 0,17 w. column - 0,13		surface - 3,38 w. column - 3,59	surface - 3,47 w. column - 3,08	
April	surface - 1,27 w. column - 0,52	surface - 1,23 w. column - 0,56	surface - 0,71 w. column - 0,41	surface - 4,46 w. column - 4,14	surface - 3,43 w. column - 3,35	surface - 3,88 w. column - 3,87
May	surface - 1,17			surface - 5,35		
June / July	surface - 0,88 w. column - 0,41	surface - 0,72 w. column - 0,38	surface - 0,54 w. column - 0,29	surface - 4,98 w. column - 4,21	surface - 3,87 w. column - 3,52	surface - 4,01 w. column - 3,56
August						
September	surface - 0,30			surface - 4,00		
October	surface - 0,22 w. column - 0,15	surface - 0,34 w. column - 0,21	surface - 0,17 w. column - 0,14	surface - 3,89 w. column - 3,72	surface - 3,34 w. column - 3,21	surface - 3,65 w. column - 3,59
November						
December						



DOC - modelled vs. experimental results



Quantification of factors influencing DOC distribution

$$\text{DOC}_M = \alpha_1 + \beta_1 C_a + \gamma_1 C_f + \lambda_1 S$$

DOC_M – modelled DOC concentration [mg/l]

C_a – observed active chlorophyll *a* concentration [mg/m³]

C_f – observed phaeopigment concentration [mg/m³]

S – salinity

$\alpha_1, \alpha_2, \beta_1, \beta_2, \gamma_1, \gamma_2, \lambda_1, \lambda_2$ – coefficients

$$\text{DOC}_M = \alpha_2 + \beta_2 C_a + \gamma_2 C_f + \lambda_2 S$$

α_1 Refractory DOC

β_1 Phytoplankton activity

γ_1 Zooplankton

λ_1 Terrestrial dilution

α_2 Refractory DOC

β_2 Phytoplankton sinking

γ_2 Zooplankton

λ_2 North Sea

Message (es)

- Sediments - important sink/**source** of carbon
 - Burial ≠ deposition
-
- Deliverables ($10 = 8 + 2$)
 - Papers (2- published; 6- submitted)