Annual Report for Baltic-C 2010

Baltic-C

Building predictive capability regarding the Baltic Sea organic/inorganic carbon and oxygen system

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1. Summary of the first year 2009

1.1Objectives:

The overall objective of Baltic-C is to develop and apply a new integrated ecosystem model framework based on the cycling of organic carbon (C_{org}) and carbon dioxide (CO_2) in the Baltic Sea water and drainage basin, taking into account fluxes across the atmosphere and sediment interfaces; the aim is to provide a tool with which to support the management of the Baltic Sea. The program will run three years starting from January 2009. The program is in line with planning and some major results and challenges from the first program year will be presented in this report, which refers to the first 12 month period of the Baltic-C project.

1.2 Scientific achievements:

Baltic-C has finished a successful first year.The program started up in January 2009 and a webpage was created through the BALTEX secretariat (http://www.baltex-research.eu/baltic-c/) were the development of the program can be followed. Two scientific meetings have been organized with the first oriented towards weathering and the second towards marine observations and research cruise design. Several contacts between the different participants have been taken to develop the program. An advanced summer course has been organized together with DTU-Agua, University of Gothenburg, BALTEX secretariat, Nordic Marine Academy and BONUS. Three research cruises for the determination of the total CO_2, C_T, and total alkalinity, A_T, were performed in 2008 and 2009 ("Maria S. Merian", June/July 2008 and August/September 2009; "Aranda", January 2009. The investigations covered all major sub-basins of the Baltic Sea between the Kattegat and the Bothnian Bay. The data together with surface water pCO_2 and O_2 measurements from VOS "FINNMAID" forms an unique base for research and model validation data. River input data for the following parameters: river flow, alkalinity, total inorganic carbon, total organic carbon, pH, temperature, Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} has been collected into a database and will also form the base for model development/validation. However, the data are in many instances incomplete, especially for river monitoring data from Russia in spite of several approaches to Russian authorities at different organizational levels. Sediment cores have been taken and analyzed. Large efforts have also been taken to collect and analyze meteorological forcing data for present and possible future developments. The first year has also been successful in develop and preparing models for the Baltic Sea drainage basin and the Baltic Sea itself that includes the CO_2 dynamics.

1.3 Conclusions:

Comparison with the original research and financial plan:
We are following the original research and financial plan.
Statement if the research plan and schedule of deliverables had to be adapted:
No adaptation necessary.
Do results of third parties will have influence on the working program?
Not expected.
Are there any changes in the future working plan expected?
No changes are expected.
Are there any changes expected for the deliverables?
No changes are expected

2 Detailed descriptions by Working Package

2.1 Work Package 1 – Management and Dissemination

Lead Partner: Anders Omstedt, University of Gothenburg

Researchers involved in the current work:

GU: Anders Omstedt and David Ryner

2.1.1 Objective

To implement the effective programme management, synthesis, assessment, and dissemination of the results of Baltic-C.

2.1.2 Methodology and scientific achievements

Task 1.1 ; *Programme management*.

Review project implementation and set annual work plans. A Baltic-C Scientific Steering Committee consisting of the project coordinator has been formed. Two scientific meetings have been organized with the first oriented towards weathering and the second towards marine observations and research cruise design. For international transparency a Baltic-C webpage was created through the BALTEX secretariat (http://www.baltex-research.eu/baltic-c/) were the development of the program can be followed. Annual Baltic-C report finalized. An advanced summer course has been organized together with DTU-Agua, University of Gothenburg, BALTEX secretariat, Nordic Marine Academy and BONUS. Starting up the work on organizing the Baltic-C data base. The outcome of the summer school is planned to become a book and a draft chapter including the Baltic-Sea CO_2 system has been submitted. To strengthen the cooperation between University of Gothenburg and Institute of Baltic Sea in Warnemuende, Dr Bernd Schneider has been appointed as Visiting Professor at University of Gothenburg.

Publications:
Omstedt, A. (2010). The Baltic Sea Marine System: An introduction. Lecture notes from the Bornholm Summer school, 2009, submitted.

Task 1.2: *Workshop and estimated environmental economic aspect*.

Due to budget cuts this workshop will be organized outside the Baltic-C program and at a later phase. Initiatives have been taken to have a joint BONUS meeting together with HELCOM and other end users.

2.2 Work Package 2 – Measuring the Baltic Sea CO_2 system and carbon inventories (Bernd Schneider, Baltic Sea Research Institute, Germany; participant code 2).

Lead Partner: Bernd Schneider, Baltic Sea Research Institute (IOW), Germany

Researchers involved in the current work:

Bernd Schneider, Dr. Anne Loeffler

2.2.1 Objective

To provide validation data for the biogeochemical modelling of the Baltic Sea carbon cycle and to derive process parameterizations for biomass production and nitrogen fixation.

2.2.2 Methodology and scientific achievements

The contributions to Baltic-C are based on a comprehensive measurement program. Records of the surface water pCO_2 and O_2 are performed with a fully automated measurement system, whereas research cruises are performed for investigations of the distribution of CO_2/organic carbon variables in the water column. The data are used to estimate biogeochemical transformation rates and are available for model validation through the Baltic-C data base. The studies resulted in three papers that refer to Tasks 2.1 to 2.3.

Task 2.1: Recording surface water pCO_2 and O_2 using a fully automated measurement system deployed on VOS "FINNMAID".

The surface water pCO_2 and O_2 measurements on VOS "FINNMAID" were performed throughout 2009 and yielded four pCO_2 and O_2 data sets each week for the transect between Lübeck and Helsinki. Since summer 2009 "FINNMAID" is also visiting Gdynia and is thus passing the also central Bornholm Sea. The FINNMAID data from a previous year were used to quantify the biomass production in the eastern Gotland Sea. Relating the production rates to the availability of dissolved inorganic nitrogen resulted in a nitrogen fixation estimate that deviated significantly with regard to the timing and intensity from other studies.

Publication:
Schneider, B., Kaitala, S., Raateoja, M. and 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.

Task 2.2: Determining the organic/inorganic carbon and oxygen pools in different Baltic Sea sub-regions.

Three research cruises for the determination of the total CO_2, C_T, and total alkalinity, A_T, were performed in 2008 and 2009 ("Maria S. Merian", June/July 2008 and August/September 2009; "Aranda", January 2009. The investigations covered all major sub-basins of the Baltic Sea between the Kattegat and the Bothnian Bay. The data were used to characterize the horizontal and vertical distribution of C_T and A_T, and to interpret these in terms of the different hydrographic and biogeochemical conditions.

Publication:

Beldowski, J., Loeffler, A., Schneider, B. and Joensuu, L., 2010. Distribution and biogeochemical control of total CO_2 and total alkalinity in the Baltic Sea. J. Mar. Sys., in press.

Task 2.3: Compiling and evaluating CO_2/carbon data collected by previous research and monitoring programmes.

The compilation of data focused on measurement of total CO_2 in the deep water at the central Gotland Sea station BY15. The investigations started 2003 and had a temporal resolution of about 3 months. A period of deep water stagnation was identified during 2004 – 2006 and was used to establish mass balances for total CO_2 and dissolved inorganic nitrogen. Taking into account vertical mixing, mineralization and denitrification rates were calculated for sub-layers (Δz = 25 m) at depths below 150 m.

Publication:
Schneider, B., Nausch, G. and Pohl, C.. Mineralization of organic matter and nitrogen transformations in the Gotland Sea deep water. Submitted to Mar. Chem., 2009.

2.3 Work Package 3 – Inventory of river runoff data

Objectives: Combining existing and new data to provide a reliable dataset of parameters for the river input evaluations of the carbon components and for validating the river runoff models.

Lead Partner: Matti Perttilä, Finnish Meteorological Institute , Finland.

Researchers involved in the current work:

Matti Pertillä, Laura Joensuu

2.3.1 Objective

Combining existing and new data to provide a reliable dataset of parameters for the river input evaluations of the carbon components and for validating the river runoff models.

2.3.2 Methodology and scientific achievements

Task 3.1: Evaluating the river input concentrations from existing monitoring and research data.
Input concentrations were collected for the following parameters: river flow, alkalinity, total inorganic carbon, total organic carbon, pH, temperature, Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}. Data was collected at one month resolution for the years 1990 – 2008. Appropriate data for Finnish

and Swedish rivers was obtained from the HELCOM data system (www.ymparisto.fi). The HELCOM monitoring system for river input is designed for eutrophication and pollution monitoring, not for studying the effects of the climate change. Of the above parameters, only TOC (total organic carbon) is included (as a voluntary parameter). Thus there was very little other data in the HELCOM data files, except from Finland and Sweden. Data for other rivers was obtained either through personal contacts or with the help of national information centers. The sources are listed in the readme file with the data compilation. For most river inputs, the available data is incomplete with respect to the aim (years 1990 – 2008 at monthly resolution), but can nevertheless be used for modelling the changes (see WP 7). The only major river for which data was not obtained is the Neva, in spite of several approaches to Russian authorities at different organizational levels. Because of the importance of Neva, the lack of data cannot probably be ignored, and thus for this river, other means of evaluation will be attempted.

The data compilation is available at ftp://ftp.fmi.fi (deliverable 12) as an Access file.

Task 3.2: Evaluating river concentrations from marine data.
The work to complete the monitoring data is proceeding. Two approaches will be used. Both of them, the extrapolation of marine data to zero salinity, and a box-model approach, will, however, yield input approximations as annual averages.

Task 3.3: Measuring input concentrations.
Input concentrations of the major Finnish and Swedish rivers running into the Gulf of Bothnia have been measured once, in order to obtain a comparison check of the sampling/analysis methodology. Possibility of creating a temporary monitoring system for the Neva river is under consideration (will be probably abandoned because of administrative difficulties?)

2.4 Work Package 4 – Mineralization of organic material, deepwater–sediment interaction

Lead Partner: Janusz Pempkowiak, Institute of Oceanology, Polish Academy of Sciences, Poland

Researchers involved in the current work:

Janusz Pempkowiak, Anna Maciejewska and Aleksandra Szczepańska

2.4.1 Objective

The work package aims to: 1. quantify organic matter remineralization rates based on organic matter concentration profiles and labile vs. resistant fractions of organic matter in bottom sediments; 2. quantify the organic matter remineralization rates at the sediment–water interface based on CO_2 concentration time series in the above-bottom water layers; 3. quantify the carbon species (both organic and inorganic) fluxes across the sediment–water interface; and 4. quantify the carbon burial in bottom sediments as the proportion of carbon originally deposited in sediments.

2.4.2 Methodology and scientific achievements

Collecting new stratified samples of bottom sediments.
In January, 2009 during the all Baltic-C scientific cruise on RV Aranda, 12 soft bottom sediment cores (21-39cm long) were collected by means of a Gemini correr (3-Bothnian Bay, 8-Baltic Proper, 1-Kattegat). The cores were cut into 10mm thick slices and stored at -20oC for analysis in the laboratory.
In May, 2009 during the RV Oceania cruise to the southern Baltic 15 sediment cores (Gemini, soft bottom, 23-37cm long, cut into 10mm thick slices) were collected from Gotland Deep (4 cores), Gdańsk Deep (6cores), Bornholm Deep (5 cores). Moreover 7 samples of sandy sediment cores (12-19 cm long) were collected from the Gdańsk Bay (2), Puck Bay (2), and Pomeranian Bay (3), Sandy cores were cut into 1cm thick slices and stored in the deep freezer.
All collected samples are being analysed for dissolved inorganic carbon (DIC), dissolved organic carbon (DOC), 210-Pb, 137-Cs, Ntot, Ptot

-Data mining
Data characterizing profiles of organic matter (POC), 210-Pb, 137-Cs, Ntot, Ptot, Fe, and Al in the sediment cores collected between 1990and 2008 were gathered, quality checked and included into Excel files.
All in all, 17 complete sets of data (profiles of the above mentioned properties) , and 32 partial data sets (some properties missing) were uncovered and preserved for further usage.

-Remineralisation rates of organic matter in the Baltic sediments
Profiles of Inorganic carbon and organic carbon in the fine sediment cores were used for calculations of 'carbon return flux' from sediments to the overlying water. All in calculations for 6 cores were completed. It turned out that the return flux amounts to 12-37gC/m2an. Most of the return flux consist of inorganic carbon (74-92 %). The return flux in from the sandy sediments merely exceeds the detection limit of the procedure used (0.5 g/m2annum).There are large spatial differences among major Baltic basins regarding the return flux and the organic components of the flux. This phenomenon is a subject of further studies.
It was also established that in the surface-most soft sediments labile carbon comprises 21-29% of organic carbon, while in the sandy sediments the fraction is 0-3%. In the subsurface (8-12 cm deep, below sediment-water interface) sediments the labile fraction constitutes some 9% of the total, while at the depth of 25 cm it is just 0-3%.
Further studies on the subject are being carried out.

Organization, administration, management

Two PhD students have been hired to carry out the Baltic-C related work: Anna Maciejewska (POC /DOC in the water column- 1D numerical modelling/experimental verification), Aleksandra Szczepańska (organic/inorganic matter in sediments, sediments radioisotopic dating).

The WP4 team (4 people strong) attended two BALTIC-C workshops: in Uppsala (06.2009) and Warnemunde (11.2009); 6 short (10min)), and 1 longer (25min) presentations were delivered covering different aspects of sedimentary, and the water column organic/inorganic matter.

One paper was published (Szczepańska A, Zaborska A, Pempkowiak J, 2009, Sediment accumulation rates in the Gotland Deep, Baltic Proper obtained by ^{210}Pb and ^{137}Cs methods. Annal.Envir.Prot., 2009, 165-174 ;this is a local journal, paper is in English).

The work is carried according to plan.

Some aspects of organic carbon dynamics in the water column (source of org. carbon in sediments) are being pursuit. This may be added as additional deliverable to the BALTIC-C workload at a later stage.

Are there any changes expected for the deliverables?

There is a possibility of introducing one additional deliverable related to POC/DOC seasonal dynamics in the water column.

2.5 Work Package 5 – Atmospheric forcing (air–sea interaction, scenarios)

Lead Partner: Anna Rutgersson, Uppsala University, Sweden

Researchers involved in the current work:

Anna Rurgersson, Björn Carlsson and Maria Norman

2.5.1 Objective

To provide acid deposition data and scenario data for the biogeochemical modelling of the Baltic Sea carbon cycle and to improve the parameterizations of the air–sea exchange of CO_2.

2.5.2 Methodology and scientific achievements

The first milestone of the project (M1) is now reached and integrated data for past, present and future model runs is available.

Task 5.1: Air–sea interaction.

There is ongoing work on taking and analysing measurements of CO2 fluxes as well as additional parameters at the Östergarnsholm site with the purpose to develop new improved formulations of the air-sea transfer coefficients.

Task 5.2: Acid deposition.

A data base for the acid deposition to the different Baltic Sea basins as well as to the Baltic Sea drainage basin is generated for the period 1960 to 2006. The acid deposition is taken from the EMEP chemical transport model (for 1990 to 2006) (http://www.emep.int/OpenSource/index.html). For the years 1960–1989, the trends in emissions were scaled by the yearly mean in 1990 and multiplied by the mean seasonal variation of the depositions. The emissions were taken from the gridded (1°x1°) EDGAR-HYDE data set (http://www.mnp.nl/edgar/model/). It contains global anthropogenic emissions of NO_x, SO_2, NH_3 among others species which are spatially modeled. Also a data base for deposition of minerals is generated over the drainage basin. The deposition of minerals is taken from the measurements of the EMEP co-operative program (http://tarantula.nilu.no/projects/ccc/emepdata.html). The measurements are spatially interpolated. In the outer regions a background field was applied, either constant at the mean value of all available stations or as a fitted southward or eastward gradient. There are data from 1977–2006, but since the observation network is very coarse until about 1990 only data after 1989 is used. To construct data for the period 1960–1989 monthly average spatial fields (precipitation-weighted) were used for the whole period. Thus it was assumed that there is no trend in mineral deposits. Data base of acid deposition, mineral deposition as well as CO2 concentration (derived according to Rutgersson et al., 2009) is reported as Deliverable 26 (D26) to the BONUS system and a report describing further analysis and a more detailed description of the method to derive the data is presently being produced.

Task 5.3: Climate scenarios and land-use data.

Global Climate scenarios regionally downscaled by the regional climate model RCA is available from the Swedish meteorological and Hydrological Institute through the EU projects PRUDENCE and ENSEMBLES. Climate scenario data is here extracted for the Baltic Sea drainage basin as well as for the Baltic Sea basins for a period representing the climate change between 1960 and 2100. Data from several emission scenarios (A1B, A2 and B1) as well as several global climate models (ECHAM 5, HadCM3 and CCSM3) is derived to be used to force the different model components within the Baltic-C. The data base of atmospheric forcing during past present and future climate in the Baltic Sea region is reported as Deliverable 27 (D27) in the project.

2.6 Work Package 6 – Modelling the organic matter input from terrestrial vegetation and soils

Lead Partner: Benjamin Smith, Lund University, Sweden

Researchers involved in the current work:

LU: Ben Smith, Guy Schurgers

External collaborator (not funded by Baltic-C): Alla Yurova, Institution for Numerical Mathematics, University of Moscow.

2.6.1 Objective

The work package will develop and validate the modelling of the organic matter input from terrestrial vegetation and soils and explore the coupling to the river runoff carbon model.

2.6.2 Methodology and scientific achievements

Task 6.1: Terrestrial carbon model setup, validation, and coupling to the river runoff carbon model (WP7).

The terrestrial vegetation/biogeochemistry model LPJ-GUESS has been enhanced by incorporation of a submodel for DOC production and sorption dynamics in organic wetland soils based on the model of Yurova et al. 2008. The model has been set up for application across the 50 x 50 km simulation grid on which climate driver data (originating from the regional climate model RCA, driven with ERA40 reanalysis and climate model scenario data) will be provided by WP5. Wetland area fractions provided by WP7 are used to scale the model-generated DOC concentrations to the grid cell scale. For coupling to the river runoff model of CSIM, monthly grid cell averages of DOC production will be provided as forcing fields to be read in by the CSIM model (WP7).

A concise validation of the model was performed to evaluate general model outcome for potential natural vegetation applying the regional climate model data. A comparison with a simulation driven by CRU data (gridded station data, provided by the Climatic Research Unit of the University of East Anglia) yielded a very similar vegetation distribution and reasonable agreement in net primary productivity (NPP). Model evaluation of DOC fluxes needs to be performed, this will be performed based on observations in both head water and in river water. For the latter, cooperation with WP7 will take place, for establishing the link between the DOC production and river discharge there are still unresolved issues with regard to mass conservation that will need to be sorted before.

Task 6.2: Modelling present and past changes in vegetation structure and functioning and in dissolved organic carbon export.

These experiments are currently being set up and we expect to deliver the results on time by June 2010.

Task 6.3: Modelling possible future changes in vegetation structure and functioning and in dissolved organic carbon export

No progress yet.

Reference

Yurova, A., Sirin, A., Buffam, I., Bishop, K. & Laudon, H. 2008. Modelling the dissolved organic carbon output from a boreal mire using the convection-dispersion equation: Importance of representing sorption. Water Resources Research 44, W08411.

2.7 Work Package 7 – Modelling the input A_T, C_T, Ca, and C_{org} from all rivers to the Baltic Sea

Lead Partner: Christoph Humborg, Stockholm University, Sweden

Researchers involved in the current work:

Christoph Humborg, Magnus Mörth and Teresia Wällstedt

2.7.1 Objective

The work package will model the river inflow of dissolved inorganic and organic carbon species, Ca, N and P from 83 major watersheds forming the Baltic Sea catchments. Also to make scenario analyses on impacts of climate change and changes in land usage patterns on A_T, C_T, Ca, and C_{org} , N and P land-sea fluxes from the Baltic Sea catchments.

2.7.2 Methodology and scientific achievements

Task 7.1: Compilation of river chemistry and hydro-meteorological forcing data.

The first year of the project within the BALTIC-C program WP7 has been highlighted with several key events. A Post Doc was hired in June 2009 (Teresia Wällstedt) to help with the work of compiling data and later look into modelling of inorganic C in rivers. Together with Matti Pertilä (WP3) river data was compiled for the whole Baltic Sea region in late June 2009 (one of the tasks within the WP). However, the data was in many instances very incomplete, especially for river monitoring data from Russia, Latvia and Lithuania. Incomplete was also data on for example water temperature at the sample occasion, which is an essential parameter for speciating the inorganic carbonate system. Much work during the last months has therefore been devoted to relate air temperature to water temperature, which at the start of the project was not foreseen, although this was foreseen to be important for climate scenario

runs. The good thing is that we now believe that we can publish something on this work as this will be an major issue for everybody dealing with river chemistry in the region.

Task 7.2: Model calibration and validation of A_T, C_T, Ca and Corg inputs.

The work package is very dependent on the data from other WPs in the project. During the year deposition data has been received from the Uppsala, which means that weathering can be estimated for each watershed. A meeting was also held in September in Lund to plan the work with WP6 that is dealing with landscape changes and leakage of organic carbon (DOC) form the root zone. Agreements were made on the landscape types to use and that the data received that will be used to run the CSIM model will be gridded (in a database format). However, data on DOC will not be delivered until July 2010 and changes in DOC with time can therefore not been tested as a function of landscape changes although one deliverable is now to calibrate and validate the model this first year. This is unfortunate.
After testing some approaches to model DIC (Dissolved Inorganic Carbon) and DOC (Dissolved Organic Carbon) we have found that the CSIM model should generate data on base cations and anions, DIC and DOC from type concentrations and thereafter solving for Alkalinity, pH and PCO2 by constraining these on chemical relationships with base cations, anions, DIC and DOC.
The model is now changed to include base cations, anions, DOC and DIC (CSIM can in the current developed version accept any input parameter by having the option to define own variables) and will for each time step calculate Alkalinity, pH and PCO2. An interface for easily run the model is still lacking, but will be added early next year. A document has been produced to show that the model is working.

Task 7.3: Scenario analyses of A_T, C_T, Ca and C_{org} inputs as a function of land cover change and changes in river discharge as an effect of regional climate change.
Will come next year

Task 7.4: Scenario analyses on effects of regional climate change on N and P fluxes from 83 major watersheds forming the Baltic Sea catchment.
Will come next year

Task 7.5: Scenario analyses on changes in land cover types (agricultural vs. forest vs. wetlands) and land use patterns (changes in fertilizer use and livestock density) on N and P fluxes from 83 major watersheds forming the Baltic Sea catchments.
Will come next year

2.8 Work Package 8 – Modelling the Baltic Sea physical–biogeochemical system based on the CO_2/O_2 dynamics and climate change

Lead Partner: Anders Omstedt, University of Gothenburg, Sweden

Researchers involved in the current work:
PhD Student Erik Gustafsson, PhD Student Karin Wesslander, PhD Student Moa Edman

2.8.1 Objective

The work package will develop, validate, and explore a new Baltic Sea physical–biogeochemical model system based on CO_2/O_2 dynamics and applied to past, present, and possible future climate change studies.

2.8.2 Methodology and scientific achievements

Task 8.1: Modelling present and past changes of the Baltic Sea CO_2 system.

The Baltic Sea CO_2 has now been introduced into a well established process-oriented Baltic Sea model and the present and past changes have been studied and will be reported Month 18.
Publications:
Wesslander, K., Omstedt, A., Schneider, B., (2010). Inter-annual and seasonal variations of the CO_2 air–sea balance in the central Baltic Sea and the Kattegat. Submitted.

Omstedt, A. , Gustafsson, E. and K., Wesslander, (2009). Modelling the uptake and release of carbon dioxide in the Baltic Sea surface water. Continental Shelf Research 29, 870–885. DOI: 10.1016/j.csr.2009.01.006.

Task 8.2: Modelling possible future changes in the Baltic Sea CO_2 system.

Before running scenarios we have analyzed factors influencing the acid-base (pH) balance of the Baltic Sea. Preparation of scenario runs are in developments and forcing fields are under preparation. Deliverable Month 24.

Publications:
Omstedt,A., Edman, E., Anderson,L., and H., Laudon (2010).Factors influencing the acid–base (pH) balance in the Baltic Sea: A sensitivity analysis. Submitted