International Baltic Earth Secretariat Publication No. 6, August 2015

International advanced PhD course on

Impact of climate change on the marine environment with special focus on the role of changing extremes

Askö Laboratory, Trosa, Sweden, 24 - 30 August 2015

Programme, Abstracts, Participants

Edited by
Marcus Reckermann and Silke Köppen

Stockholm University

Baltic Earth
Earth System Science for the Baltic Sea Region

Impressum

International Baltic Earth Secretariat Publications
ISSN 2198-4247

International Baltic Earth Secretariat
Helmholtz-Zentrum Geesthacht GmbH
Max-Planck-Str. 1
D-21502 Geesthacht, Germany

www.baltic-earth.eu
balticearth@hzg.de

Front page photo courtesy Baltic Sea Centre, Stockholm University.

International advanced PhD course on

Impact of climate change on the marine environment with special focus on the role of changing extremes

Askö Laboratory, Trosa, Sweden, 24 - 30 August 2015

Co-Organized by

Funded by

“Baltic Ecosystem Adaptive Management” (BEAM)

www.su.se/beam

Course Description

The course focuses on the impact of climate change on the marine environment, in particular on Baltic Sea hydrodynamics and biogeochemistry - one of BEAM’s research areas. However, the other research areas of BEAM are addressed as well (nutrient enrichment, management, hazardous substances and ecosystem functioning). Hence, the marine ecosystem will be studied with the help of a multi-stressor approach taking into account the changing climate, eutrophication, de-oxygenation, acidification, pollution, habitat degradation, invasive species and overfishing.

To address stressors and ecosystem response, a holistic Earth System approach as well as key processes in meteorology, climatology, oceanography, marine and land chemistry and biology will be presented. Challenges in regional climate system modeling to be addressed are the unclosed water cycle, altered sensitivity due to bias correction, unknown nutrient load changes on the 100-yr timescale, unknown bioavailability of nutrients in land runoff, deficiencies in knowledge about coastal zone – open sea exchange, unknown initial conditions for the Baltic Sea, unreliable parameterizations of sediment fluxes and turnover of nutrients in the sediments, lack of process understanding in the northern Baltic Sea under oligotrophic conditions, etc.

The impact of extreme events on the marine environment is a special focus in this course. Projected changes in salt water inflow frequency, intermittently occurring hypoxia (e.g. seasonal hypoxia in the coastal zone), heat wave frequency, sea ice cover variability, sea level and wave (resuspension) extreme events, etc. will have a profound impact on the marine environment. Whereas some studies are available for the impacts of changing mean conditions, our knowledge on changing extremes and their impact on the ecosystem are limited. The course investigates recent literature and introduces time series analysis in the tutorials to better understand the variability of the Earth system.

Course Objectives

The course aims to provide the students with interdisciplinary scientific knowledge on climate variability and ecosystem dynamics in the Baltic Sea catchment area and other regions surrounding coastal seas with similar climatic and environmental conditions (North Sea, Black Sea, Mediterranean Sea, Barents Sea, Laptev Sea, etc.). The aim is to develop an understanding of how changing climate influences biogeochemical and carbonate cycles and upper levels of the food web to enable the students' participation in discussions on how to manage the Baltic Sea and to accommodate various stakeholder perspectives.

Examples of society relevant information to be discussed during the course, are possible measures to counteract eutrophication and to achieve good environmental status (Baltic Sea Action Plan, geoengineering measures), strategies how to establish marine protected areas as efficient as possible and strategies how to implement the Ecosystem Approach to Management in the Baltic Sea and other regional seas.

The main objective of the course is to introduce students to problem-solving skills within individual disciplines via lectures, hands-on exercises and tutorials (e.g. running a global climate model in the format of an Excel sheet) as well as group work during the entire course and final presentations, oriented to societal management objectives for marine ecosystems.

Lecturers

Prof. Agneta Andersson, Umeå University, Sweden
Dr. Thorsten Blenckner, Stockholm University, Sweden
Prof. Keith Brandner, Technical University of Denmark, Charlottenlund, Denmark
Prof. Daniel Conley, University of Lund, Sweden
Dr. Kari Eilola, Swedish Meteorological and Hydrological Institute, Västra Frölunda, Sweden
Prof. Ragnar Elmgren, Stockholm University, Sweden
Dr. Jana Friedrich, Helmholtz-Zentrum Geesthacht, Germaby
Prof. Christoph Humborg, University of Stockholm, Sweden
Prof. Erik Kjellström, Swedish Meteorological and Hydrographic Institute, Norrköping, Sweden
Prof. Markus Meier, SMHI, Norrköping, Sweden
Prof. Anders Omstedt, University of Gothenberg, Sweden
Dr. Marcus Reckermann, International Baltic Earth Secretariat, Helmholtz-Zentrum Geesthacht, Germany
Prof. Anna Rutgersson, Uppsala University, Sweden
Prof. Benjamin Smith, University of Lund, Sweden
Dr. Emma Undeman, University of Stockholm, Sweden
Dr. Eduardo Zorita, HZG, Geestacht, Germany

Organizing committee

Markus Meier, Swedish Meteorological and Hydrological Institute and Stockholm University, Sweden
Marcus Reckermann, International Baltic Earth Secretariat, Helmholtz-Zentrum Geesthacht, Germany
Silke Köppen, International Baltic Earth Secretariat, Helmholtz-Zentrum Geesthacht, Germany

Outreach: Nastassja Åstrand Capetillo, Baltic Sea Centre, Stockholm University, Sweden

The support by Stockholm University's Strategic Marine Environmental Research Fund "Baltic Ecosystem Adaptive Management" (BEAM) is gratefully acknowledged.

Find up-to date information on the Baltic Earth website: www.baltic-earth.eu/asko2015

Agenda

Day	1 Monday, 24 Aug	2 Tuesday, 25 Aug	3 Wednesday, 26 Aug	4 Thursday, 27 Aug	5 Friday, 28 Aug	6 Saturday, 29 Aug	7 Sunday, 30 Aug
General topic	Course introduction, Baltic Sea climate variability	Past and future climate variability	Baltic Sea climate variability, biogeochemical cycles, pollution	Land-sea interaction, eutrophication, hypoxia, carbon cycle, acidification	Sediments, ecosystem function and structure, light penetration	Overfishing, habitat degradation, regime shifts, marine management	Paleoclimate variability, review of climate models
Speaker/title Morning session 08:30-10:30 (2 x 45 min)	Travel to Askö	Short student presentations of their thesis work (10 min. each)	Markus Meier: Past and future climate variability of the Baltic Sea	Christoph Humborg: Terrestrial and marine carbon cycle	Jana Friedrich: Sediment processes, sediment-water fluxes	Markus Meier: Climate impacts on biogeochemical cycles	Eduardo Zorita: Historical and paleo-climate variability
10:30-12:30 (2 x 45 min)	Markus Meier, Marcus Reckermann: Course introduction	Erik Kjellström: The climate system and global climate models	Kari Eilola: Biogeochemical cycles in the Baltic Sea	Benjamin Smith: Land sea interaction, dynamical vegetation modeling	Ragnar Elmgren: Marine ecosystem in the Baltic proper	Thorsten Blenckner: Regime shifts	Eduardo Zorita: A critical review of climate models
Speaker/title Afternoon session: 14:00-16:00 (2 x 45 min)	Anna Rutgersson: Climate variability and extremes	Erik Kjellström: Regional climate simulations	Emma Undeman: Pollution in the Baltic Sea	Daniel Conley: Hypoxia in the Baltic Sea	Agneta Andersson: Ecosystem in the Gulf of Bothnia	Keith Brander: Climate impacts on fish	Thorsten Blenckner: Marine management, socioeconomic scenarios
16:00-18:00 (2 x 45 min)	Anders Omstedt: Physics and chemistry of the Baltic Sea	Tutorial (“run your own global climate model”)	Tutorials and exercises	Tutorials and exercises	Tutorials and exercises	Tutorials and exercises	Students’ group presentations, resumé of the school
Evening session 19:30-21:30 (45 min plus discussion)	Short student presentations of their thesis work (10 min. each)	Social activities	Christoph Humborg: Land surface processes, socio-economy	Daniel Conley: Eutrophication and geoengineering methods	Students group work	Students group work	Social activities

Abstracts in alphabetical order (first author)

Climate change impact on hydrological extremes in Lithuanian rivers

Vytautas Akstinas

Lithuanian Energy Institute, Kaunas, Lithuania, (vytautas.akstinas@lei.lt)

This PhD project is based on hydrologic modelling data analysis and evaluation of hydrological extreme events using the HBV model under climate change conditions. The main tasks of this research are:

- preparation of precipitation and temperature data according to different RCM and downscaling methods in 21st century;
- hydrological modelling of river runoff according to climate change scenarios;
- intercomparison of statistical downscaling methods in the analysis of hydrological extremes of the Lithuanian rivers;
- analysis of hydrological model uncertainty under climate change conditions (uncertainty sources: downscaling methods, RCM/GCM projections and parameters of HBV hydrological model).

Primary research data (in this case daily precipitation and temperature) has been taken from http://ensemblesrt3.dmi.dk (SMHI RCM), which is based on driving GCM ECHAM5-r3 and HadCM3Q3. Both GCM were generated according to A1B climate change scenarios. SMHI RCM covered all Europe and had resolution with 25 km grid cell. All area is consisting of 170 grid cells in horizontal axis and 190 grid cells in vertical axis. Lithuania enters from 108 to 123 cells in horizontal axis and from 111 to 122 cells in vertical axis. Meteorological data for hydrologic modelling has been taken from eight grid cells, which represent real points of meteorological stations (MS). These data were used for three different rivers districts.

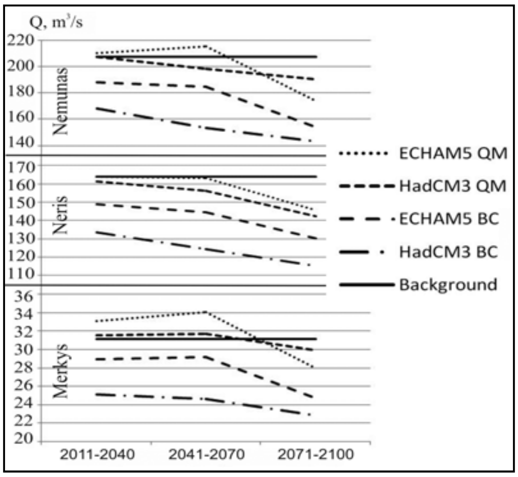

Figure 1 Distribution of the forecasted and observed discharges of three different Lithuanian rivers according to RCM and downscaling methods

Precipitation and temperature data of 21st century were performed with Bias Correction (BC) and Quantile Mapping (QM) methods, which are used to delete errors of RCM output. After performance, daily precipitation and temperature data were used for HBV hydrological modelling of three different Lithuanian rivers. Some results of hydrological modelling are shown in Fig. 1.

Period (1961–1990) of observed discharge data is set as a background. In average, for the river Nemunas, all RCM and downscaling methods predict lower discharge than the background, except ECHAM5 QM, which predict little bit higher values in 2011–2040 and 2041–2070 periods. In the river Neris average annual discharge is forecasted lower than the background of this river. Forecasted runoff of the Nemunas and Neris has decreasing trend. For the river Merkys the climate models ECHAM5 and HadCM3 RCM with QM downscaling method predict higher values of discharge in the first and the second periods. In other cases a forecast of the average annual discharge is lower than the river Merkys background discharge.

All these results of PhD project are just the beginning of basic research. In the future it will be done more experiments of hydrological modelling, analysis of hydrological extremes and analysis of hydrological model uncertainty under climate change conditions.

Modelling effects of river inflow of dissolved organic carbon on coastal production

Agneta Andersson

Umeå University, Sweden agneta.andersson@emg.umu.se

The balance between autotrophic and heterotrophic processes plays a key role in aquatic systems as it dictates the production and function of the ecosystem. This trophic balance is suggested to be influenced by the concentrations and stoichiometry of dissolved organic carbon (DOC) and inorganic nitrogen and phosphorus (NP); however the mechanism is poorly understood as it may be governed by the bioavailability of the DOC and the light attenuation it causes in the recipient water. We studied how inputs of terrestrial colored DOC and NP nutrients would affect the production and trophic balance in coastal areas in the boreal zone, by using a modeling approach. The food web consisted of phytoplankton and bacteria at the basal level, protozoa at the intermediate level, and mesozooplankton at the top level. The bioavailability of DOC was 5 and 100% and the light attenuation varied from 0 to 80% in different simulations. Model outcomes showed that the DOC bioavailability, input level and light attenuation all were important factors which could force ecosystems from autotrophy towards heterotrophy. DOC addition in general caused lower food web efficiency, because of the establishment of an intermediate trophic level within the food web. The results from this study indicate that aquatic systems receiving carbon in addition to N and P can turn heterotrophic, which would reduce ecosystem productivity at higher trophic levels. This situation is likely to occur in northern Europe, where climate change is expected to lead to more precipitation. Increased river inflow, containing high concentrations of colored terrestrial DOC, may thus cause reduced production in coastal systems.

Reconstruction of climate and environmental changes in the Baltic Sea and the Skagerrak during the last 6000 years, based on microfossil proxies-foraminifera.

Anna Binczewska

Paleoceanography Unit, Faculty of Geosciences, University of Szczecin, Szczecin, Poland (anna.binczewska@gmail.com)

1. Abstract

Three gravity and three multi cores from Bornholm Basin, Gdansk Bay and Skagerrak are being investigated in order to reconstruct changes in the bottom water mass composition during the mid- and late Holocene by using foraminiferal assemblages. Together with other paleoproxies, such as diatoms, stable isotopes (δ18O and δ13C), Mg/Ca and sediment geochemistry (LOI, TOC, TIC, CNS), the study will provide a detailed information of past variability of temperature, salinity, ventilation, productivity and biodiversity. The AMS ^{14}C, ^{210}Pb and ^{137}Cs chronology will allow to place this variability in time scale and link proxy data with natural climate extremes in a transect from North Atlantic to the Baltic Sea, showing common climate change forcing factors.

Introduction

Paleoecology is the study that attempts to reconstruct the evolution of the main environmental changes of the ecosystems, by using the biological remains preserved in the aquatic sediments. One of the most well-known micropaleontological methods is application of foraminifera. Their patterns of reproduction, growth and distribution are controlled by abiotic and biotic factors in the oceans. They play an important role in interpretation of geological material and recent bio-monitoring due to their preservation in the fossils record (Murray, 1991). Changes in the foraminiferal assemblages, their diversity and abundance are related to environmental conditions and water mass exchange (Murray, 2006; Boersma et al. 1998), what makes them of huge importance for better understanding processes taking place in a wide range of marine environments.

Those and several not mentioned here advantages of foraminifera have proved usefulness of foraminifera in the present study. Moreover, a link between the North Atlantic and the Baltic Sea in terms of natural climate extremes and ecological changes needs to be more precisely detected. No doubt high-resolution analysis of foraminiferal assemblages will improve interpretation of past changes in both areas.

2. Objectives and hypothesis

The main objective of the present PhD project is to monitor and reconstruct past climate induced ecosystem changes in in selected key sites and to detect and identify climatic linkages and common forcing factors driving climate change in these regions.

In order to achieve the given objective the following questions have been addressed:

- How these inflow periods to the Baltic Sea can affect bottom water conditions or ecological and oceanographic parameters?
- How inflows from the Nordic Seas and outflows from the Baltic Sea influence environmental changes in the Skagerrak ?
- If oceanic conditions of the Skagerrak and Baltic Sea are driven by common forcing factors ?
- Can the past environment changes be determined by using foraminiferal assemblages?
- Can modern ecological preferences of foraminifera be applied to the sediment record in order to reconstruct past ecological changes ?

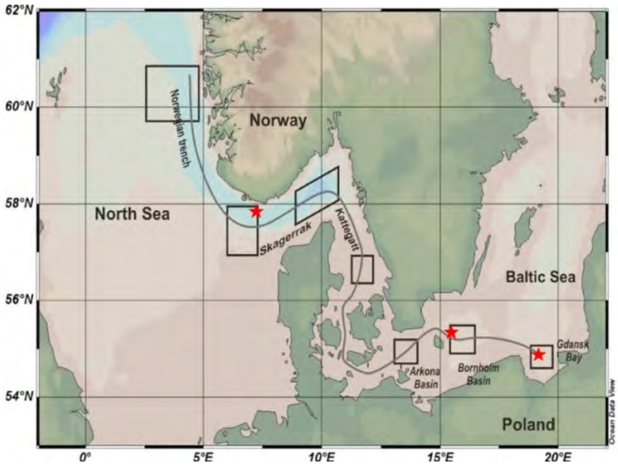

Figure 1. Map over ClimLink study area showing a transect from the Norwegian Sea to the SE Baltic Sea. Red stars mark core sampling sides used in the presented PhD study. udy Area

To link the eastern Atlantic and the Baltic Sea we are studying cores from the Skagerrak, the Bornholm Basin, and the Gdansk Bay (Fig. 1.).

The Baltic Sea is surrounded by nine countries for which it plays an enormous role in economic, natural and tourist aspects. This relatively young sea is formed during the Quaternary, covers around 415 266 km^2 and has a water volume of 21,700 km^3 (Matthaus, 2006). This semi-enclosed sea is connected to the Atlantic through the narrow and shallow Danish Straits, being the largest brackish sea in the world. The hydrography of the Baltic Sea is strongly dependent on inflows from the North Sea and its environmental conditions are influenced by meteorological and anthropogenic factors.

The Skagerrak is a strait placed between north-coast of Denmark, southeast coast of Norway and southwest-coast of Sweden. It is an important passage for a water mass exchange between the North Sea, through the Kattegat and into the brackish Baltic Sea. It is separated from the rest of the North Sea by a sill at 270 m water depth. The average Skagerrak depth is about 210 m with a maximum depth close to 700 m (Rodhe 1996).

3. Materials and Methods

The gravity and multi cores from the Skagerrak were taken during the cruise of R/V "Elsabeth Mann Borgese" in May 2013. Cores from the Bornholm Basin and Gdansk Bay have been made available by the Leibniz Institute for Baltic Sea Research (IOW). Surface samples were collected from key sites and stained by Rose Bengal to identify living foraminifera. In the laboratory, all cores were split in two halves for an archive part (stored one) and a work part. The work part of the cores was sectioned into 0,5 cm (MUCs) and 1 cm slices (gravity cores) and prepared for further analyses.

For analysing the foraminiferal assemblage we used 'wet' counting method. Around 10 g of fresh sediment is taken, washed over >63 µm sieves and counted wet. The counted foraminifera are identified on species or genus level. After counting samples are dried at 50 C. Dry foraminiferal test of *Melonis barleeanum* from the Skagerrak cores are utilized for stable isotopes and Mg/Ca analysis. For AMS 14C chronology we use mixed benthic foraminiferal species for the Skagerrak material, while mostly mollusc *Macoma balthica* is used for dating for the Baltic Sea cores due to dissolution and bad test preservation of foraminiferal assemblages.

4. Expected results

High-resolution studies based on foraminiferal assemblages combined with geochemical analysis will allow reconstructing past environmental changes (Kotilainen et al., 2014). Specifically:

- Gravity cores will be used to determined long-term faunal changes and link them with natural climate extremes (Polovodova et al., 2011, 2013)
- Variability in foraminiferal species abundance and diversity in sediment cores will be used to detect changes in past environmental conditions (Murray, 2006)
- In sediment cores from the Baltic Sea, a total number of foraminifera/gram will be counted to detect changes in the influence of Atlantic water on the Baltic Sea (Kotilainen et al., 2014)
- In sediment cores from the Skagerrak, stable isotopes, Mg/Ca and foraminiferal assemblages data will be used as a paleothermometry proxy to detect changes in temperature and salinity of the Atlantic water, providing information about climate/temperature cycles (Rohling et al., 1999; Ravelo et al., 2007)

Acknowledgements

Presented PhD research is carried out within the ClimLink project funded by the Norwegian Grant in the Polish-Norwegian Research Programme, operated by the National Center for Research and Development.

References

Andren E., Andren T., Sohlenius G. (2000), The Holocene history of the southwestern Baltic Sea as reflected in a sediment core from the Bornholm Basin, Boreas, vol. 29, pp. 233-250

Bjorck S. (1995), A revive of the history of the Baltic Sea, 13.08-8.0ka BP, Pergamon, Quaternary international, vol. 27 pp. 19--40

Boersma, A., In Haq, B. U. (1998), Foraminifera, Boersma A. (ed.), Introduction to marine micropaleontology. Elsevier, pp. 19-78

Boltovskoy, E., and Wright, R. (1976) Recent Foraminifera.

Borsenkova I. el al. (2013), Climate changes in the Baltic Sea Area HELCOM thematic assessment in 2013, Helsinki Commission 2013

Kotilainen A. T. et al. (2013), Echoes form the Past: A Healthy Baltic Sea Requires More Effort, The Royal Swedish Academy of Sciences, vol. 43, pp. 60-68

Kristjansottir, G. B., Lea, D. W., Jennings, A. E., Pak, D. K., Belanger C., (2007), New spatial Mg/Ca-temperature calibrations for three Arctic, benthic foraminifera and reconstruction of north Iceland shelf temperature for the past 4000 years, Geochemistry Geophysics Geosystems, 8

Lea, D. W. (1999), Trace elements in foraminiferal calcite. In Sen Gupta, B. K. (ed.), Modern Foraminifera. Great Britain: Kluwer, pp. 259-277

Martin, P. A., Lea, D. W., Rosenthal, Y., Shackleton, N. J., Sarnthein, M., Papenfuss, T. (2002), Quaternary deep sea temperature histories derived from benthic foraminiferal Mg/Ca. Earth and Planetary Science Letters, 198, pp.193–209.

Matthäus W. (2006), The history of investigation of salt water inflows into the Baltic Sea –from the early beginning to recent results, Marine Science Report, no. 65

Murray, J. W. (1991), Ecology and Palaeoecology of Benthic Foraminifera, Longman

Murray, J. W. (2006) Ecology and Applications of Benthic Foraminifera, Cambridge

Polovodova, I. I., Nordberg, K., Filipsson H. L. (2011), The benthic foraminiferal record of the Medieval Warm Period and the recent warming in the Gullmar Fjord, Swedish west coast, Marine Micropaleontology, vol. 81, pp. 95-106

Polovodova Asteman, I., Nordberg, K., Filipsson H. L. (2013), The Little Ice Age: evidence from a sediment record in Gullmar Fjord, Swedish west coast, Bigeosciences, vol. 10, pp 1275-1290

Ravelo, A. Ch., Hillaire-Marcel, C. (2007), The use of oxygen and carbon isotopes of foraminifera in Paleoceanograpy. In Hillaire–Marcel, C., De Vernal, A. (ed.), Developments in Marine Geology. 1, pp 735-760

Rodhe J. (1996), On the dynamics of the large circulation of the Skagerrak, Journal of Sea Research 35, pp. 9-21.

Rohling, E. J., Cooke S. (1999), Stable oxygen and carbon isotopes in foraminiferal carbonate shells. In Sen Gupta, B. K. (ed.), Modern Foraminifera. Great Britain: Kluwer, pp. 239-258

Sen Gupta, B. K. (1999) Introduction to modern foraminifera. In Sen Gupta, B. K. (ed.), Modern Foraminifera, Kluwer, pp. 3-6

Influence of surface runoff from urban territory on the ecosystem of the receiving river

Ina Bulskaya

Brest State University named after A.S. Pushkin, Brest, Republic of Belarus (inabulskaya@gmail.com)

1. Introduction

Surface runoff from urban territories caries a vast number of pollutants (Göbel, 2007). The extent of pollution can vary significantly, depending on many factors, such as intensity of traffic, percent of impervious surfaces, territory management practices etc. Studying chemical pollution of the runoff and comparison to the regulation levels does not give the understanding of how dangerous the runoff can be for the ecosystem of receiving waters. Biological methods become a suitable alternative. The aim of this work is to study influence of surface runoff from the territory of the city of Brest, Belarus on the receiving river ecosystem.

2. Materials and methods

Analysis. The pollutants were measured by standard methods (Methods 1992, Aleshka 1997). Each parameter was analyzed in 2 parallel measurements.

Total suspended solids were measured by a gravimetric method. The concentration of chloride ions was measured by a titrimetric method with silver nitrate and potassium chromate as an indicator.

The concentrations of nitrate, phosphate, and ammonium ions were measured by a photometric method on MS-122 PROSCAN Special Instruments (2010) spectrophotometer (Department of Chemistry, Brest State University named after A.S. Pushkin). Heavy metals (Pb, Cu, Mn, Zn, Fe, Ni, Cr) were measured by atomic absorption spectrometry on SOLAAR Mkll M6 Double Beam (2004) spectrometer with flame atomizer (Laboratory of Biochemistry, Polesski Agrarian-Ecological Institute NAS of Belarus).

Due to the difference in the formation process and content of pollutants we had divided all tested samples in 2 big groups – rain surface runoff, formed during April-October, and snowmelt surface runoff, formed during November-March.

Biotest. The culture of duckweed (*Lemna minor* L.) was cultivated in the laboratory in modified Hoagland solution. Then plants of duckweed with 2-4 well-developed fronds were placed in Erlenmeyer flasks containing samples of surface runoff and control (tap water). Morphological parameters (total number of fronds) and biochemical parameters (catalase activity and content of photosynthetic pigments) were measured before the experiment and after 9 days of exposure with photoperiod 14/10 h, temperature 22-25 ° C and humidity 65 %.

3. Results and discussion

Results of analysis of chemical composition of runoff from the territory of Brest City for 4 discharges are presented in table 1.

The snowmelt runoff is more heavily polluted then rain runoff first of all due to high content of chloride ions and suspended solids, which originate from deicing composites. The high degree of variability is typical for the surface runoff pollutants (Stone and Marsalek, 1996; Brown, 2006) which reflects the variety of sources of the contamination within urban catchment and the complex wash-off dynamics of the pollutants (Krein and Schorer, 2000, Brown, 2006).

Observed rates of the pollutants are typical for urban runoff in countries with moderate climate (Polkowska, 2001). Never the less, several parameters overcome regulation levels for surface runoff and for fish breading surface waters (see Table 1).

The next step of experiment was to assess the toxicity of runoff for living organisms, which was made by means of the test with duckweed (*Lemna minor* L.). The samples with high content of salts (typical for snowmelt runoff), first of all, with high chloride content showed significant inhibition of growth rate of test organisms (see figure 1). There was no significant difference of the growth-rate between samples with low salt content (rain surface runoff) and control.

However, biochemical parameters showed that even with ought inhibition of the growth rate test organisms showed some signs of oxidative stress, e.g. increase of the content of carotenoids in the lives of duckweed both in experiment with snowmelt and rain runoff. Carotenoids are a part of antioxidant system of the cell and play protective role. Increased levels of carotenoids is the adaptive mechanisms of the photosynthetic system of the cell in a response to unfavorable environment.

Changes in activity of catalase and content of chlorophyll a and b were observed only in experiments with snowmelt runoff, which reflects that this runoff is more toxic for duckweed plants.

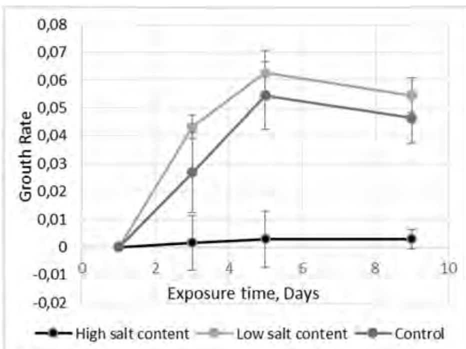

Figure 1. Growth rate of *Lemna minor* L. in test with runoff samples with high and low salt content and control.

Concentration of parameter, mg/L*

	pH	TSS	Cl^-	NO_3^-	NH_4^+	PO_4^{3-}	Pb	Cu	Mn	Zn	Cr
Rain Runoff											
Discharge 1	7,531	160,141	99,794	2,607	1,382	1,974	0,038	0,160	0,102	0,586	0,004
Discharge 2	7,837	177,700	56,826	2,148	1,290	3,563	0,021	0,561	0,137	0,537	0,000
Discharge 3	7,500	69,700	109,270	10,278	0,980	1,097	0,040	0,642	0,068	0,632	0,000
Discharge 4	8,030	0,000	52,485	7,905	0,149	2,585	0,000	0,019	0,075	0,093	0,049
Overal mean	7,724	**101,885**	79,594	5,734	**0,950**	**2,305**	0,025	**0,345**	**0,095**	**0,462**	**0,013**
Snowmelt runoff											
Discharge 1	7,867	365,838	4486,919	4,460	1,631	4,959	0,009	0,033	0,175	0,456	0,014
Discharge 2	7,810	283,163	2409,220	6,771	2,570	4,879	0,011	0,006	0,144	0,312	0,000
Discharge 3	7,557	146,400	1406,460	5,426	1,312	2,535	0,012	0,010	0,138	0,400	0,004
Discharge 4	7,370	84,000	1864,110	8,649	0,468	4,066	0,000	0,024	0,110	0,674	0,001
Overal mean	7,651	**219,850**	**2541,677**	6,327	**1,495**	**4,110**	0,008	**0,018**	**0,142**	**0,461**	0,005
PC SR**	6,5-8,5	20,000	–	–	–	–	–	–	–	–	–
MPC FBSW***	6,5-8,5	–	300,000	40,000	0,050	0,066	0,100	0,004	0,050	0,016	0,005

* except pH

** permissible concentrations for surface runoff (TCGP 17.06-08-2012)

***maximum permissible concentrations for fish breeding surface waters (Regulation No. 43/42)

4. Conclusions

From the results of the study we can conclude that surface runoff was polluted with vast number of substances, and there is an obvious need for the regular monitoring of the runoff on several paramiters.

Surface runoff was proved to be toxic for living organisms on the example of *Lemna minor* L., depending on the extent of the pollution of the runoff.

References

Aleshka V.I., 1997, Collection of measurement techniques allowed for use in operation of laboratories of environmental monitoring of industries and organizations of Republic of Belarus.

Brown J.N., Peake B.M. (2006) Sources of heavy metals and polycyclic aromatic hydrocarbons in urban stormwater runoff, Science of the Total Environment, No. 359, pp. 145– 155.

Chirkova T.V. (2002) Physiological bases of plant resistants. Tutorial., St. Petersburg, pp. 58–68. (in Russian)

Dymova O.V., Golovko T.K. (2007) The state of the pigment system of plants of Ajuga reptans in conection to adaptation to light conditions of growth, Plant Physiology,Vol. 54, No. 1, pp. 47–53. (in Russian)

Göbel, P. Dierkers C. and Coldewey W.G. (2007) Storm water runoff concentration matrix for urban areas., Journal of Contaminant Hydrology, No 91, pp. 26–42.

Krein A, Schorer M. (2003) Road runoff pollution by polycyclic aromatic hydrocarbons and its contribution to river sediments, Water Res., No. 34, pp. 4110– 4415.

Polkowska Ż., Grynkiewicz M., Zabiegała B., Namieśnik J. (2001) Levels of Pollutants in Runoff Water from Roads with High Traffic Intensity in the City of Gdańsk, Poland, Polish Journal of Environmental Studies, Vol. 10, No. 5, pp. 351-363.

Regulation of the Ministry of Natural Resources and Environmental Protection of Republic of Belarus, Ministry of Health Protection of Republic of Belarus 'About some issues of water quality regulation in fish briding water bodies', 2007, No. 43/42, 67 pp., 08.05.2007 (in Russian).

Standard Methods for the Examination of Waters and Wastewaters Including Bottom Sediments and Sludges, 1992, Twelfth Edition, American Public Health Association, 650 pp.

Stone M, Marsalek J. (1996) Trace metal composition and speciation in street sediment: Sault Ste Marie, Canada. Water Air Soil Pollut., No. 87, pp. 149– 69.

TCGP – Technical Code of Good Practice, 2012a, Environmental protection and nature. The procedure for establishing standards for discharging chemical and other substances with waste waters, 17.06-08-2012(02120), 75 pp., (in Russian).

Hydrologic modeling of the Nemunas River watershed

Natalja Čerkasova

Marine Science and Technology Centre, Klaipeda University, Klaipeda, Lithuania (natalja.cerkasova@gmail.com)

1. Introduction

Curonian Lagoon, which is the largest European coastal lagoon with a surface area of 1578 km^2 and a drainage area of 100458 km^2, is facing severe eutrophication problem. With the increasing water management difficulties, a need for a sophisticated hydrological model of the Curonian Lagoon watershed area arose, to assess possible changes due to local and global processes.

Nemunas River is the major contributory that discharges into the Curonian lagoon; in terms of flow rates and nutrient inputs it supplies about 98% of its inflows. Annual Nemunas River water inflow into the Curonian Lagoon is more than three times greater than the volume of water in the lagoon. According to researches, the average annual runoff in 1812-2002 was 22.054 km^3 (698.86 m^3/s) (Gailiušis B. et al. (2005)), from 1960 to 2007 – 21.847 km^3 (692.30 m^3/s) (Jakimavičius D. et al. (2010)). During the years, water discharge to the lagoon changes, this leads to water balance parameter value fluctuation. The major changes are observed in the winter-spring period. In winter months of January and February, due to observed warmer winters, Nemunas runoff has increased, while spring floods are decreasing, therefore, runoff during the year became more even.

High quality hydrological model of Nemunas River watershed would provide great assistance in understanding the behavior of hydrologic systems of the area for the benefit of making better predictions and facing major challenges in water resources management.

2. Relevance of the topic

Nemunas River is the major contributory that discharges into the Curonian lagoon. It is not only important for changing and governing its mass balance, but it is also bringing nutrients and sediments into the lagoon.

Nemunas River basin is shared by Belorussia, Lithuania, Poland and the Russian Federation Kaliningrad oblast (Figure 1). Agriculture has a significant impact on the status of water bodies in the Nemunas River basin, especially in the subbasins of Šešupė and Nevėžis Rivers; this factor has a local, but a serious impact. Chemicals that enter the river from agriculture and fish ponds are a major source of pollution (Chilton J. et al. (2011)). Furthermore, a substantial part of point source pollution comes from industry. According to the Second Assessment of Transboundary Rivers, Lakes and Groundwaters by United Nations Economic Commission for Europe, there is room for development in monitoring, as the current list of monitored pollutants is limited; there is a lack of biological observations, also a lack of monitoring pollutants in bottom sediments, and a joint, harmonized monitoring programme for the transboundary watercourses is needed (Chilton J. et al. (2011)). Therefore, it is important to be able to model nutrient and other biogeochemically significant dissolved substance contributions that are altering and influencing the ecosystem in view of a better understanding of the dynamics of the Nemunas River and Curonian lagoon.

Figure 1. Nemunas River watershed area.

3. Research goals and objectives

Main research objective is to apply hydrological modelling techniques and tools to construct a hydrological model that is able to describe the water, sediment and nutrient dynamics of the Nemunas River watershed; apply this model to forecast trends related to climate change, agricultural practices and other human-induced factors and analyze possible consequences on ecosystems.

Research goals are:

- Gather and pre-process input data, identify suitable model input parameters and apply hydrological modelling tool to create a model of the Nemunas River watershed and its elements;
- Achieve sufficient model performance ratings by calibration and validation of model parameters;
- Using this model perform and analyze forecast trends related to climate change and other factors;
- Analyze model coupling possibilities and make the model and its output available for application with other models.

4. Research methods, materials and equipment

SWAT (Soil and Water Assessment Tool) could be used for hydrological modeling of Nemunas River as it has gained international acceptance as a robust interdisciplinary watershed modeling tool. This tool is freely accessible, distributed under GNU General Public License terms, it can be manually modified via program source code, it integrates with an open-source GIS, has extensive documentation and user manuals, and it is highly regarded and reported to produce reliable results (Gassman P. et al. (2007)).

At present, over 1500 peer-reviewed published articles have been identified that report SWAT applications, reviews of SWAT components, and other research that includes SWAT. SWAT has also been used extensively in Europe, including projects supported by various European Commission agencies. Several models including SWAT were used to quantify the impacts of climate change for five different watersheds in Europe and a suite of nine models including SWAT were tested in 17 different European watersheds (Gassman P. et al. (2007)).

Major model components include: weather, hydrology, soil temperature and properties, plant growth, nutrients, pesticides, bacteria and pathogens, land management. No matter what type of problem studied with SWAT, water balance is the driving force behind everything that happens in the watershed. Model would require the following input data:

- Weather, hydrological and sediment data. Some data is available at Lithuanian Hydrometeorological Service under the Ministry of Environment free of charge for students and University workers. Data from other countries could be attained from open international databases or acquired from commercial databases.
- Soil data (some is available free of charge in the WaterBase project database (waterbase.org), although other resources, including local environment agencies, should be considered);
- Landuse data (available free of charge in the WaterBase project database);
- Climate model data.

As agricultural land is the main source of nutrients that affect the lagoon ecosystem, it is important to build and/or to select such agro-ecosystem dynamics models (crop models) that would provide a coherent set of models together with river basin hydrologic models. Such an integrated simulation system should allow for a detailed analysis and assessment of changes of the river and lagoon hydrological and biogeochemical cycles, depending on the agricultural land use change. The crop simulation models needed should be capable to simulate biotic and abiotic processes in different agroecosystems with an accuracy applicable to daily time step of hydrological transport models. The potential model candidates are: DIASPORA (Denisov V. (2001)), DSSAT (Jones J. et al. (2003)), APEX-AGROTOOL (Medvedev S. et al (2011), Poluektov R. et al. (2002)), although other similar models should be considered.

The expected result of this study is a fully functioning, calibrated and validated hydrological model with sediment and nutrient dynamics of the Nemunas River basin, which could be coupled with ecological models for a better understanding of the dynamics in the study area and relevant regions, such as Curonian Lagoon.

References

Gailiušis B., Kovalenkovienė M., Kriaučiūnienė J. (2005), Hydrological and hydraulic investigations of water area in the Curonian Lagoon between the island Kiaulės nugara and Alksnynė. Energetika Vol. 4, pp. 34–41.

Jakimavičius D., Kovalenkovienė M. (2010) Long-term water balance of the Curonian Lagoon in the context of anthropogenic factors and climate change, Baltica, Vol. 23, pp. 33–46

Chilton J. et. al. (2011) United Nations Economic Commission for Europe (UNECE) Second Assessment of Transboundary Rivers, Lakes and Groundwaters, Chapter 8, Drainage basin of the Baltic Sea, pp. 384-386

Gassman P., Reyes M., Green C., Arnold J. (2007) The Soil and Water Assessment Tool: historical development, applications, and future research directions, T ASABE Vol. 50, No. 4, pp. 1211-50.

Denisov V. (2001) Development of the Crop Simulation System DIASPORA, Agronomy, Vol. 93, No.3, pp. 660-666

Jones J., Hoogenboom G., Porter C., Boote K., Batchelor W., Hunt L., Ritchie J. (2003) The DSSAT cropping system model, European Journal of Agronomy, Vol. 18(3–4), pp. 235–265

Medvedev S., Topaj A. (2011) Crop simulation model registrator and polyvariant analysis, IFIP Advances in Information and Communication Technology, AICT, No. 359, pp. 295-301

Poluektov R., Fintushal S., Oparina I., Shatskikh D., Terleev V., Zakharova E. (2002) AGROTOOL – a system of crop simulation, Archives of Agronomy and Soil Science, Vol. 48, pp. 609–635

Transport dynamics of the Baltic Sea system at the coastal scale

Yuanying Chen

Department of Land and Water Resources Engineering, Royal Institute of Technology (KTH), Stockholm, Sweden (yuanying@kth.se)

1. Background

The ecosystem of the Baltic Sea is severely endangered with increasing nutrients [Rönnberg, 2004], of which more than 75% come from land as waterborne[Helcom, 2011]. Coastal areas, including archipelagos, typically act as filters between the land sources and the sea [Helminen et al., 1998]. The transport dynamics of the coastal areas is complicated and vital for the water qualtiy in the sea. However, detailed studies related to transport processes in the coastal area are still very limited. In order to better understand the transport dynamics of the whole Baltic Sea system, deeper understanding of transport dynamics at coastal and archipelago scale is needed.

2. Aim

The overall aim of the PhD project is to improve the understanding of the whole dynamic process of the Baltic Sea system on various scale, especially the trends under climate change. Moreover, effort will be focused to understand transport dynamics at archipelago scale. Two sites of coastal areas around the Oskarshamn harbour and Forsmark potential nuclear waste disposal site are selected for case study.

3. Emphasis

- Scaling study of hydrodynamics for coastal areas of the Baltic Sea. The hydrodynamic process at coastal area will be incorporated with larger scale Baltic Sea model to further study the interaction between the small scale coastal area and larger scale Baltic Sea system. Influence of climate change and the anthropogentic activities on the hydrodynamic interaction of the coupling system will be investigated, especiallyon the coastal side.
- Transport processes in coastal areas from point and distributed sources. Based on the nesting study of hydrodynamics, transport process of land loading as point or distributed sources in coastal areas will be further investigated. Pathways of the pollution, and their fluxes to the sea will be discussed in detail. Besides, the transport patterns at different part of the coastal areas, such as retention time, renewal time and fluxes between basins, will be studied under the present condition and under climate change.
- Case study applications along the Swedish coast. Sites with great need in transport study along Swedish coastline are selected. For example, one is the Oskarshamn harbour, which is heavily polluted by discharged metal in sediment. Another is Forsmark, where high-level nuclear waste disposal is being planned, and the study of possible discharge pathways is relevant as part of the safety assessment.

4. Method

The research would be based on integrating basic approaches:

i) Data analysis. Large sum of data related water quality in coastal area of Baltic Sea are available, provided by the harbour company and nuclear company SKB. Mathematical methods such as statistics and PDF will be used to discuss the pollution transport characteristics in the areas.

ii) Numerical simulations. Open source model COHERENS is to be used for hydrodynamic simulation. Nesting technique will be used to learn the dynamics of the coastal area and the Baltic Sea system on different scales. Further, the hydrodynamic model will be coupled with a water quality model for the transport patterns study and water quality simulation in the coastal area.

Hypoxia in the Baltic Sea

Daniel J. Conley[1], Jacob Carstensen[2], Bo Gustafsson[3], Caroline Slomp[4]

[1]Department of Geology, Lund University, Sweden (daniel.conley@geol.lu.se); [2]Department of BioScience, Aarhus University, Denmark; [3]Baltic Sea Centre, Stockholm University, Sweden; and [4]Caroline Slomp, GeoSciences, Utrecht University, The Netherlands

1. Abstract

A number of synthesis efforts have documented the world-wide increase in hypoxia, which is primarily driven by nutrient inputs with consequent organic matter enrichment. Physical factors including freshwater or saltwater inputs, stratification and temperature also play an important role in causing and sustaining hypoxia. The Baltic Sea provides an interesting case study to examine changes in oxygen dynamics over time because of the diversity of the types of hypoxia that occur, which ranges from episodic to seasonal hypoxia to perennial hypoxia. Hypoxia varies spatially across the basin with differences between open water bottoms and coastal systems. In addition, the extent and intensity of hypoxia has also varied greatly over the history of the basin, e.g. the last 8000 years. We will examine the mechanisms causing hypoxia in the Baltic Sea at different spatial and temporal scales. The hydrodynamical setting is an important governing factor controlling possible time scales of hypoxia, but enhanced nutrient fluxes and global warming amplify oxygen depletion when oxygen supply by physical processes cannot meet oxygen demands from respiration. Our results indicate that climate change is counteracting management efforts to reduce hypoxia. We will address how hypoxia in the Baltic Sea is terminated at different scales. More importantly, we will explore the prospects of getting rid of hypoxia with the nutrient reductions that have been agreed upon by the countries in the Baltic Sea basin and discuss the time scales of improvement in bottom water oxygen conditions.

References

Carstensen, J., J. Andersen, B.G. Gustafsson, D.J. Conley. 2014. Deoxygenation of the Baltic Sea during the last century. Proc. Natl. Acad. Sci. 111: 5628-5633.

Carstensen, J., D.J. Conley, E. Bonsdorff, B.G. Gustafsson, S. Hietanen, U. Janas, T. Jilbert, A. Maximov, A. Norkko, J. Norkko, D.C. Reed, C.P. Slomp, K. Timmermann, M. Voss. 2014. Hypoxia in the Baltic Sea: Biogeochemical cycles, benthic fauna and management. Ambio 43: 26–36.

Conley, D.J., C. Humborg, L. Rahm, O.P. Savchuk, and F. Wulff. 2002. Hypoxia in the Baltic Sea and basin-scale changes in phosphorus biogeochemistry. Environ. Sci. Tech. 36: 5315-5320.

Conley, D.J., J. Carstensen, G. Ærtebjerg, P.B. Christensen, T. Dalsgaard, J.L.S. Hansen, and A.B. Josefson. 2007. Long-term changes and impacts of hypoxia in Danish coastal waters. Ecol. Appl. 17: S165-S184.

Conley, D.J., S. Björck, E. Bonsdorff, J. Carstensen, G. Destouni, B.G. Gustafsson, S. Hietanen, M. Kortekaas, H. Kuosa, H. E.M. Meier, B. Müller-Karulis, K. Nordberg, A. Norkko, G. Nürnberg, H. Pitkänen, N.N. Rabalais, R. Rosenberg, O.P. Savchuk, C.P. Slomp, M. Voss, F. Wulff, L. Zillén. 2009. Critical Review: Hypoxia-related processes in the Baltic Sea. Environ. Sci. Tech. 43: 3412-3420.

Conley, D.J., E. Bonsdorff, J. Carstensen, G. Destouni, B.G. Gustafsson, L.-A. Hansson, N.N. Rabalais, M. Voss, L. Zillén. 2009. Viewpoint: Tackling hypoxia in the Baltic Sea: Is engineering a solution? Environ. Sci. Tech. 43: 3407-3411.

Conley, D.J., J. Carstensen, J. Aigars, P. Axe, E. Bonsdorff, T. Eremina, B.-M. Haahti, C. Humborg, P. Jonsson, J. Kotta, C. Lännegren, U. Larsson, Alexey Maximov, M.R. Medina, E. Pastuszak, N. Remeikaitė-Nikienė, J. Walve, S. Wilhelms, and L. Zillén. 2011. Hypoxia is increasing in the coastal zone of the Baltic Sea. Environ. Sci. Tech. 45: 6777-6783.

Conley, D.J. 2012. Saving the Baltic Sea. Nature 486: 463-464.

Funkey, C.P., D.J. Conley, N.S. Reuss, C. Humborg, T. Jilbert, and C.P. Slomp. 2014. Hypoxia sustains cyanobacteria blooms in the Baltic Sea. Env. Sci. Tech. 48:2598-2602.

Jilbert, T., D.J. Conley, B.G. Gustafsson, C.P. Funkey and C.P. Slomp. 2015. Glacio-isostatic control on the Holocene distribution of hypoxia in a high-latitude shelf basin. Geology 43: 427–430.

HMeier, H.E.M., H. C. Andersson, K. Eilola, B.G. Gustafsson, I. Kuznetsov, B. Müller-Karulis, T. Neumann and O.P. Savchuk. 2011. Hypoxia in future climates: A model ensemble study for the Baltic Sea. Geophys. Res. Lett. 38: L24608.

Norkko, J., D.C. Reed, K. Timmermann, A. Norkko, B.G. Gustafsson, E. Bonsdorff, C.P. Slomp, J. Carstensen, D.J. Conley. 2012. A welcome can of worms? Hypoxia mitigation by an invasive species. Global Change Biol. 18: 422–434.

Zillén, L. and D.J. Conley. 2010. Hypoxia and cyanobacterial blooms - are they really natural features of the late Holocene history of the Baltic Sea. Biogeosciences 7: 2567–2580.

Zillén, L., D.J. Conley, T. Andrén, E. Andrén, and S. Björck. 2008. Past occurrences of hypoxia in the Baltic Sea and the role of climate variability, environmental change and human impact. Earth Sci. Rev. 91: 77-92.

The provision of ecosystem services in a Baltic Sea coastal food-web

Eva Ehrnsten

Tvärminne Zoological Station, University of Helsinki, Finland and Baltic Sea Centre, Stockholm University, Sweden (eva.ehrnsten@su.se)

1. Introduction

The human population benefits from the Baltic Sea in many ways. The sea provides us with food and raw materials, regulates the climate, recycles nutrients and provides opportunities for recreation. However, many of these ecosystem services are threatened by changes in climate and human-induced pressures, such as nutrient loads and fishing (e.g. HELCOM 2010).

Lately there has been joint efforts by the Baltic Sea countries to ensure the future provisioning of ecosystem services from the sea, e.g. through assigning ambitious nutrient reduction targets (HELCOM 2007) and catch limits for fish stocks (EU 2013). But the effects of such measures are not straight-forward. To be able to predict the outcome of different management options we need to understand the underlying processes in the ecosystems they affect.

Niiranen et al. (2013) applied a multi-model approach to study the combined effects of climate change, nutrient loads and cod fisheries on the open-sea ecosystem of the Baltic Proper. By combining biogeochemical and food-web models, they could simulate the effects of different management scenarios in combination with climate projections on all trophic levels in the food-web. The results showed non-linear responses of different trophic groups, suggesting that food-web interactions play a major role in determining the outcome of management actions.

The picture is further complicated when we look at coastal ecosystems. In contrast to the open-sea ecosystem that is mostly pelagic, the fine-scale variations in e.g. depth, exposure and salinity in the coastal regions give rise to complex underwater ecosystems with a strong benthic-pelagic coupling. Tomczak et al. (2009) constructed food-web models for five south-eastern Baltic coastal ecosystems, but they did not explore future development of the food-webs.

The main aim of my thesis is to study the provision of ecosystem services in a northern Baltic coastal food-web at present and under different scenarios for socio-economic development and climate using food-web modeling tools.

The thesis is part of the project BalticApp (2015-2017) and receives funding from the EUs BONUS-program and national funding from the Academy of Finland.

2. Food-web modeling as a tool to study ecosystem services: case Tvärminne

In my thesis, I will create a food-web model for the coastal zone of the northern Baltic Sea using Ecopath with Ecosim software, a widely used tool for quantifying the biomass and flows of energy through aquatic ecosystems (Christensen & Walters 2004). The modeling software is very data demanding, and therefore the model will be built around Tvärminne Zoological Station, Southwest Finland, where intensive research activities and monitoring by governmental institutions provide exceptional data coverage. However, the model will be representative for similar areas along the coasts of Finland and Sweden.

Through this model indicators for core ecosystem services can be quantified, such as the biomass of commercially and recreationally important fish species or functionally important groups such bivalves filtering the water.

3. Future scenarios

To study the future faith of ecosystem services in the area, two different modeling approaches will be tested. First, we will use the results of regionally downscaled biogeochemical models (Meyer et al. 2011) developed for pre-defined socio-ecological development scenarios as forcing for time-dynamic simulations of the food-web model using the Ecosim extension for Ecopath software in a similar manner as Niiranen et al. (2013). In addition, we will add a spatial dimension to the simulations through the Ecospace package (Walters et al. 1999). This approach is though dependent on finding a matching scale between the existing biogeochemical models and the food-web model.

Second, for a more conceptual understanding of changes in the ecosystem, the functional groups in the present-day Ecopath model will be manipulated and the model re-balanced. For example, we can compare the present-day model with models where the benthic fauna is partly or completely eliminated, corresponding to the hypothetical assumption that hypoxia will spread in the coastal zones in the future (Conley et al. 2011). Similarly, if we assume the salinity to drop due to climate change we can simulate this by manipulating the biomass of marine organisms such as blue mussels and flatfish. The advantage of the second approach is that it is much less time-consuming than creating simulations, which means that we can explore a greater number of scenarios including events outside the range of the simulations.

4. Linking ecology to economy and policy-making

Within the BalticApp project, the results of the food-web-models described above together with the results of an improved open-sea food-web model and coupled physical-biogeochemical models will be translated into quantifiable measures of core ecosystem services. These measures will then be used in economic analyses to evaluate the costs and benefits of nutrient abatement under the different scenarios (see Ahlvik et al. 2014, Hyytiäinen et al. 2014).

In the end, the results will be communicated to decision-makers to aid in the process of choosing optimal management strategies taking into account the complex interplay of human activities, biogeochemical processes and food-web interactions as well as the inherent uncertainties in predicting the future.

References

Ahlvik L, Pitkänen H, Ekholm P, Hyytiäinen K (2014) An economic-ecological model to evaluate impacts of nutrient abatement in the Baltic Sea. Environmental Modelling & Software, 55, pp. 164-175

Christensen V, Walters C (2004) Ecopath with Ecosim: methods, capabilities and limitations, Ecological Modelling, 172, 2-4, pp. 109–139

Conley DJ, Carstensen J, Aigars J, Axe P, Bonsdorff E, Eremina T, Haahti BM, Humborg C (2011) Hypoxia is increasing in the coastal zone of the Baltic Sea. Environmental Science and Technology, 45, 16, pp. 6777-6783

HELCOM (2007) HELCOM Baltic Sea Action Plan adopted by the HELCOM Ministerial meeting, Krakow, Poland 15th November 2007

HELCOM (2010) Ecosystem Health of the Baltic Sea 2003–2007: HELCOM Initial Holistic Assessment, Baltic Sea Environmental Proceedings No. 122, 63 p.

Hyytiäinen K, Ahlvik L, Ahtiainen H, Artell J, Huhtala A, Dahlbo K (2014) Spatially explicit bioeconomic modelling for the Baltic Sea: Do the benefits of nutrient abatement outweigh the costs?, Environmental and Resource Economics, 61,2, pp. 217-241

Meier H E M, Eilola K, Almroth E (2011) Climate-related changes in marine ecosystems simulated with a three-dimensional coupled biogeochemical-physical model of the Baltic Sea. Climate Research, 48, 1, pp. 31–55

Niiranen S, Yletyinen J, Tomczak MT, Blenckner T, Hjerne O, Mackenzie BR, Müller-Karulis B, Neumann T, Meier HE (2013) Combined effects of global climate change and regional ecosystem drivers on an exploited marine food web, Global change biology, 19, 11, pp. 3327-42

Regulation (EU) no 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy, Official Journal of the European Union, L 354/22

Tomczak M, Müller-Karulis B, Järv L, Kotta J, Martin G, Minde A, Põllumäe A, Razinkovas A, Strake S, Bucas M, Blenckner T (2009) Analysis of trophic networks and carbon flows in south-eastern Baltic coastal ecosystems, Progress in Oceanography, 81, 1-4, pp. 111-131

Walters C, Pauly D, Christensen V (1999) Ecospace: Prediction of Mesoscale Spatial Patterns in Trophic Relationships of Exploited Ecosystems, with Emphasis on the Impacts of Marine Protected Areas, Ecosystems, 2, 6, pp. 539-554

Future climate change effects in the Baltic Sea proper

Ragnar Elmgren

Dept. Ecology, Environment and Plant Sciences, Stockholm University

A number of recent studies have produced predictions or scenarios of likely future ecological changes in the Baltic Sea as an effect of climate change, the most recent large collaborative effort being the BACC II volume published earlier this year. I will argue that most recent publications tend to be overconfident in their predictions or scenario presentations of likely future ecological effects. To surmise future ecological conditions, we need first a reasonably reliable idea of future abiotic conditions. This we can only get from global climate models, down-scaled for the area of interest, under the assumption of a particular future emissions scenario, and checked against recent climate trends. Individual climate models have relatively low credibility, since models tend to vary considerably in their predictions, hence the reliance on ensembles of models. Trends on which almost all models agree, and which agree with recent measured trends, seem more likely to continue, even if their strength in still rather uncertain. Still, there are many processes that are not fully included in any of these models, e.g. in feed-back from human land-use and ecological changes, including the possibility of regime shifts, meaning that we cannot rule out surprises. The model ensembles agree mainly on that the concentration of CO_2 in the air will increase considerably, making future warming as well as ocean acidification almost certain. Estimates of precipitation, cloudiness, wind-speed, storm frequency and intensity, and sea-level rise all vary more among models, and in addition are prone to errors of down-scaling.

Secondly, based on this rather shaky foundation, we need to predict ecological effects. Most models for this purpose are either biogeochemical models that include no biology above the zooplankton trophic level or population dynamics models of fish stocks and their food items, but with weak connection to nutrient cycling processes. End-to-end models do exist, but tend to become so complicated that even their creators have trouble understanding the results they generate. Still, models can never fully represent the enormous complexity of even simple ecosystems, like those of the Baltic Sea. In addition, we cannot meaningfully predict changes due to climate without taking into account also other anthropogenic changes, for example in nutrient loads and fishing intensity. Therefore, to feel reasonably confident in predicting an ecological effect, one would like to have not only a model prediction, but also an ecological mechanism explaining how the effect is thought to generated, plus some environmental observations corroborating that the effect really occurs in nature.

Given the above, it seems near-certain that the temperature of the Baltic will increase, and that the extension and duration of winter ice will be reduced, all of which agrees with already measured trends. Precipitation is likely to increase, but over which part of the Baltic drainage basin is uncertain. If it rains more in the south, we can expect increased input of nutrients from diffuse sources, fuelling eutrophication, but the possibility exists that runoff will decrease in the south and increase mainly in northern areas where river nutrient concentrations are rather low, but concentrations of coloured dissolved organic matter are high, in which case the opposite result may result.

The Baltic Sea proper has a very characteristic annual production cycle, with a spring bloom that is strictly nitrogen-limited, followed by a summer bloom of mainly phosphorus-limited nitrogen-fixing cyanobacteria. The zooplankton largely miss the spring bloom, but peak during the summer bloom, until reduced by predation from fish, predominantly larvae and young-of-the-year. An earlier warming of the sea is likely to result in an earlier, but smaller spring bloom. This will likely leave more phosphate-phosphorus in the water column, creating a potential for larger cyanobacterial blooms in the coming summer. Trends towards smaller spring blooms and/or larger cyanobacterial summer blooms has been seen in several recent studies. The aspect of the summer cyanobacterial bloom most negative for humans is the surface accumulations dominated by toxic *Nodularia* that occur during July-August of most summers. These have become more frequent and earlier in recent years, but the cause remains unclear. The relationship between residual phosphate after the spring bloom and cyanobacterial biomass or surface accumulations is not significant, indicating that other factors, such as insolation, temperature and stratification are also of great importance.

Salinity is the ecological master factor in the brackish Baltic Sea, where many organisms live at the margin of their salinity tolerance, and even a small decrease in salinity will greatly reduce the number of species of marine origin in the community, and ecological dominants, such as blue mussels, bladder wrack or cod may disappear from large areas. Studies of the effect of increased precipitation on Baltic salinity vary considerably in their predictions, however, and none of them take the effect of increased sea level into account, making it difficult to use them for confident ecological predictions.

Deep-water oxygen deficiency is typical of the Baltic Sea in the recent half-century, and greatly influences the biogeochemical cycles of the major plant nutrients nitrogen and phosphorus. Anoxic sediments release more phosphate-phosphorus to the water column than oxidized sediments, increasing the availability of phosphorus. Effects of anoxia on the nitrogen cycle are more complicated. On the one hand, bioavailable nitrogen is not removed through transformation to N_2 under continuous anoxia, since this requires oxidized nitrogen. On the other hand, when large volumes of low-oxygen water with high concentrations of oxidized nitrogen forms, mainly nitrate and nitrite, turn anoxic, the loss of bioavailable nitrogen can be massive. The end result is that relatively less nitrogen than phosphorus is returned from the sediments to the water column creating the preconditions for the peculiar annual production cycle of the Baltic proper.

Warming seems likely to increase the oxygen deficiency in the Baltic proper deep water, since warmer water can dissolve less oxygen, and warmer temperature stimulates organismal respiration. On the other hand, in recent times, periods of low salinity in the Baltic proper have also been periods with a deeper halocline, meaning that the area affected is smaller, again making confident prediction of effects difficult.

The future effect of acidification of the Baltic ecosystem would seem likely to be considerable, especially for calcifying organisms, such as bivalves, gastropods, barnacles, ostracods and calcified foraminifera. Still, it has recently been reported that there are alkalinity-creating processes within the Baltic Sea that may lessen the impact of acidification.

For management, effects on cyanobacterial blooms and cod seem to be the most critical. Cyanobacterial blooms are likely to occur even earlier in the summer, and be stimulated by the increased water temperature and earlier onset of stratification of the water column, as well as by the continued presence of sufficient amounts of residual phosphorus after the spring bloom. The future of cod in the Baltic proper is uncertain, since it requires a combination of relatively high salinity and a minimum oxygen level for its reproduction. The Baltic cod stock is adapted to the low salinity and genetically distinct, and will probably not be easy to replace if lost.

Early diagenesis in sediments, sediment-water fluxes and pelagic-benthic coupling

Jana Friedrich

Institute of Coastal Research, Helmholtz Zentrum Geesthacht Center for Materials and Coastal Research, Max-Planck Str. 1, 21502 Geesthacht, Germany (Jana.Friedrich@hzg.de)

1. Introduction

This lecture provides an overview of early diagenetic processes in sediments, sediment-water interactions and benthic-pelagic coupling in coastal and shallow seas. The knowledge provided is put in an ecosystem perspective and illustrated with own examples of field studies.

In shallow marine areas in particular, benthic and pelagic processes are closely coupled (Fig. 1). Hence, sediments are an important compartment the functioning of marine ecosystems. Sediments are home to infauna, epifauna and -flora and provide habitat for demersal fishes. Sediments often contain the legacy of anthropogenic perturbations like the accumulation of hazardous substances or hypoxia resulting from eutrophication. Sediments represent the memory of the pelagic system.

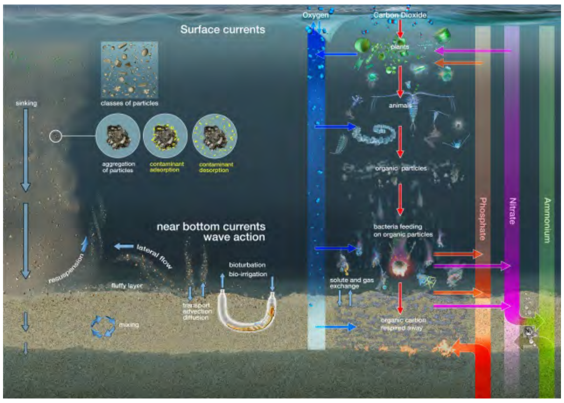

Figure 1. Sketch of pelagic-benthic coupling along with transport processes and biogeochemical cycling of organic matter. Source: G.Gorick

2. Early diagenetic processes in sediments

This section gives an overview about microbial and chemical reaction processes in the upper sediment layers, the basic transport processes and their impact on sediment biogeochemistry (e.g., Huettel et al. 2003).

Early diagenetic processes in sediments like the microbial turnover of organic matter are introduced (Aller 1982), i.e. aerobic respiration, nitrification denitrification, nitrate reduction, anammox, manganese & iron reduction, sulfide oxidation, sulfate reduction and methanogenesis. Some basics on the calculation of transport rates, e.g., solute fluxes across the sediment water interface are given. Hydrodynamically mediated transport processes comprise e.g., resuspension, pressure gradient-induced porewater advection and current-induced bedform migration. Fauna-mediated transport in sediments comprise e.g., bioturbation and bioirrigation. The interactions of macro- and microorganisms in sediments and their impact on biogeochemical processes are discussed (e.g., Kristensen et al. 2013). The differences in diffusive and advective fluxes of solutes in cohesive and permeable sediments (e.g., Huettel et al. 2014) are explained.

3. Methods and instrumentation for in-situ and laboratory measurements of sediment-water processes

This section introduces state-of-the-art methods for sediment sampling and measurement of sediment-water fluxes. In-situ approaches to measure benthic exchange rates include non-invasive techniques like eddy correlation (e.g., Holtappels et al. 2013) along with a laser scanning device, and invasive techniques like e.g., benthic chamber landers (e.g., Tengberg et al. 1995, Janssen et al. 2005) and high-resolution profiles by micro-sensor equipped profilers (e.g., Boetius & Wenzhöfer 2009). Laboratory methods comprise, e.g., sediment-core incubations to measure benthic respiration or benthic primary production, sediment porewater extraction with rhizones (Seeberg-Elverfeldt et al. 2005) and porewater dialysis samplers (Urban et al. 1997). Various methods on the measurement of benthic oxygen uptake are presented (Friedrich & Janssen et al. 2014). The capabilities, but also the limitations, of currently available approaches are discussed.

4. Sedimentary archives

Sediments are natural archives of environmental change due to natural variability or anthropogenic impact in the marine ecosystems and in adjacent river watersheds. Dating of sediments with natural and artificial fallout radionuclides helps to decipher the deposition history. This part of the lecture gives an overview about dating of recent sediments with lead-210 and caesium-137.

5. Modelling of benthic-pelagic fluxes

This section will not introduce model approaches as such, as modelling is not within the author's expertise. Instead, the awareness is raised for the problem-oriented choice of a model (e.g., Soetaert et al. 2000) and close collaboration between researchers doing the measurements and the experts doing the modelling.

References

Aller, R. (1982). The Effects of Macrobenthos on Chemical Properties of Marine Sediment and Overlying Water. Animal-Sediment Relations. P. McCall and M. S. Tevesz, Springer US. 100: 53-102.

Appleby, P. G. (2008). Three decades of dating recent sediments by fallout radionuclides: a review. The Holocene 18(1): 83-93.

Berner, R. A. (1980). Early diagenesis: A theoretical approach. NJ, Princeton University Press, Princeton.

Boetius, A. and Wenzhöfer, F. (2009) In situ technologies for studying deep-sea hotspot ecosystems, Oceanography, 22, 177, doi: 10.5670/oceanog.2009.17.

Friedrich, J. & Janssen, F. et al. (2014). Investigating hypoxia in aquatic environments: diverse approaches to addressing a complex phenomenon. Biogeosciences 11(4): 1215-1259.

Furrer, G. and B. Wehrli (1996). Microbial reactions, chemical speciation and multicomponent diffusion in pore waters of an eutrophic lake. Geochim Cosmochim Acta 60(13): 2333–2346.

Holtappels, M., Glud, R. N., Donis, D., Liu, B., Hume, A., Wenzhöfer, F., and Kuypers, M. M. M.(2013) Effects of transient bottom water currents and oxygen concentrations on benthic exchange rates as assessed by eddy correlation measurements, J. Geophys. Res.- Oceans, 118, 1157–1169.

Huettel, M., et al. (2003). Hydrodynamical impact on biogeochemical processes in aquatic sediments. Hydrobiologia 494(1-3): 231-236.

Huettel, M., et al. (2014). Benthic Exchange and Biogeochemical Cycling in Permeable Sediments. Annual Review of Marine Science 6(1): 23-51.

Janssen, F., et al. (2005). Pore-water advection and solute fluxes in permeable marine sediments (I): Calibration and performance of the novel benthic chamber system Sandy. Limnology and Oceanography 50(3): 768-778.

Kristensen, E., et al. (2013). Interactions Between Macro- and Microorganisms in Marine Sediments. Washington, DC, American Geophysical Union.

Libes, S. M (1992) An introduction to Marine Biogeochemistry. ISBN 0-471-50946-9, John Wiley & Sons.

Lichtschlag, A., et al. (2015). Effects of fluctuating hypoxia on benthic oxygen consumption in the Black Sea (Crimean Shelf). Biogeosciences Discuss. 12(8): 6445-6488.

Seeberg-Elverfeldt, J., et al. (2005). Rhizon sampling of porewaters near the sediment- water interface of aquatic systems. Limnology and Oceanography: Methods 3: 361-371.

Soetaert, K., et al. (2000). On the coupling of benthic and pelagic biogeochemical models. Earth-Science Reviews 51(1-4): 173-201.

Tengberg, A., et al. (1995). Benthic chamber and profile landers in oceanography - a review of design, technical solutions and functioning. Prog Oceanogr 35: 265–294.

Urban, N. U., et al. (1997). Solute transfer across the sediment water interface of a eutrophic lake: I. Porewater profiles from dialysis samplers. Aquatic Sciences 59: 1-25.

Consequences of alterable phytoplankton traits for ecosystem dynamics in a changing environment

Jana Hinners

Institute of Hydrobiology and Fisheries Science, University of Hamburg, Hamburg, Germany (jana.hinners@uni-hamburg.de)

1. Working Hypothesis

Environmental changes affect phytoplankton traits, leading to changes in ecosystem dynamics. Specifically we hypothesize that

(i) the functional relationship between growth rate and environmental factors will significantly change in time due to evolutionary adaptation. Evolutionary adaptation has already been identified in several studies (Lohbeck et al. 2012, Lennon and Martiny, 2008; Yoshida et al. 2004).

(ii) there will be no changes in the conditions that regulate life cycle transition (we assume that life cycle transitions are critical for a species and thus fixed, i.e., a species cannot easily change the sensitivity to environmental cues to shift the timing of life cycle transition on these time scales)

(iii) changing environmental conditions together with changes in phytoplankton traits will alter ecosystem functioning, i.e. total annual primary production, export production, grazing through zooplankton, etc.

2. Specific research questions

2.1 Do we see significant temporal changes in phytoplankton characteristics/traits between <u>two time slices?</u>

Resting stages of a dinoflagellate (Scrippsiella hangoei) are taken from 2 different time windows "100 yrs old" and "recent" (~5yrs old), the spores are set for germination, and 5 parallel cultures for "old" and "recent", respectively are build up to account for intraspecific variability. Comparable germination with sediment samples was performed by Ribeiro et al. (2013).

Laboratory experiments will be conducted to describe functional relationships between growth and two environmental factors (temperature, salinity) and to determine growth optima for the respective environmental factor used in aquatic ecosystem models. The laboratory experiments are moreover conducted to describe transitions between different life cycle stages; therefore, cell size and cell volume will be monitored during the growth experiments.

A temporal change is defined as significant when the differences in growth optima and functional relationship between the "100 yrs old" and "recent" are higher than among the parallel cultures (intraspecific variability); we expect that this will be the case.

2.2 Can we derive a general mathematical framework to formulate possible changes in a biologically meaningful way?

The different model approaches to account for intraspecific variability and "evolution" will be compared and if possible a new mathematical framework will be designed. The different populations of dinoflagellates of the two time windows can be described in ecosystem models by using the "subcompartment-approach" introduced by Beckmann and Hense (2004). A biologically meaningful way implies that the description is not simply based on an empirical relationship but knowledge about biological functions is considered.

2.3 What are the consequences of these temporal species-specific changes for ecosystem dynamics?

An existing Baltic Sea ecosystem 1D- or 3D-model setup will be used to investigate the effects on total primary production, export production, seasonal cycle, nutrients,and zooplankton. By consequences, we mean that there will be a shift in ecosystem functioning from 100 years ago to today.

References

Beckmann A, Hense I (2004), Torn between extremes: the ups and downs of phytoplankton. Ocean Dynamics, Vol. 54, No. 6, pp. 581-592

Lennon J, Martiny J (2008) Rapid evolution buffers ecosystem impacts of viruses in a microbial food web, Ecology Letters, Vol. 11, No. 11, pp. 1178-1188

Lohbeck, K, Riebesell U, Reusch T (2012) Adaptive evolution of a key phytoplankton species to ocean acidification, Nature Geoscience, Vol. 5, No. 5, pp. 346-351

Ribeiro S, Berge T, Lundholm N, Ellegaard M (2013) Hundred Years of Environmental Change and Phytoplankton Ecophysiological Variability Archived in Coastal Sediments. PLoS ONE, Vol 8, No. 4, doi:10.1371/journal.pone.0061184

Yoshida T, Hairston N, Ellner S (2004) Evolutionary trade–off between defence against grazing and competitive ability in a simple unicellular alga, Chlorella vulgaris, Proceedings of the Royal Society of London B: Biological Sciences, Vol. 271, No. 1551, pp. 1947-1953

Ecosystem Services of Coastal Lagoons

Miguel Inácio

Klaipeda University, Klaipeda, Lithuania / Leibniz Institute for Baltic Sea Research, Warnemuende, Germany
(miguel.inacio@io-warnemuende.de)

1. Background

Depending on the precise definition used, coastal zones occupy around 20% of the earth's surface, but host more than 45% of the global population and 75% of the world's largest urban agglomerations (Turner et al., 2014). A "slice" of this percentage is related to transitional water ecosystems, such as Coastal Lagoons. According to the United Nations glossary of environmental statistics (UNSD, 2006) coastal lagoons are defined as "Sea-water bodies situated at the coast, but separate from the sea by land spits or similar features. Coastal lagoons are open to the sea in restricted spaces". These ecosystems account for nearly 13% (Barnes, 1980) of world coastlines and 5.3% of European coastlines (Razinkovas et al., 2008).

These ecosystem services are not only economically valuable but also have societal heritage, aesthetic and scientific values (Newton, et al., 2014), these ecosystem services are described by the Millennium Ecosystem Assessment (MEA, 2005) as "the benefits that people obtain from ecosystems" and this assessment also classifies the ecosystem services into supporting services (e.g. nutrient cycling, soil formation, primary production), regulating services (e.g. climate regulation, flood regulation, water purification), provisioning services (e.g. food, fresh water), and cultural services (e.g. aesthetic, spiritual, recreational and other non-material benefits.

There have been some developments and updates to Millennium Assessment classification, the research effort of TEEB and the now used by EU, CICES Ecosystem Services Classification. But all these efforts since the MA to CICES have one major objective which is to assess and map ecosystem services with the ultimate objective of integrate it into policy and decision making efforts, and this is particularly important for the study object in this case coastal lagoons because the characteristics of coastal lagoons make them particularly vulnerable to global changes and to environmental, economic and social pressures, especially when they are associated with river-mouths systems (Newton, et al., 2012)

Europe has already been doing many efforts primarily to the management of coastal lagoons and coastal waters through policies, and a recent effort under the umbrella of European Union Biodiversity 2020 Strategy, the project "Mapping and assessment of ecosystems and their services" (MAES).

2. Main Aim

The main aim is to study mainly two coastal lagoons (Curonian Lagoon, Lithuania; and Oder Lagoon, Germany/Poland), and synthesize information about ecosystem services linked with socio-economic aspects.

Later this information will be used to develop and apply a methodological classification assessment tool which would allow a score regarding ecosystem services. Then this information will be applied with the SAF approach in order to support managers and stakeholders in their decisions to achieve sustainable management of these ecosystems.

This study also focus on linking the Ecosystem Services analysis with modeling discipline as a proxy for predictions on ecosystem services changes in past and future.

There is a straight and close connection of this study with the recent ICM Project named BaltCoast – A Systems Approach Framework for Coastal Research and Management in the Baltic Sea – in which both study and Project objectives work together, being this Project a vital pillar for the fulfillment of PhD studies.

3. Methodology

The methodology will be approached in two different ways.

The first will be based on literature review and expert interviews, this allows to compile information needed about state of art for proposed research topics and also the personal view of experts in order to achieve a correct approach to fully understand the study and accomplish an up to date study.

The second approach will be based on data collection and analysis, performing statistical analysis when necessary. This will contribute for the accomplishment of objectives regarding the comparison study between lagoons and the modelling linkage with ecosystem services.

One of end products consists on developing a spreadsheet classification tool for ecosystem services to be applied in the system. This then will be applied into SAF approach as a product for support decision for managers and stakeholders to implement a sustainable management plan, and also this end product will be applied within EU policies and frameworks.

The research was divided into four work packages with different objectives but in the end complementing each other.

Work Package 1

This work package will consist on "Developing a spreadsheet classification tool for Ecosystem Services"

- Objectives:
  - Allow classification of different ES;
  - Make use of existing WFD water bodies classification;
  - Use of Matrix Approach on expert judgement;
  - Make ES comparable;
  - Allowing a scoring for ES;
  - Application of Tool to different systems;

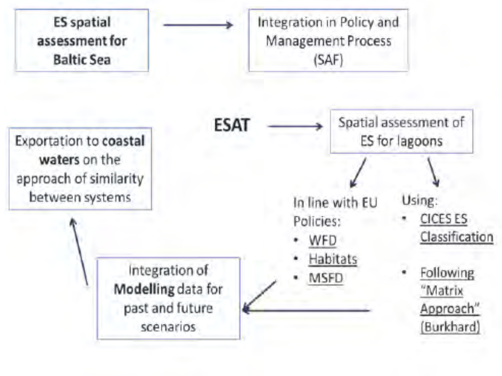

Figure 1 - Work Flow. The steps of the research methodology, beginning with the development of the tool (ESAT) until its application and integration in Policy and Management Processes

Work Package 2

This work package will consist on "Application of Classification Tool in Oder and Curonian Lagoons"

- Objectives:
  - Test the tool into case studies;
  - Compile comprehensive datasets on ES;
  - Define a historic baseline for the evaluation of ES;
  - Carry out comparative applications using this classification tool;
  - Quantify changes in ES supply during long term temporal analysis;
  - Adapt and develop indicator system to analyze the changes;
  - Provide recommendations for the use of Tool to support managers and stakeholders;

Work Package 3

This work package will focus on "Addressing specific major Ecosystem Services in depth / Application of ESAT in Baltic Sea"

- Objectives:
  - Work on specific major ES in more detail;
  - Specify relationship matrix between ES
  - Interactions regarding impacts in the system;
  - How to ameliorate and attenuate the effects and impacts;
  - Considerations for nature protection remediation;

Work Package 4

This work package will focus on "The application of modelling within Ecosystem Services analysis / Application of ESAT in Baltic Sea"

- Objectives:
  - Integration of modelling tools into ES assessment, and analysis;
  - Modelling as a tool for predicting ES-Indicator relationship;
  - Prediction model for ES "behaviour" for past and future scenarios;

Doctoral Studies Contribution

This Doctoral Study has the main aim to study mainly two coastal lagoons (Curonian Lagoon, Lithuania; and Oder Lagoon, Germany/Poland), and synthesize information about ecosystem services linked with socio-economic aspects. Later this information will be used to develop and apply a methodological classification assessment tool which would allow a score regarding ecosystem services. Then this information will be applied with the SAF approach in order to support managers and stakeholders in their decisions to achieve sustainable management of these ecosystems. This study also focus on linking the Ecosystem Services analysis with modelling discipline as a proxy for predictions on ecosystem services changes in past and future. Other very important aim is to transfer the knowledge on coastal lagoons and apply it to coastal waters, performing an ecosystem services assessment for the Baltic Sea.

These objectives follow the future research on ecosystem services in Europe, by bridging the gap of marine and coastal lagoons assessments and mapping of ecosystem services, developing a tool that follow the latest knowledge of scientific community. Also this study will be important for the knowledge about the interaction between land-sea interface and the relation between the services in order to obtain the best sustainable results to be include in management and policy, as well as integrating modelling discipline as a proxy to predict the relative change in the supply of ecosystem services compared to past and future scenarios.

There will be also close collaboration with ongoing research efforts on ecosystem services mapping and assessment, the already mentioned BaltCoast Project, cooperation/synergies between/with Institutes from the Baltic States and European Project named ESMERALDA with the objective of delivering a flexible methodology to provide the building blocks for pan-European and regional ecosystem services assessment

References

Barnes R., 1980, Coastal Lagoons, The Natural History of a Neglected Habitat, 106 pp. Cambridge University Press, Cambridge.

Millennium Ecosystem Assessment, 2005, Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC

Newton A., et al., 2014 An overview of ecological status, vulnerability and future perspectives of European large shallow, semi-enclosed coastal systems, lagoons and transitional waters, Estuarine, Coastal and Shelf Science. 140, pp. 95-122

Newton A., 2012 A systems approach for sustainable development in coastal zones, Ecology and Society, 17, 3, pp 41

Razinkovas A., Gasi-unait Z., Viaroli P., Zaldívar J., 2008 European lagoons and need for further comparison across spatial and temporal scales, Hydrobiologia, 611, pp. 1-179

Turner K., Schaafsma M., Elliott M., Burdon D., Atkins J., Jickells T., Tett P., Mee L., van Leeuwen S., Barnard S., Luisetti T., Paltriguera L., Palmieri G., & Andrews J., 2014 UK NationalEcosystem Assessment Follow-on. Work Package Report 4: Coastal and marine ecosystem services: principles and practice. UNEP-WCMC, LWEC, UK.

UNSD, 2006. Manual for the national standardization of geographical names, ST/ESA/STAT/SER.M/88, 2006. United Nations, New York, pp. 169

The development of hypoxia in coastal basins of the northern Baltic Sea during the last 2000 years

Sami Jokinen

Department of Geography and Geology, University of Turku, Finland (sami.jokinen@utu.fi)

1. Background

The dynamics and long-term spreading of hypoxia in the central deep Basins of the Baltic Proper is a well-documented phenomenon. However, in enclosed coastal sub-basins the spatio-temporal evolution of hypoxia and changes in the main factors affecting it (e.g. climate, nutrient loading) are inadequately understood. Notably, the conventional environmental monitoring programmes reach back only to the 1970s (Hänninen et al. 2000), when intense human activities in these ecologically sensitive areas were already considerable. Therefore, long-term information on environmental conditions predating the anthropogenic impact is necessary for determining the natural extent for the spreading of hypoxia.

Although the occurrence of hypoxic coastal areas during the Modern Warm Period has recently been put together (Conley et al. 2011), further sedimentological and ichnological studies are required in order to assess millennial trends in the oxygen concentrations, macrobenthic communities and the possible coupling between offshore and coastal areas. Fortunately, the past environmental conditions and macrobenthic community dynamics are recorded in the fabric, mineralogy and trace fossil assemblages of the sediments (e.g. Virtasalo et al. 2011b).

2. Objectives

The main objective of this study is to assess how the coastal areas of the northern Baltic Sea respond to natural climate variability such as the Medieval Climatic Anomaly (950–1250 AD) and the Little Ice Age (1350–1850 AD). The obtained high resolution data on the natural variation in oxygen concentration is a prerequisite for delineating to what extent the modern coastal hypoxia results from anthropogenic impact.

The gained understanding of bottom water conditions during the Medieval Climatic Anomaly (anomalously warm period) will provide an analogue for inferring forthcoming environmental changes in coastal areas due to the ongoing global warming. Through assessing the long-term changes in the depositional environment, future changes in oxygen and phosphorus concentration, and in salinity will be anticipated more accurately, facilitating the evaluation of adequate measures that must be taken to ensure a healthier coast (e.g. Kotilainen et al. 2014). Furthermore, long-term time series obtained in this study are essential for reliable validation of the coastal ecosystem models.

3. Project execution

The first publication (Jokinen et al. 2015) examines the origin and microfabric of modern laminated sediments that are formed in isolated anoxic coastal sub-basins. By comparing the observed sedimentation cycle with coastal sediment trap studies, it is shown that the lamina successions reflect (sub-)seasonal sedimentation. Consequently, these laminites offer a potential tool for environmental reconstructions at intra-seasonal resolution (Fig. 1).

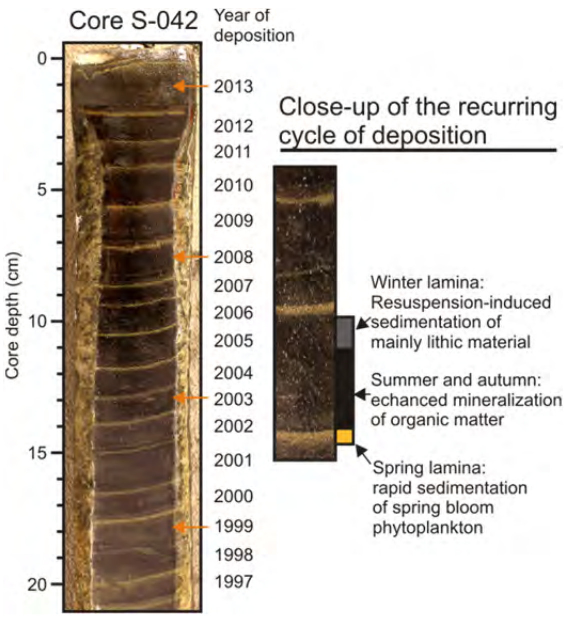

Figure 1. Photographs of annually laminated sediments in the coastal Archipelago Sea. The annual cycle of deposition was inferred based X-radiography, optical microscopy and SEM imaging of epoxy impregnated samples. The high annual accumulation rates of up to 2 cm a^{-1} provide sub-seasonal resolution for reconstructing past environmental changes.

The second publication discusses how the active microbial communities affect the sediment mineral magnetism. According to Reinholdsson et al. (2013), the occurrence of biogenic greigite mineral (Fe_3S_4) produced in the sediment by magnetotactic bacteria, can be used as a proxy for spatio-temporal variations in hypoxic conditions in the Baltic Sea. The fluctuations in biogenic greigite concentration will be determined using mineral magnetic measurements complemented with FE-SEM imaging.

The third publication concerns sedimentary trace fossils as indicators of long-term changes in the composition of benthic fauna communities. Trace fossils being sensitive indicators of the benthic environment (Virtasalo et al. 2011a), long-term changes in the near-bottom oxygen concentration, salinity and deposition of organic matter will be assessed. The analyses will be conducted through detailed examination of X-radiographs obtained from long sediment cores.

The fourth publication assesses coastal depositional paleoenvironment utilizing mineral-specific microanalyses of sediment samples impregnated in epoxy resin. The investigations are focused on early-diagenetic mineral phases, which are formed during or shortly after the sediment deposition. This is an entirely novel approach that concentrates the microanalyses on carefully chosen fine grains of relevant mineral phases. The formational environments of these mineral are known, enabling reconstruction of the depositional paleoenvironment (oxygen concentration, salinity, trophic state) in unprecedented detail. The depositional environments between laminated (anoxic conditions) and bioturbated (oxic conditions) will be compared.

4. Coring locations and geochronology

The sediment coring locations along the Finnish coast are chosen based on acoustic-seismic profiles recorded in previous studies. Coring locations with substantial urban impact as well as remote sites are included in the sampling programme.

The high resolution geochronology for the sediment cores is constructed using varve counting, paleomagnetic dating, ^{137}Cs and ^{210}Pb dating, and anthropogenic lead fallout. Further support for the chronology will be obtained using radiocarbon dating.

References

Conley, D.J., Carstensen, J., Aigars, J., Axe, P., Bonsdorff, E., Eremina, T., Haahti, B.-M., Humborg, C., Jonsson, P., Kotta, J., Lännegren C., Larsson, U., Maximov, A., Medina, M.R., Lysiak-Pastuszak, E., Remeikate-Nikiene, N., Walve, J., Wilhelms, S., Zillén, L. (2011). Hypoxia is increasing in the coastal zone of the Baltic Sea. Environmental Science & Technology, Vol. 45, pp. 6777–6783.

Hänninen, J., Vuorinen, I., Helminen, H., Kirkkala, T., Lehtilä, K. (2000). Trends and gradients in nutrient concentrations and loading in the Archipelago Sea, Northern Baltic, in 1970–1997. Estuarine, Coastal and Shelf Science, Vol. 50, pp. 153–171.

Jokinen, S.A., Virtasalo, J.J., Kotilainen, A.T., Saarinen, T. (2015). Varve microfabric record of seasonal sedimentation and bottom flow-modulated mud deposition in the coastal northern Baltic Sea. Marine Geology, Vol. 366, pp. 79–96.

Kotilainen, A.T., Arppe, L., Dobosz, S., Jansen, E., Kabel, K., Karhu, J., Kotilainen, M.M., Kuijpers, A., Lougheed, B.C., Meier, M., Moros, M., Neumann, T., Porsche, C., Poulsen, N., Rasmussen P., Ribeiro, S., Risebrobakken, B., Ryabchuk, D., Schimanke, S., Snowball, I., Spiridonov, M., Virtasalo, J.J., Wecström, K., Witkowski, A., Zhamoida, V. (2014). Echoes from the past: a healthy Baltic Sea requires more effort. Boreas, Vol. 43, pp. 60–68.

Reinholdsson, M., Snowball, I., Zillén L., Lenz, C., Conley, D.J. (2013). Magnetic enhancement of Baltic Sea sapropels by greigite magnetofossils. Earth and Planetary Science Letters, Vol. 366, pp. 137–150.

Virtasalo, J.J., Bonsdorff, E., Moros, M., Kabel, K., Kotilainen, A.T., Ryabchuk, D., Kallonen, A., Hämäläinen, K. (2011a). Ichnological trends along an open-water transect across a large marginal-marine epicontinental basin, the modern Baltic Sea. Sedimentary Geology, Vol. 241, pp. 40–51.

Virtasalo, J.J., Leipe, T., Moros, M., Kotilainen, A.T. (2011b). Physicochemical and biological influences on sedimentary-fabric formation in a salinity and oxygen-restricted semi-enclosed sea. Sedimentology, Vol. 58, pp. 352–375.

Effect of variability in environmental conditions on Baltic Sea Calanoid Copepod egg bank and recruitment. Preliminary results – *Acartia* and E*urytemora* long-term population analysis.

Astra Labuce

Latvian Institute of Aquatic Ecology, Riga, Latvia (astra.labuce@lhei.lv)
University of Latvia, Faculty of Biology, Riga, Latvia

1. Introduction

Diapause is a necessity to survive through harsh conditions for organisms all over the world and calanoid copepods are not an exception. Both strategies - hibernation as a resting egg or/and overwintering in water column are common in calanoid copepods from temperate seas, such as the Baltic Sea. The main objective of this study is to determine contribution of hibernated copepods and egg bank to population recruitment and evaluate importance of these two overwintering strategies in life cycles of copepod key species in the Gulf of Riga. As the study has started recently many sections are still in progress and in this extended abstract only long-term population analysis of key copepods will be described, and conclusions made here could be changed during the process of further work.

2. Methods

The study area is the Gulf of Riga, an enclosed waterbody in the eastern part of the Baltic Sea. Mesozooplankton community of the Gulf of Riga is very similar to estuarine ecosystems due to high fresh:saline water inflow ratio. *Acartia* spp. (A.*bifilosa*, A.*tonsa*) and *Eurytemora* spp. (E.*affinis*, E.*carolleeae*) are dominant calanoid copepod species in the area (Kotta et al. (2008); Sukhikh et al. (2013)) and in text they will be referred as "key species". For several years increase in amount of calanoid copepod *Limnocalanus macrurus* has been observed as well (pers. obs.), but in order to research its life cycle traits and overwintering strategies few more years of observations are needed.

Mesozooplankton samples used in this analysis were collected in the center of the Gulf of Riga (57°18'N 23°51' E) from 1993 to 2013 three to twenty times per year with WP-2 net (mesh size 100 µm). Station depth was approximately 45 meters. Samples were preserved using formaldehyde solution in seawater with final concentration of 4%, and they were analyzed under a binocular or compound microscope following HELCOM recommendations (1998). Water temperature, salinity and concentration of chlorophyll a were measured at the same sampling event, as well as phytoplankton samples were collected.

3. *Acartia* and *Eurytemora* population analysis

Acartia and *Eurytemora* are two quite different genera, regarding their reproduction strategy. *Acartia* spp. is free-spawning r-strategic species, with high egg production, even up to 100 eggs fm^{-1} d^{-1} (Kiørboe, Sabatini (1995)), although studies with Baltic *Acartia* females show that egg production in brackish Baltic Sea is two to four times lower depending on the species and season (Dutz et al. (2003); Holste, Peck (2006); Hansen et al. (2009)). Though *Eurytemora* is sac-spawning K-strategic species with lower egg production (Hirche (1992); Ask et al. (2006)), but higher hatching rates (Ask et al. (2006)).

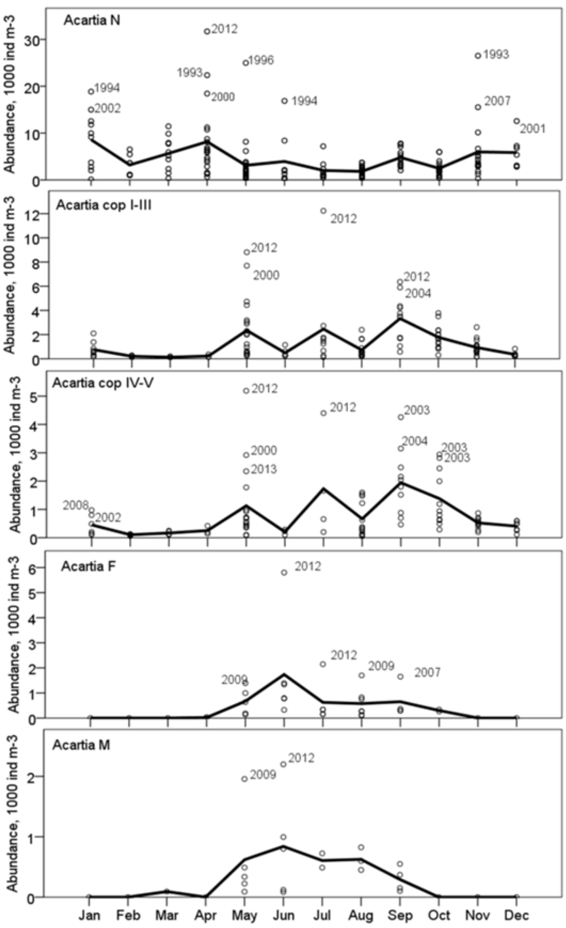

Figure 1. *Acartia* spp. abundance per month (if two or more sampling events were performed in the same month, each of them are shown as separate data point), data from 1993 to 2013 (white dots). Black line shows long term average. Outliers have label of respective year.

Amount of *Acartia* spp. nauplii varies greatly during all seasons, except for summer, in the Gulf of Riga (Figure 1), whilst amount of *Eurytemora* spp. nauplii is mutable during summer and late autumn (Figure 2). This variability could point to most sensitive periods of year when recruitment could be strongly influenced by one or several factors, which will be determined using statistical methods in further working process – at the moment analysis is in starting phase.

The firsts thought is that recruitment of *Acartia* spp. is based more on egg hatching from egg bank in the sediments, as nauplii are always in the water column, regardless of female presence or absence and independently of environmental factors (Figure 1). But regarding *Eurytemora* population, it could be other way around – the main recruitment comes from present female production, when the environmental conditions are favorable for survival, as *Eurytemora* overwinters as adults in the Gulf of Riga (Figure 2) and the highest amount of nauplii match peaks of female abundance (Figure 2).

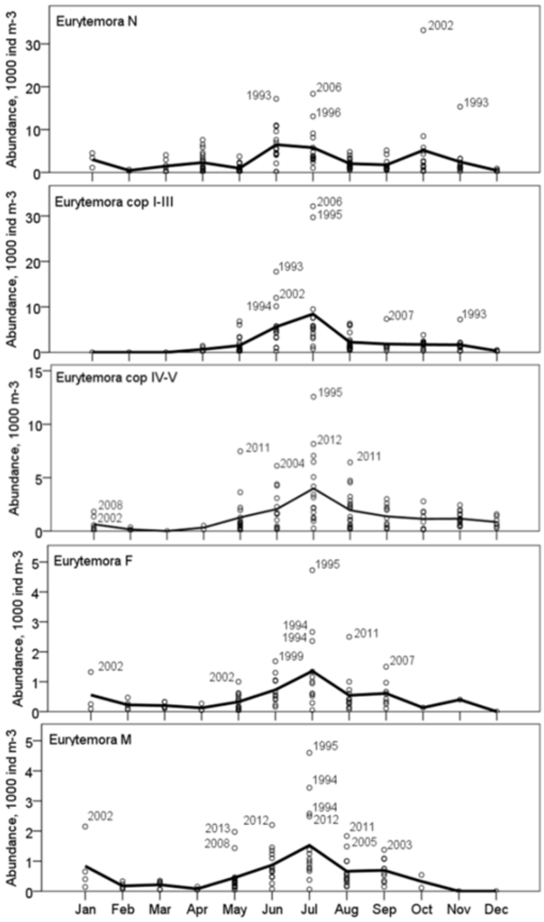

Figure 2. *Eurytemora* spp. mean abundance per month (if two or more sampling events were performed in the same month, each of them are shown as separate data point), data from 1993 to 2013 (white dots). Black line shows long term average.

Further plans is to examine both of previously mentioned assumptions, combining population data analysis (abundance, environmental factors, density of egg bank, distribution among layers) and experimental work (egg production, hatching success and recruitment evaluation per season – depending on temperature and oxygen regime) in order to evaluate the variability of recruitment in different seasons for each key species separately.

References

Ask J., Reinikainen M., Båmstedt U. (2006) Variation in hatching success and egg production of *Eurytemora affinis* (Calanoida, Copepoda) from the Gulf of Bothnia, Baltic Sea, in relation to abundance and clonal differences of diatoms, Journal of Plankton Research, 28, 7, pp.683-694

Dutz J., Morholz V., Peters J., Renz J., Alheit J. (2003) A strong impact of winter temperature on spring recruitment of a key copepod species in the Bornholm Basin: potential linkages to climate variability, GLOBEC International Newsletter. Global Ocean Ecosystem Dynamics, 10, 1, pp. 13-14

Dzierzbicka-Glowacka L., Piskozub J., Jakacki J., Mudrak S., Żmijewska M.I. (2012) Spatiotemporal distribution of copepod populations in the Gulf of Gdansk (southern Baltic Sea), Journal of Oceanography, 68, pp. 887-904

Hansen B.W., Drillet G., Kristensen R.M., Sørensen T.F., Tøttrup M.T. (2009) Production, hatching success and surface ornamentation of eggs of calanoid copepods during a winter at 57°N, Marine Biology, 157, 1, pp. 59-68

HELCOM (1998) Guidelines for the Baltic monitoring programme for the third stage, Baltic Sea Environment Proceedings, 27, 193 pp.

Hirche H.J. (1992) Egg Production of *Eurytemora affinis* – Effect of k-Strategy, Estuarine, Coastal and Shelf Science, 35, pp.395-407

Holste L., Peck M.A. (2006) The effects of temperature and salinity on egg production and hatching rate success of Baltic Acartia tonsa (Copepoda: Calanoida): a laboratory investigation, Marine Biology 148, pp. 1061-1070

Kiørboe T., Sabatini M. (1995) Scaling of fecundity, growth and development in marine planktonic copepods, Marine Ecology Progress Series, 120, pp. 285-298

Sukhikh N., Souissi A., Souissi S., Alekseev V. (2013) Invasion of *Eurytemora* sibling species (Copepoda:Temoridae) from north America into the Baltic Sea and European Atlantic coast estuaries, Journal of Natural History, 47, 5-12, pp. 753-767

Loads, transport and transformations of N, P and Si along the continuum of Nemunas - coastal zone of the Baltic sea

Irma Lubiene

Coastal Research & Planning Institute, Marine Science & Technology Centre, Klaipeda University, Klaipeda, Lithuania (irma.lubiene@apc.ku.lt)

1. Introduction

Nitrogen, phosphorus and silica are considered key elements for both terrestrial and aquatic ecosystems. They undergo complex biogeochemical transformations during their paths from inland to the coastal areas, in particular while they cross estuarine, transitional zones (Galloway et al., 2004; Boyer and Howarth, 2008). The passive flushing of these nutrients offshore can be limited by temporary retention by primary producers, sedimentation and burial in sediments, microbially - mediated or abiotic transformations or transfer to the atmosphere (Fulweiler et al., 2007; Zilius et al., 2014). However, the role of estuaries as one-way sink of nitrogen, phosphorus and silica has been repeatedly questioned, as for example biological N-fixation can enhance nitrogen accumulation into transitional systems as well as hypoxia can determine massive release of P from estuarine sediments (Howarth et al., 1988; Fulweiler et al., 2007; Zilius et al., 2014).

The loads and the chemical forms of nitrogen (N), phosphorus (P) and silica (Si) reaching coastal areas have changed in the last decades as a consequence of expanding human population and activities near watercourses, multiple water use, increased use of organic and synthetic fertilizers, simplification of the landscape and river damming (Downing et al., 1999). Any alteration of N, P and Si loads, affecting their ecological stoichiometry, has significant impacts on the biomass and composition of benthic and pelagic primary producer (Justic et al., 1995). Excess nitrogen has determined the disappearance of submersed macrophyte meadows from coastal areas and their replacement by opportunistic macroalgae or phytoplankton (Viaroli et al., 2008). Proliferation of macroalgae has triggered a cascade of negative consequences as large oxygen variations in the water column (from supersaturation to hypoxia), dystrophy and release of toxic sulphides from sediments (Giordani et al., 1996). Retention of silica within watersheds, a demonstrated consequence of river damming, has resulted in inhibition of diatom growth in the coastal area and has favored the blooms of harmful cyanobacteria.

A relevant question of this work will be whether changes at the basin level due to global changes and altered precipitation pattern affect the ecological stoichiometry of N, P and Si and result in strongly unbalanced ratios with the possibility to turn one of the three elements at limiting concentrations. Another question will be to investigate whether, and in which direction, the processes occurring in the lagoon change the N:Si:P ratios. In particular, I will investigate whether N, Si and P biogeochemistry within the estuary can unbalance the relative amount of the three elements, and can have consequences in the adjacent coastal zone.

Analysing the biogeochemical cycles of 3 elements implies to develop specific analytical skills as P and Si have important sedimentary cycles and their pools include refractory and bioavailable forms which need to be quantified and considered separately. The control of P and Si mobility is expected to be largely based on abiotic processes even if microbes and primary producers can have a relevant role in driving their fluxes. The N transformations in estuaries were studied in detail in the last 20 years and have produced an impressive body of literature (Bartoli et al., 2009) where many different biogeochemical paths (ammonification, nitrification, denitrification, nitrate reduction to ammonium, anaerobic ammonium reduction, nitrogen fixation) were analysed in details. In this panorama, the N fluxes from the atmosphere to the water column/sediment system are probably underestimated also in eutrophic, N-enriched sites. Once again, the ecological stoichiometry more than the concentration of a single nutrient seems the relevant factor in determining the observed trends.

Taking into account the importance of N, P and Si for the functioning of aquatic and terrestrial environments, the calculation of their budgets can be an useful approach for the better understanding of estuarine nutrient dynamics and a more effective environmental management (Nixon et al. 1996; Rabouille et al. 2008).

2. General aim

The main aim of my thesis is to evaluate how the biological and physical processes occurring within the Curonian lagoon and how global changes at the Nemunas watershed level affect the loads of the three key nutrients N, Si and P during their path from the inland, terrestrial side to the Baltic Sea. This will be pursued via a combination of black box approaches (loads and LOICZ budgets) together with the upscaling of pelagic and benthic process measurements carried out at representative sites within the lagoon.

3. Specific aims

Analyze inflowing and outflowing monthly nutrient loads during 3 years, and in particular their interannual variability and discuss the possible determinants (meteorological events affecting Nemunas River discharge, blooms of microalgae, dystrophic events, etc.);

Compare such data with available information of the last 10-20 years and discuss how climate change or the economic crisis can impact nutrient transport and stoichiometry and how they regulate the equilibrium between diatoms and cyanobacterial blooms;

Perform a LOICZ budget of N, Si and P for the Curonian Lagoon;

Analyse in detail pelagic and benthic processes affecting the 3 nutrients (uptake, regeneration, burial, atmospheric losses, etc.) and upscale the results in order to provide a mechanistic explanation of the LOICZ Budget.

The study area: the Curonian lagoon

The Curonian Lagoon is a large (1,584 km^2), shallow (mean depth 3.8 m), highly eutrophicated and mainly freshwater estuary connected to the Baltic Sea by a narrow strait (Fig. 1). Occasionally, wind driven intrusion of brackish water rises salinity up to 1-2 psu, but only in the northern portion of the lagoon.

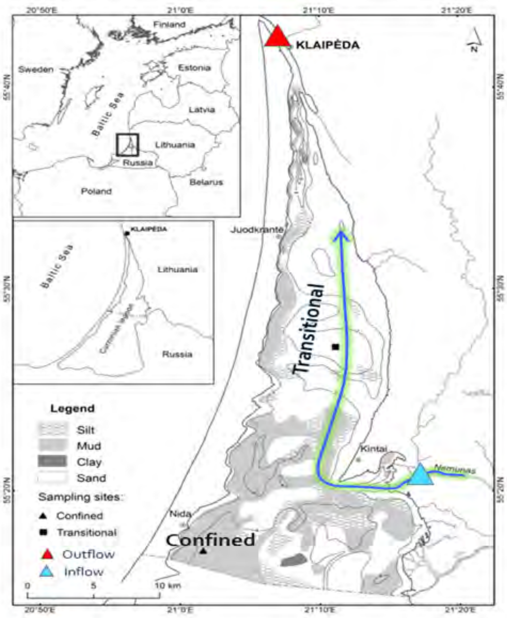

Figure 1. A map with the Lithuanian part of the Curonian lagoon and sampling stations (Zilius et al., 2014).

The Nemunas River brings 98% of the total freshwater runoff (annual discharge 23 km^3) and enters the lagoon in its central area. It divides the water body in a northern, transitional riverine-like part exporting freshwater into the sea and in a confined, southern part with long water residence time (Ferrarin et al., 2008). Annual amplitude of water temperatures is wide, up to 25-29°C; the strait is permanently ice free, whereas the rest of the lagoon is ice covered for ~100 days per year, on average (Zilius et al. in prep.).

Shallowness, wind regimes, sediment resuspension and frequent microalgal blooms make this system permanently turbid. Nutrient concentration dynamics are similar to those of temperate and boreal transitional waters with strong riverine inputs; the highest concentration of nutrients (>100 µM DIN) are observed in early spring, just after ice melting (Zilius, 2011). Bottom sediments are a mosaic of sand and silt, with muddy areas on the western border, along the Curonian Spit. Seasonal succession of the phytoplankton assemblages consists of spring diatom blooms followed, when weather conditions are favourable and coupled with low inorganic N:P ratios, by a summer bloom of cyanobacteria (Zilius et al., 2014).

References

Bartoli, M., Longhi, D., Nizzoli, D., Como, S., Magni, P., Viaroli, P. Short term effects of hypoxia and bioturbation on solute fluxes, denitrification and buffering capacity in a shallow dystrophic pond (2009) Journal of Experimental Marine Biology and Ecology, 381 (2), pp. 105-113.

Boyer, E. W., Howarth, R. W. (2008). Nitrogen fluxes from rivers to the coastal oceans. Nitrogen in the Marine Environment, second ed. Academic Press, San Diego, 1565-1587.

Downing, J. A., McClain, M., Twilley, R., Melack, J. M., Elser, J., Rabalais, N. N., Howarth, R. W. (1999). The impact of accelerating land-use change on the N-cycle of tropical aquatic ecosystems: current conditions and projected changes. Biogeochemistry, 46(1-3), 109-148.

Ferrarin, C., Razinkovas, A., Gulbinskas, S., Umgiesser, G., Bliūdžiutė, L., 2008. Hydraulic regime-based zonation scheme of the Curonian Lagoon. Hydrobiologia 611, 133–146.

Fulweiler, R. W., Nixon, S. W., Buckley, B. A., Granger, S. L. (2007). Reversal of the net dinitrogen gas flux in coastal marine sediments. Nature, 448(7150), 180-182.

Galloway, J. N., Dentener, F. J., Capone, D. G., Boyer, E. W., Howarth, R. W., Seitzinger, S. P., Vöosmarty, C. J. (2004). Nitrogen cycles: past, present, and future. Biogeochemistry, 70(2), 153-226.

Giordani G, Cattadori M, Bartoli M, Viaroli P (1996) Sulphide release from anoxic sediments in relation to iron availability and organic matter recalcitrance and its effects on inorganic phosphorus recycling. Hydrobiologia 329: 211–222.

Howarth, R. W., Marino, R., Cole, J. J. (1988). Nitrogen fixation in freshwater, estuarine, and marine ecosystems. 2. Biogeochemical controls. Limnology and Oceanography, 33(4), 688-701.

Justić, D., Rabalais, N. N., Turner, R. E., Dortch, Q. (1995). Changes in nutrient structure of river-dominated coastal waters: stoichiometric nutrient balance and its consequences. Estuarine, Coastal and Shelf Science, 40(3), 339-356.

Nixon, S.W., J.W. Ammerman, L.P. Atkinson, V.M. Berounsky, G. Billen, W.C. Boicourt, W.R. Boynton, T.M. Church, D.M. DiToro, R. Elmgren, R.H. Garber, A.E. Giblin, R.A. Jahnke, N.J.P. Owens, M.E.Q. Pilson, S.P. Seitzinger, 1996. The fate of nitrogen and phosphorus at the land-sea margin of the North Atlantic Ocean.Biogeochemistry 35: 141-180.

Rabouille, C., Conley, D. J., Dai, M. H., Cai, W. J., Chen, C. T. A., Lansard, B., McKee, B. (2008). Comparison of hypoxia among four river-dominated ocean margins: The Changjiang (Yangtze), Mississippi, Pearl, and Rhone rivers. Continental Shelf Research, 28(12), 1527-1537.

Viaroli, P., M. Bartoli, G. Giordani, M. Naldi, S. Orfanidis, J.M. Zaldivar. 2008. Community shifts, alternative stable states, biogeochemical controls and feedbacks in eutrophic coastal lagoons: a brief overview. Aquat. Conserv., DOI: 10.1002/aqc.956.

Zilius, M., 2011. Oxygen and nutrient exchange at the sediment-water interface in the eutrophic boreal lagoon (Baltic sea). Summary of PhD dissertation, Klaipėda University, Klaipėda.

Zilius, M., Bartoli, M., Bresciani, M., Katarzyte, M., Ruginis, T., Petkuviene, J., Lubiene, I., Giardino, C., Bukaveckas, P., Wit R, Razinkovas-Baziukas, A. (2014). Feedback Mechanisms Between Cyanobacterial Blooms, Transient Hypoxia, and Benthic Phosphorus Regeneration in Shallow Coastal Environments. Estuaries and coasts 37 (3), 680-694.

Past and future climate variability of the Baltic Sea

H.E. Markus Meier

Research Department, Swedish Meteorological and Hydrological Institute, Norrköping, Sweden and Department of Meteorology, Stockholm University, Stockholm, Sweden (markus.meier@smhi.se)

1. Overview

In this presentation past and future climate variability of the Baltic Sea (Fig.1) are discussed and drivers of the variability are investigated based upon existing literature. We limit the discussion to physical variables like water temperature, salinity, currents, sea level, sea ice concentration, sea ice thickness, etc. and we focus on multi-annual to multi-centennial time scales. As climate is the statistics of weather, basically differences in mean variables between 30-year long time slices are investigated. However, some problems with this approach arise because the wind field over the region has a pronounced decadal variability affecting ocean parameters like transports and sea level significantly. Both BACC reports (BACC Author Team, 2008; BACC II Author Team, 2015) and even the most recent literature are reviewed.

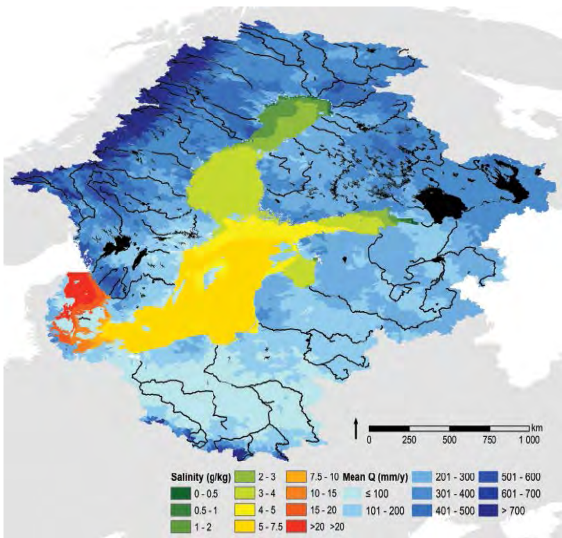

Figure 1. The Baltic Sea drainage basin together with the spatial variability in annual mean water discharge (Q) calculated with the Hydrological Predictions for the Environment (HYPE) model (Arheimer et al., 2012) and with annual mean sea surface salinity in the Baltic Sea. This salinity diagram shows the gradient from high (red) to low (green) salinities, calculated with the Rossby Centre Ocean model (Meier et al., 2003). Source: Meier et al. (2014).

2. Past climate variability

We investigate past variability from observations (instrumental records) and historical reconstructions since 1850, paleo-climate proxy data of the past 8000 years and climate model simulations. An example of an attribution study of decadal variability during 1902-1998 is shown in Figure 2. Meier and Kauker (2003) discovered that the freshwater storage anomaly and the accumulated freshwater inflow are well correlated. They found two exceptionally long stagnation periods during 1902-1998 and concluded that about half of the decadal variability is related to the accumulated freshwater inflow. Another significant part of the decadal variability of salinity is caused by the low-frequency variability of the wind associated to the large-scale sea level pressure over Scandinavia. River regulation since the 1970s, sea ice cover and sea level variability in Kattegat on decadal time scale have no impact on decadal variations in Baltic Sea salinity.

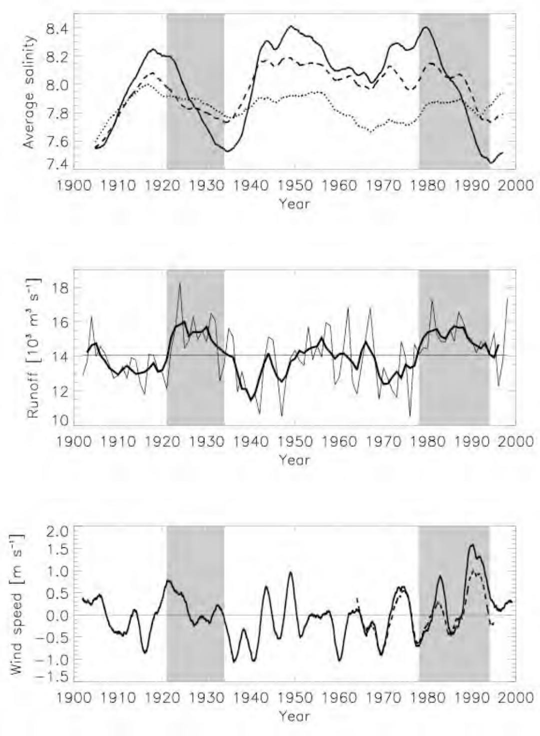

Figure 2. Upper panel: The 4-year running mean salinity in the Baltic Sea without Kattegat: hindcast experiment (solid), experiment with climatological monthly mean runoff (dashed), and experiment with climatological monthly mean runoff and 4-year high-pass-filtered sea level pressure and wind forcing (dotted). Middle panel: Annual mean river runoff to the Baltic Sea without Kattegat (thin line). In addition, the 4-year running mean (thick line) and the total mean for the period 1902–1998 (horizontal line) are shown. Lower panel: The 4-year running mean zonal wind speed anomalies at Landsort: reconstruction (solid) and observations (dashed). The shaded ranges in all panels indicate periods with positive anomalous 4-year running mean runoff, which are related to stagnation phases. Source: Meier and Kauker (2003).

3. Future climate variability

With the help of statistical and dynamical (using regional models) downscaling of global climate model projections changes in regional climate for the coming 100 years can be studied. However, uncertainties caused by model biases, natural variability, and uncertain emission scenarios need to be taken into account. To estimate these uncertainties multi-model ensemble simulations are used. We will discuss existing approaches of regional climate modeling (including advantages and disadvantages) and will present results of scenario simulations. An example is shown in Figure 3. Meier et al. (2006c) studied multi-model ensemble simulations to investigate future salinity in the Baltic Sea. They found that salinity projections suffer from the large uncertainties due to internal variability and model biases. The largest uncertainty in their study is caused by global climate model biases. In most of the scenario simulations wind and freshwater inflow changes are important for salinity changes. If only wind changes are considered, average salinity changes vary between -31 and +9%. In the projections for 2071–2100, average salinity changes vary between -45 and +4%. However the largest positive change is not statistically significant. In the projection with the largest negative change, sea surface salinity in the Bornholm Basin is as low as in the northern Bothnian Sea in present climate and the Belt Sea front is shifted northward (Fig.3). In this study global sea level rise is not considered.

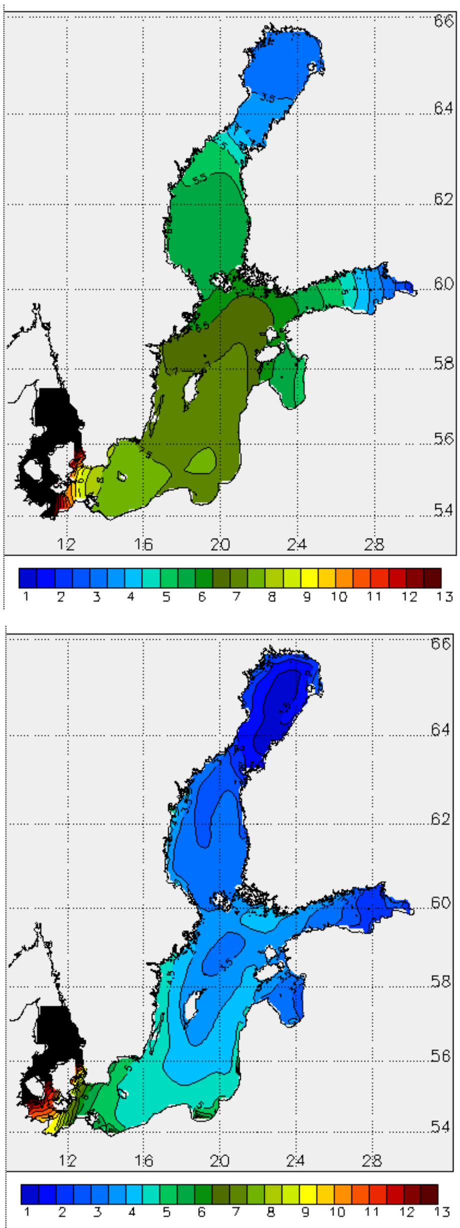

Figure 3. Sea surface salinity (in psu). Upper panel: Climatological data by Janssen et al. (1999). Lower panel: projection with the largest salinity change in 2071–2100 (RCAO-ECHAM4/A2). In the lower panel projected changes were added to climatological data. Salinities larger than 13 psu are shown in black. Source: Meier et al. (2006c).

References

Arheimer B, Dahne´ J, Donnelly C (2012) Climate change impact on riverine nutrient load and land-based remedial measures of the Baltic Sea Action Plan. AMBIO 41: 600–612, doi:10.1007/s13280-012-0317-0

Ådlandsvik B (2008) Marine downscaling of a future climate scenario for the North Sea. Tellus 60A:451-458

BACC Author Team (2008) Assessment of climate change for the Baltic Sea basin. Regional Climate Studies, Springer Verlag Berlin Heidelberg, 473 pp.

BACC II Author Team (2015) Second assessment of climate change for the Baltic Sea basin. Regional climate studies. Berlin: Springer.

Belkin I (2009) Rapid warming of large marine ecosystems. Prog Oceanogr 81:207-213

Döscher R, Willén U, Jones C, Rutgersson A, Meier HEM, Hansson U, Graham LP (2002) The development of the regional coupled ocean-atmosphere model RCAO. Boreal Environ Res 7:183-192

Dreier N, Schlamkow C, Fröhle P (2011) Assessment of Future Wave Climate on basis of wind-wav e correlations and climate change scenarios. JCoast Res, SI 64:210-214

Eilola K, Almroth-Rosell E, Dieterich C, Fransner F, Höglund A, Meier HEM (2012) Nutrient transports and interactions between coastal regions and the open Baltic Sea: A model study in present and future climate. AMBIO 41(6):586-599 doi:10.1007/s13280-012-0317-y

Fenger J, Buch E, Jakobsen PR, Vestergaard P (2008) Danish Attitudes and Reactions to the Threat of Sea-level Rise. J Coast Res 24(2):394-402

Gräwe U, Burchard H (2011) Global Change and Baltic Coastal Zones - Regionalisation of Climate Scenarios for the Western Baltic Sea. In: Global Change and Baltic Coastal Zones. Schernewski G, Hofstede J, Neumann T (eds) Springer, Dordrecht, The Netherlands

Gräwe U, Burchard H (2012) Storm surges in the Western Baltic Sea: the present and a possible future. Clim Dynam 39:165-183. DOI: 10.1007/s00382-011-1185-z

Gräwe U, Friedland R, Burchard H (2013) The future of the western Baltic Sea: two possible scenarios. Ocean Dynamics, 63(8): 901-921Gustafsson EO, Omstedt A (2009) Sensitivity of Baltic Sea deep water salinity and oxygen concentration to variations in physical forcing. Boreal Environ Res 14:18-30

Groll N, Hünicke B (2011) Baltic Sea wave conditions in a changing climate. Geophys Res Abstr14:EGU2012-5481

Haapala J, Lönnroth N, Stössel A (2005) A numerical study of open water formation in sea ice. JGeophys Res 110:C09011

Hansson D, Eriksson C, Omstedt A,Chen D (2011) Reconstruction of river runoff to the Baltic Sea, AD 1500–1995. Int J Climatol DOI:10.1002/joc.2097

Hordoir R, Meier HEM (2011) Effect of climate change on the thermal stratification of the Baltic Sea: a sensitivity experiment. Clim Dynam 38:1703-1713, DOI: 10.1007/s00382-011-1036-y

Holt J, Wakelin S, Lowe J, Tinker J (2010) The potential impacts of climate change on the hydrography of the northwest European continental shelf. ProgrOceanogr 86:361-379

Hünicke B (2010) Contribution of regional climate drivers to future winter sea-level changes in the Baltic Sea estimated by statistical methods and simulations of climate models. Int J Earth Sci 99:1721-1730, doi: 10.1007/s00531-009-0470-0.

Hünicke B,Zorita E (2008) Trends in the amplitude of Baltic Sea level annual cycle. Tellus A 60:154-164

IPCC (2001) Climate Change 2001: The Scientific Basis. Contribution from Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Houghton JT, Ding Y, Griggs DJ, Noguer M, van der Linden PJ, Dai X, Maskell K, Johnson CA (eds). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp 881

IPCC (2007) Climate Change 2007: The Physical Science Basis. Solomon S, Qin D, Manning M, Marquis M, Averyt K, Tignor MMB, Miller HL, Chen Z (eds) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp 996

Jylhä K, Fronzek S, Tuomenvirta H, Carter TR, Ruosteenoja K (2008) Changes in frost, snow and Baltic sea ice by the end of the twenty-first century based on climate model projections for Europe. Climatic Change 86:441-462

Kjellström E, Nikulin G, Hansson U, Strandberg G, Ullerstig A (2011) 21st century changes in the European climate: uncertainties derived from an ensemble of regional climate model simulations. Tellus, 63A(1):24-40. DOI: 10.1111/j.1600-0870.2010.00475.x

Kont A, Jaagus J, Aunao R, Ratas U, Rivis R (2008) Implications of Sea-Level Rise for Estonia. J Coast Res 24(2):423-431

Kriezi EE, Broman B (2008) Past and future wave climate in the Baltic Sea produced by the SWAN model with forcing from the regional climate model RCA of the Rossby Centre. In: IEEE/OES US/EU-Baltic International Symposium, May 27-29, 2008, Tallinn, Estonia, , pp. 360-366. IEEE.

Madsen KS (2009) Recent and future climatic changes in temperature, salinity and sea level of the North Sea and Baltic Sea. PhD thesis, Planet and Geophysics, Niels Bohr Institute, University of Copenhagen.

Meier HEM (2002) Regional ocean climate simulations with a 3D ice ocean model for the Baltic Sea. Part 1: Model experiments and results for temperature and salinity. Clim Dynam 19:237-253

Meier HEM (2005) Modeling the age of Baltic Sea water masses: Quantification and steady state sensitivity experiments. J Geophys Res 110 :C02006. doi:10.1029/2004JC002607

Meier HEM (2006) Baltic Sea climate in the late twenty-first century: a dynamical downscaling approach using two global models and two emission scenarios. Clim Dynam 27:39-68. DOI 10.1007/s00382-006-0124-x

Meier HEM, Kauker F (2003) Modeling decadal variability of the Baltic Sea Part 2: Role of freshwater inflow and large-scale atmospheric circulation for salinity. J Geophys Res 108,C11, 3368 doi:101029/2003JC001799

Meier HEM, Döscher R, Halkka A (2004a) Simulated distributions of Baltic sea-ice in warming climate and consequences for the winter habitat of the Baltic ringed seal. Ambio 33:249-256

Meier HEM, Broman B, Kjellström E (2004b) Simulated sea level in past and future climates of the Baltic Sea. Clim Res 27(1):59-75

Meier HEM, Andréasson J, Broman B, Graham LP, Kjellström E, Persson G, Viehhauser M. (2006a) Climate change scenario simulations of wind, sea level, and river discharge in the Baltic Sea and Lake Mälaren region - a dynamical downscaling approach from global to local scales. Reports Meteorology and Climatology No.109, SMHI, Norrköping, Sweden, pp 52

Meier HEM, Broman B, Kallio H, Kjellström E (2006b) Projections of future surface winds, sea levels, and wind waves in the late 21st century and their application for impact studies of flood prone areas in the Baltic Sea region. In: Schmidt-Thomé P (ed) Sea level changes affecting the spatial development of the Baltic Sea region, Geological Survey of Finland, Special Paper 41, Espoo pp 23-43

Meier HEM, Kjellström E, Graham LP (2006c) Estimating uncertainties of projected Baltic Sea salinity in the late 21st century. Geophys Res Lett 33(15): L15705, doi: 10.1029/2006GL026488

Meier HEM, Andersson H, Dieterich C, Eilola K, Gustafsson BG, Höglund A, Hordoir R, Schimanke S (2011a) Transient scenario simulations for the Baltic Sea Region during the 21st century. Rapport Oceanografi No.108, SMHI, Norrköping, Sweden, pp 81

Meier HEM, Andersson HC, Eilola K, Gustafsson BG, Kuznetsov I, Müller-Karulis B, Neumann T, Savchuk OP (2011b) Hypoxia in future climates - a model ensemble study for the Baltic Sea. Geophys.. Res.. Lett 38:L24608

Meier HEM, Eilola K, Almroth E (2011c) Climate-related changes in marine ecosystems simulated with a three-dimensional coupled biogeochemical-physical model of the Baltic Sea. Clim Res 48:31-55

Meier HEM, Höglund A, Döscher R, Andersson H, Löptien U,Kjellström E (2011d) Quality assessment of atmospheric surface fields over the Baltic Sea of an ensemble of regional climate model simulations with respect to ocean dynamics. Oceanologia 53:193-227

Meier HEM, Eilola K, Gustafsson BG, Kuznetsov I, Neumann T, Savchuk OP (2012a) Uncertainty assessment of projected ecological quality indicators in future climate. Rapport Oceanografi No.112, SMHI, Norrköping, Sweden, pp 11

Meier HEM, Hordoir R, Andersson HC, Dieterich C, Eilola K, Gustafsson BG, Höglund A, Schimanke S (2012b) Modeling the combined impact of changing climate and changing nutrient loads on the Baltic Sea environment in an ensemble of transient simulations for 1961-2099. Clim Dynam 39:2421-2441. DOI 10.1007/s00382-012-1339-7

Meier H E M, Müller-Karulis B, Andersson HC, Dieterich C, Eilola K, Gustafsson BG, Höglund A, Hordoir R, Kuznetsov I, Neumann T, Ranjbar Z, Savchuk O P, Schimanke S (2012c) Impact of climate change on ecological quality indicators and biogeochemical fluxes in the Baltic Sea - a multi-model ensemble

study. AMBIO 41:558-573. DOI:10.1007/s00382-012-1339-y
Meier, H. E. M., A. Rutgersson, and M. Reckermann (2014) Baltic Earth - A new Earth System Science Program for the Baltic Sea Region. EOS, Trans. AGU, 95(13), 109-110
Müller M, Cherniawsky J, Foreman M, von Storch J-S (2013) Global map of M2 internal tide and its seasonal variability from high resolution ocean circulation and tide modelling, Geophys Res Lett 39:L19607. doi:10.1029/2012GL053320.
Nakicenovic N, Alcamo J, Davis G, De Vries B, Fenhann J, Gaffin S, Gregory K, Grübler A, Jung TY, Kram T, Lebre La Rovere E, Michaelis L, Mori S, Morita T, Pepper W, Pitcher H, Price L, Riahi K, Roehrl A, Rogner H, Sankovski A, Schlesinger M, Shukla P, Smith S, Swart R, Van Rooijen S, Victor N, Dadi Z (2000) Emission scenarios. A special report of Working Group III of the Intergovernmental Panel on Climate Change, Cambridge University Press, pp 599
Neumann T (2010) Climate-change effects on the Baltic Sea ecosystem: A model study. J Mar Syst 81:213-224
Neumann T, Friedland R (2011) Climate change impacts on the Baltic Sea. In: Global Change and Baltic Coastal Zones. Schernewski G, Hofstede J, Neumann T (eds) Dordrecht: Springer Science+Business Media (Coastal Research Library, 1(1) 1):23-32. DOI: 10.1007/978-94-007-0400-8_2
Neumann T, Eilola K, Gustafsson BG, Müller-Karulis B, Kuznetsov I, Meier HEM, Savchuk OP (2012) Extreme values of temperature, oxygen and blooms in the Baltic Sea in changing climate. AMBIO 41:574-585. DOI:10.1007/s13280-012-0317-y
Nikulin G, Kjellström E, Hansson U, Jones C, Strandberg G,Ullerstig A (2011) Evaluation and Future Projections of Temperature, Precipitation and Wind Extremes over Europe in an Ensemble of Regional Climate Simulations. Tellus 63A(1):41-55. DOI: 10.1111/j.1600-0870.2010.00466.x
Pickering MD, Wells NC, Horsburgh KJ, Green JAM (2012) The impact of future sea-level rise on the European Shelf tides. Continental Shelf Research, 35:1-15Pruszak Z, Zawadzka E (2005) Vulnerability of Poland's coast to sea level rise. Coast Eng J 47:131-155
Pruszak Z, Zawadzka E (2009) Potential Implications of Sea-Level Rise for Poland. J Coat Res 24(2):410-422
Räisänen J, Hansson U, Ullerstig A, Döscher R, Graham LP, Jones C, Meier HEM, Samuelsson P, Willén U (2004) European climate in the late 21st century: Regional simulations with two driving global models and two forcing scenarios. Clim Dynam 22:13-31
Tinz B (1996) On the relation between annual maximum extent of ice cover in the Baltic Sea and sea level pressure as well as air temperature field. Geophysica 32(3):319-341
Weisse R, Günther H (2007) Wave climate and long-term changes for the Southern North Sea obtained from a high-resolution hindcast 1958–2002. Ocean Dynam 57:161-172

Climate impacts on biogeochemical cycles in the Baltic Sea

H.E. Markus Meier

Research Department, Swedish Meteorological and Hydrological Institute, Norrköping, Sweden and Department of Meteorology, Stockholm University, Stockholm, Sweden (markus.meier@smhi.se)

1. Overview

Physical processes like diffusion, advection, light penetration, etc. and physical parameters like water temperature, salinity, etc. have considerable impacts on biogeochemical cycling in the Baltic Sea. Hence, changing physics in future climate will very likely impact the marine ecosystem. Possible projections are discussed.

2. Modeling biogeochemical cycles in changing climate

In detail the combined future impacts of climate change and industrial and agricultural practices in the Baltic Sea catchment on the Baltic Sea ecosystem are assessed following Meier et al. (2012). For this purpose transient simulations for the 21st century using coupled physical-biogeochemical models of the Baltic Sea are performed. Annual and seasonal mean changes of ecological quality indicators describing the environmental status of the Baltic Sea like bottom oxygen, nutrient and phytoplankton concentrations and Secchi disk depths are studied (Fig.1). Cause and effect studies suggest that both increased volume flows caused by increased net precipitation in the Baltic catchment area and enhanced nutrient flows from the sediments due to warmer water may play important roles for the biogeochemistry of eutrophicated seas in future climate partly counteracting nutrient load reduction efforts like the Baltic Sea Action Plan (BSAP).

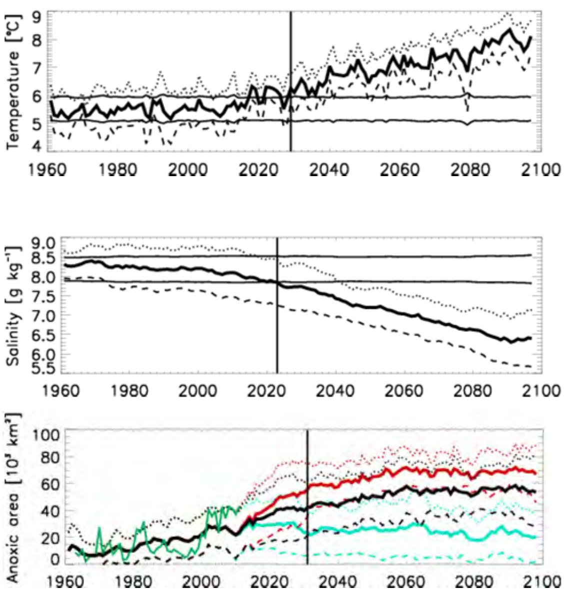

Figure 1. Volume averaged temperature and salinity, as well as anoxic bottom areas for the entire Baltic Sea including Kattegat (solid lines). The ranges of the ±1 standard deviation band around the ensemble averages are depicted by dotted and dashed lines. Almost straight lines indicate the 95% confidence interval calculated with a t-test for statistically significant deviations from the ensemble mean temperature and salinity during 1978–2007. In the lower panel simulated anoxic areas for the three nutrient load scenarios, BSAP (blue), REF (black) and BAU (red), are shown. Vertical lines mark the years 2029, 2023, and 2031 for temperature, salinity and anoxic area, respectively, when during all subsequent years either the ensemble average temperature and salinity will become significantly different from the ensemble average during 1978–2007 or when the ensemble average anoxic area in BSAP will significantly deviate from the corresponding ensemble averages in REF (at the 95% confidence level). Source: Meier et al. (2011).

3. Comparison with other coastal seas

The results of the coupled physical-biogeochemical modelling of the Baltic Sea are compared to similar simulations of the North Sea, Barents Sea, North East Atlantic and the Black Sea. It is found that regional seas are exceptionally vulnerable to climate change with a wide range of physical processes that control biogeochemical cycling. The first order (low- and mid-latitude) effect in the open ocean projections of increased permanent stratification leads to reduced nutrient levels, and so to reduced primary production. This effect is largely absent in coastal seas. Instead a highly heterogeneous response of primary production to changing physics is found. In future climate of the Baltic Sea increased loads and temperature dependent rates of biogeochemical processes may result in an overall intensification of internal nutrient cycling, including substantial increases in both primary production of organic matter and oxygen consumption for its mineralization. In the North Sea warming causes a reduction by up to 30% of the biological production on the NW European shelf suggesting a reduced carbon shelf pump.

References

BACC Author Team (2008) Assessment of climate change for the Baltic Sea basin. Regional Climate Studies, Springer Verlag Berlin Heidelberg, 473 pp.

BACC II Author Team (2015) Second assessment of climate change for the Baltic Sea basin. Regional climate studies. Berlin: Springer.

Eilola K, Almroth-Rosell E, Dieterich C, Fransner F, Höglund A, Meier HEM (2012) Nutrient transports and interactions between coastal regions and the open Baltic Sea: A model study in present and future climate. AMBIO 41(6):586-599 doi:10.1007/s13280-012-0317-y

Hordoir R, Meier HEM (2011) Effect of climate change on the thermal stratification of the Baltic Sea: a sensitivity experiment. Clim Dynam 38:1703-1713, DOI: 10.1007/s00382-011-1036-y

Meier HEM, Andersson H, Dieterich C, Eilola K, Gustafsson BG, Höglund A, Hordoir R, Schimanke S (2011a) Transient scenario simulations for the Baltic Sea Region during the 21st century. Rapport Oceanografi No.108, SMHI, Norrköping, Sweden, pp 81

Meier HEM, Andersson HC, Eilola K, Gustafsson BG, Kuznetsov I, Müller-Karulis B, Neumann T, Savchuk OP (2011b) Hypoxia in future climates - a model ensemble study for the Baltic Sea. Geophys.. Res.. Lett 38:L24608

Meier HEM, Eilola K, Almroth E (2011c) Climate-related changes in marine ecosystems simulated with a three-dimensional coupled biogeochemical-physical model of the Baltic Sea. Clim Res 48:31-55

Meier HEM, Höglund A, Döscher R, Andersson H, Löptien U,Kjellström E (2011d) Quality assessment of atmospheric surface fields over the Baltic Sea of an ensemble of regional climate model simulations with respect to ocean dynamics. Oceanologia 53:193-227

Meier HEM, Eilola K, Gustafsson BG, Kuznetsov I, Neumann T, Savchuk OP (2012a) Uncertainty assessment of projected ecological quality indicators in future climate. Rapport Oceanografi No.112, SMHI, Norrköping, Sweden, pp 11

Meier HEM, Hordoir R, Andersson HC, Dieterich C, Eilola K, Gustafsson BG, Höglund A, Schimanke S (2012b) Modeling the combined impact of changing climate and changing nutrient loads on the Baltic Sea environment in an ensemble of transient simulations for 1961-2099. Clim Dynam 39:2421-2441. DOI 10.1007/s00382-012-1339-7

Meier H E M, Müller-Karulis B, Andersson HC, Dieterich C, Eilola K, Gustafsson BG, Höglund A, Hordoir R, Kuznetsov I, Neumann T, Ranjbar Z, Savchuk O P, Schimanke S (2012c) Impact of climate change on ecological quality indicators and biogeochemical fluxes in the Baltic Sea - a multi-model ensemble study. AMBIO 41:558-573. DOI:10.1007/s00382-012-1339-y

Neumann T (2010) Climate-change effects on the Baltic Sea ecosystem: A model study. J Mar Syst 81:213-224

Neumann T, Friedland R (2011) Climate change impacts on the Baltic Sea. In: Global Change and Baltic Coastal Zones. Schernewski G, Hofstede J, Neumann T (eds) Dordrecht: Springer Science+Business Media (Coastal Research Library, 1(1) 1):23-32. DOI: 10.1007/978-94-007-0400-8_2

Neumann T, Eilola K, Gustafsson BG, Müller-Karulis B, Kuznetsov I, Meier HEM, Savchuk OP (2012) Extreme values of temperature, oxygen and blooms in the Baltic Sea in changing climate. AMBIO 41:574-585. DOI:10.1007/s13280-012-0317-y

Omstedt A, Edman M, Claremar B, Frodin P, Gustafsson E, Humborg C, Hägg H, Mörth M, Rutgersson A, Schurgers G, Smith B, Wällstedt T, Yurova A (2012) Future changes in the Baltic Sea acid-base (pH) and oxygen balances. Tellus B, 64, 19586, http://dx.doi.org/10.3402/tellusb.v64i0.19586

Anthropogenic impacts on phytoplankton on the Swedish coast
- Part 1: Is seawater scrubbing the solution to acidic rain?
- Part 2: Climate effects on the spring bloom in the Baltic Proper

Jenny Nilsson

Department of Biological and Environmental Sciences, University of Gothenburg, Gothenburg, Sweden (gusnjenn03@student.gu.se)

1. Introduction

The effects of two current anthropogenic disturbances on phytoplankton were studied experimentally, i.e. the impacts of scrubbing to reduce ship exhausts of SO_x and climate change. These two experiments will be presented separately, starting with seawater scrubbing.

2. Background and aim for the seawater scrubbing (SWS) experiment

The industrial emissions of SO_2 have been legislated since the 1970´s (Karle & Turner, 2007) whereas the emissions of shipping have been ignored for a long time. At the same time as the global emissions of SO_2 has decreased the contribution from shipping has continued to increase (Karle & Turner, 2007) and shipping was in 2009 considered to be responsible for 60 % of the SO_x emissions from transport (Ma et al., 2012 and references therein).

To reduce the amount of SO_x in ship exhausts, the IMO restricts the sulfur content globally to 3.5 %, of the total fuel weight, from the 1st of January 2012 and with a stepwise decrease down to 0.05 % by the 1st of January 2020 (IMO, 2009). Especially sensitive areas, like the Baltic Sea, have been classified as Emission Control Areas (ECAs) in which the sulfur content regulations are stricter.

SWS has been suggested as a method to meet the sulfur restrictions decided by the IMO. Seawater is normally used to cool the ship´s engine, in the operation of a scrubber a portion of that water is instead used in the desulfurization of the flue gas. When the exhausts come in contact with seawater the SO_x are dissolved. However, this process produces excess hydrogen ions which initially are neutralized by the buffering capacity of the seawater (Karle & Turner, 2007) but after that the pH of the water is lowered, sometimes to as low as 3.

To prevent environmental harm, due to low pH, the US EPA (1991) and the IMO (2009) have compiled regulations for the mixing of discharged scrubber water with ambient seawater (Karle & Turner, 2007). The process has been divided into two zones, the acute mixing zone and the chronic mixing zone. In the acute mixing zone a pH of 6.5 should be reached within 15 minutes. There are no time restrictions for the chronic mixing zone, the requirements are instead a pH no lower than 0.2 relative ambient water (Karle & Turner, 2007).

It is easy to see the appeal of SWS, no additives are needed and no byproducts are created, few studies have, however, been conducted to investigate possible effects, from the scrubbing process, on the marine ecosystem. The aim of this experiment was therefore to test if scrubbing has any effects upon phytoplankton.

4. Method for the SWS experiment

An 8 day laboratory experiment was set up to test the effects scrubbing water might have upon the diatom *Skeletonema marinoi* (Sarno & Singone) and the cyanobacterium *Synechococcus* sp. Scrubbing water was collected by the SWS onboard the ro-ro vessel Ficaria Seaways, during its route in the North Sea. This water was mixed with deep water collected at the Sven Lovén Center for Marine Sciences Kristineberg to the two pH levels 6.5 and 7.8 (the latter 0.2 below ambient water). One additional treatment contained only deep water as a control.

The experiment was carried out in a thermoconstant room. Every day at 1 pm samples were taken for photosynthetic activity and pH, and on days 0 and 8 samples for POC/PON, total alkalinity, inorganic nutrients, biovolume, bacterial biomass and DOC was collected as well as samples for pH and photosynthetic activity. On day 0 samples were also taken to analyze the metal content in undiluted scrubber water and in respective treatment.

5. Results and conclusions for the SWS experiment

S. marinoi were negatively affected by the increased amount of scrubbing water. The biovolume, SGR and POC all displayed significantly lower values in the pH 6.5 treatment. The DIN:DIP and POC:PON ratios were also altered showing an increased amount of PON compared to POC and DIN compared to DIP, indicating a disturbance in the metabolism might have occurred.

The results for *Synechococcus* sp. were not as straightforward. The photosynthetic activity showed that the cyanobacteria in treatment pH 6.5 were dead by day 5, and that the cyanobacteria in the other two treatments were negatively affected. In general no statistical difference could be found for *Synechococcus* sp. the results for DIN and DIP being an exception with significantly higher values found in the pH 6.5 treatment. Just as for *S. marinoi*, the DIN:DIP ratios for *Synechococcus* sp. and the control (no phytoplankton added) were altered towards a higher value in pH 6.5.

The concentrations of metal were several times higher in the scrubbing water compared to in untreated water for all analyzed metals except molybdenum and cadmium which had showed almost the same values in all treatments.

More studies are needed before any definite conclusions can be drawn regarding the suitability of using SWS on a large scale. Something, or a combination of factors, clearly had a negative impact on the phytoplankton in the study. It is therefore crucial to conduct further investigations to decide which aspects need to be adjusted to avoid harming the ecosystem. The present study did not give a definite conclusion as to which factor produced the negative effects since several of the measured variables have the potential to do so.

7. Background and aim for the climate change experiment

Climate change is a fact and a temperature increase of 3 to 5° C has been projected for the Baltic Sea (HELCOM, 2007). The oceans have absorbed approximately 30-50% of the emitted CO_2 since the beginning of the industrialization. This has caused an average decrease in pH of about 0.1 units, in the open ocean, equivalent to a 25 % increase in acidity (The Royal Society, 2005; Havenhand, 2012). According to the “business-as-usual” scenario (A1FI) from the IPCC (2007) a further increase to the atmospheric CO_2 level to about 960 ppm might be possible by the year 2100 (Meehl et al., 2007) and may cause the ocean´s pH level to drop between 0.14 to 0.35 units.

The Baltic Sea is shallow and brackish, with a salinity gradient from approximately 15 in the south to 2-3 in the far north (Wasmund et al., 2011). This creates an environment where only a limited number of organisms are able to survive, making the ecosystem vulnerable.

Earlier studies have not given a conclusive result regarding the anticipated increase in temperature and CO_2 level, and the accompanying drop in pH. Even though the growth of phytoplankton, generally, is in close positive relation with temperature (Eppley, 1972) an overall decrease in biovolume have been reported at elevated temperature, due to an altered species composition favouring smaller species (Hoppe et al., 2008; Sommer & Lewandowska, 2011). Diatoms have, however, been shown to favour higher CO_2 levels increasing both growth and photosynthetic activity with a change from smaller pennate species, to larger, chain-forming centric diatoms (Tortell et al., 2008). Similar contradictory results have been found for the peak of the spring bloom, which has been found both unaffected and accelerated by increased temperature (Hoppe et al., 2008; Sommer & Lewandowska, 2011). The aim of this experiment was therefore to study the effects ocean acidification and increased sea surface temperature might have on the sensitive Baltic Sea ecosystem.

8. Method for the climate change experiment

A natural spring bloom community from the Baltic Proper was exposed to two different temperature and CO_2 levels, the present values and the ones suggested in the “business-as-usual-“scenario (IPCC, 2007). The mesocosm experiment was run for 18 days and samples were taken for analysis of biovolume, POC, PON, POP, fatty acids and pH. The experiment was carried out in 50 L plastic bags hanging from rods in to four water filled tubs, each with a separate combination of temperature and CO_2 level. Three times a day the rods were lifted 20 times, to ensure homogeneity in the bags, and at the same time the light intensity, temperature of the water and the gas flow were controlled.

9. Results and conclusions for the climate change experiment

No treatment differences could be found during this experiment. It is possible that the Baltic spring bloom community is resilient towards changes, it is, however, believed that the large within-treatment differences and the loss of replicas concealed any possible effects.

References

Eppley, R. W. (1972). Temperature and Phytoplankton Growth in the Sea.Fishery Bulletin, Vol. 70 (4), 1063-1085.

Havenhand, J. N., (2012). How will Ocean Acidification Affect Baltic Sea Ecosystems? An Assessment of Plausible Impacts on Key Functional Groups.*AMBIO, Vol. 41,* 637-644.

HELCOM. (2007). Climate Change in the Baltic Sea Area – HELCOM Thematic Assessment in 2007 . Balt. Sea Environ. Proc. No. 111

Hoppe, H.-G., Breithaupt, P., Walther, K., Koppe, R., Bleck, S., Sommer, U., Jürgens, K., (2008). Climate Warming in Winter Affects the Coupling between Phytoplankton and Bacteria during the Spring Bloom: a Mesocosm Study. Aquatic Microbial Ecology, Vol. 51, 105-115.

International Maritime Organization (IMO). (2009). Second IMO GHG Study 2009. Reading (UK): CPI Book Limited.

Intergovernmental Panel on Climate Change (IPCC). (2007). Climate Change 2007 – The Physical Science Basis. Cambridge: Cambridge University Press.

Karle, I.-M., & Turner, D. (2007). Seawater Scrubbing – Reduction of SO_x Emissions from Ship Exhausts(The Alliance for Global Sustainability (AGS), 2007). Göteborg: AGS Office at Chalmers.

Ma, H., Steernberg, K., Riera-Palou, X., & Tait, N. (2012). Well-to-Wake Energy and Greenhouse Gas Analysis of SO_x Abatement Options for the Marine Industry. Transportation Research Part D: Transport and Environment, Vol. 17(4), 301-308.

Meehl, G. A., Stocker, T. F., Collins,W.D., Friedlingstein, P., Gaye, A. T., Gregory, J. M.,... Zhao, Z.-C. (2007). Climate Change 2007: The Physical Science Basis.Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Global Climate Projections). Cambridge (UK) and New York (USA): Cambridge University Press.

Sommer, U., & Lewandowska, A. (2011). Climate Change and the Phytoplankton Spring Bloom: Warming and Overwintering Zooplankton have the same Effect on Phytoplankton. Global Change Biology, Vol. 17, 154-162.

The Royal Society. (2005). Ocean Acidification due to Increasing Atmospheric Carbon Dioxide. Cardiff: The Clyvedon Press Ltd.

Tortell, P. D., Payne, C. D., Li, Y., Trimborn, S., Rost, B., Smith, W. O., Riesselman, C., Dunbar, R. B., Sedwick, P., & DiTullio, G. R. (2008). CO_2 Sensitivity of Southern Ocean Phytoplankton.Geophysical Research Letters, Vol. 35.

US Environmental Protection Agency (EPA). (1991). Technical Support Document for Water-Quality Based Toxics Control. Washington DC.

Wasmund, N., Tuimala, J., Suikkanen, S., Vandepitte, L., & Kraberg, A. (2011). Long-term Trends in Phytoplankton Composition in the Western and Central Baltic Sea.Journal of Marine Systems, Vol. 87 (2011), 145-159.

Physics and chemistry of the Baltic Sea

Anders Omstedt

Institute of Marine Sciences, University of Gothenburg, Göteborg, Sweden (anders.omstedt@gvc.gu.se)

1. Marine observations and model data

Over the past decades, increasing numbers of marine data have become available, and great efforts have been made to collect and store data and to make these data available to the research community. The available marine data sets are of great help, for example, in analyzing and synthesizing marine environmental conditions, but the data are often not so easy to interpret. During these lectures we will go through some important marine data portals, different kind of marine observations, monitoring and model data and learn how to work with them to improve our understanding.

2. Screening observed data and model data

With increasing data availability comes increasing variability within data representation, making screening necessary. The amount of screening depends on how well each dataset are screened and documented initially. In general all data available in data bases needs to be screened. The data should be checked for outliers, and outer limits should be set so that all parameters adhere to realistic minimum and maximum values. One should also ensure that the data preserve their stability over depth. Some margins should be allowed for instrument or measurement errors, but if the error of a data point exceeds the allowed margins or error, that data point should be removed and coded as a missing value.

3. Analysis of screened data

When the initial screening has been completed, both visually plots of all datasets, and using statistical measure should be done. There is no standard statistical measure but different methods applied to the data sets will deepen the insight in the observations. Data interpretation and using different kind of plots will guide the analyze. The scientist need to be awarded that trends, regime shifts and oscillations in data sets goes with strong message to the society, e.g. Figure 1.

4. Integrated physical and chemical properties

Integrated properties such as the Baltic Sea mean (vertically and horizontally integrated) temperature, mean (vertically and horizontally integrated) salinity, Maximum Annual Ice Extent, Area of Hypoxic or Anoxic water all provide important knowledge about the marine system. In the same way as total concentration (vertically and horizontally integrated) of any chemical component or ecological component. Integrated properties may therefore give lots of important information about the marine system.

5. Budget calculations

A deeper analyses of data often leads to budget calculations. The basic idea is to look into the sea area in a simplified way and ask how much of a property that is entering and leaving the system. The conservation principals then often are applied first to water, salinity and temperature and later to different chemical properties. We can learn lots from budget calculation. Recent studies have been able to illustrate the importance of also including internal sources in the budget calculations.

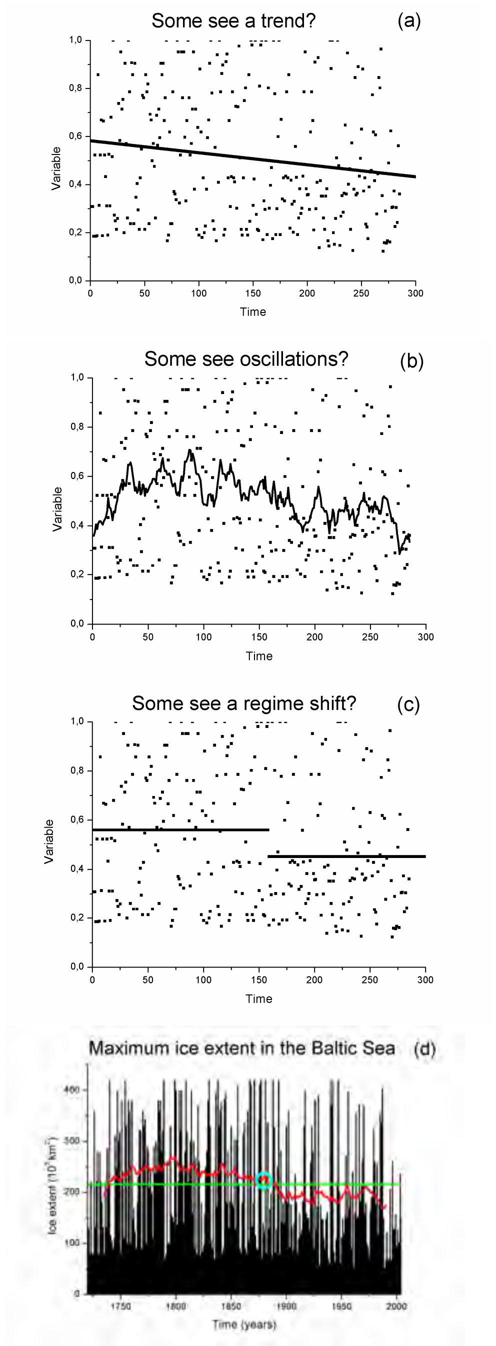

Figure 1. Observations can be analyzed in terms of trends, oscillations, jumps, or regime shifts. Often scientists prefer to present only one interpretation that is supported by general societal discourse which is not a sustainable science approach. In this figure, the same data are used and normalized in panels a–c. The original dataset is presented in panel d (redrawn from BACC Author Team, 2008).

6. Natural and anthropogenic changes

The importance of using well defined words when addressing different marine questions are illustrated from some climate change definitions. The importance of detection and attribution studies in relation to observed data is then discussed together with some exercises.

References

BACC Author Team (2008). The BALTEX Assessment of Climate Change for the Baltic Sea basin. pp. 1-34.ISBN: 978-3-540-72785-9. Springer-Verlag.

BACC II Author Team (2015). Second Assessment of Climate Change for the Baltic Sea basin. Springer Regional Climate Studies. ISSN 1862-0248 ISSN 1865-505X (electronic). ISBN 978-3-319-16005-4 ISBN 978-3-319-16006-1 (eBook). DOI 10.1007/978-3-319-16006-1. Springer Cham Heidelberg New York Dordrecht London.

Edman, M., and A., Omstedt (2013). Modeling the dissolved CO_2 system in the redox environment of the Baltic Sea. Limnol. Oceanogr., 58(1), 2013, 74-92

Eilola, K., B.G. Gustafson, I. Kuznetsov, H.E.M. Meier, T. Neumann, O. P. Savchuk, (2011). Evaluation of biogeochemical cycles in an ensemble of three state-of-the-art numerical models of the Baltic Sea during 1970-2005. J. Marine Systems, 88, 267-284, doi:10.1016/j.jmarsys.2011.05.004

Elam, Grimvall and Omstedt (2014). A protocol for evaluating marine monitoring and model data, and the added value gained. In manuscript.

Grimvall and Omstedt (2012). Reanalysis of trends and change-points in the concentration of plant nutrients in the Baltic Sea. In manuscript.

HAVET 1888 , utgiven av Havsmiljöinstitutet 2015. ISBN: 978-91-982291-0-3.

HELCOM (2014). Manual for Marine Monitoring in the COMBINE Program of HELCOM. http://www.helcom.fi/

Jutterström, S., Andersson, H.C., Omstedt, A. and J.M., Malmaeus (2014). Multiple stressors threatening the future of the Baltic Sea-Kattegat marine ecosystem: Implications for policy and management actions. Marine Pollution Bulletin 86, 468-480.

Omstedt and Axell (2003). Modelling the variation of temperature ands salinity in the large Gulfs of the Baltic Sea. Continental Shelf Research, 23, 265-294. DOI 10.1016/S0278-4343(02)00207-8

Omstedt, A. and C., Nohr (2004). Calculating the water and heat balances of the Baltic Sea using ocean modelling and available meteorological, hydrological and ocean data. Tellus 56A, 400-414. DOI 10.1111/j.1600-0870.2004.00070.x

Omstedt, A, Edman, E, Claremar , B, and A. Rutgersson (2015) Modelling the contributions to marine acidification from deposited SOx, NOx, and NHx in the Baltic Sea: Past and present situations. In press.

Oschlies, A., J. Blackford, S. C. Doney, and M. Gehlen. 2010. Modelling considerations, p. 233–242. *In* U. Riebesell, V. J. Fabry, L. Hansson and J.-P. Gattuso [eds.], Guide to best practices for ocean acidification research and data reporting. Luxemburg: Publications Office of the European Union.

Stigebrandt, A., Rahm, L., Viktorsson, L., Ödalen, M., Hall, P.O.J., and B., Liljebladh (2013). A New Phosphorus Paradigm for the Baltic Proper. Ambio, DOI 10.1007/s13280-013-0441-3.

Winsor, Rodhe and Omstedt (2001). Baltic Sea ocean climate: an analysis of 100 yr of hydrographic data with focus on the freshwater budget, Clim. Res., 18, 5-15, 2001.

Winsor, Rodhe and Omstedt (2003). Erratum: Baltic Sea ocean climate: an analysis of 100 yr of hydrographic data with focus on the freshwater budget, Clim. Res., 18:5-15, 2001. Climate Research, 25, 183.

Bacterial community structure and petroleum hydrocarbon degradation in the Baltic Sea

Anna Reunamo

University of Turku, Finland (anna.reunamo@utu.fi)

The Baltic Sea is unique by its biological, geochemical and physical features. The number of species of larger organisms is small and the species composition is distinctive. On the contrary microbial communities are diverse. Because of the low salinity levels, bacterial communities differ from the ones in the oceans. Knowing the structure of these communities better and how they response to different environmental conditions helps us to estimate how different factors affect the balance and function of the Baltic Sea ecosystem. Bacteria are the key players when it comes to natural biogeochemical processes and human-induced phenomena like eutrophication, oil spills or disposal of other harmful substances to the sea ecosystem.

In this thesis, bacterial community structure in the sea surface microlayer and subsurface water of the Archipelago Sea were compared. In addition, the effect of diatom derived polyunsaturated aldehydes on bacterial community structure was studied by a mesocosm experiment. Diesel, crude oil and polycyclic aromatic hydrocarbon degradation capacity of the Baltic Sea bacteria was studied in smaller scale microcosm experiments. In diesel oil experiments bacteria from water phase of the Archipelago Sea was studied. Sediment and iron manganese concretions collected from the Gulf of Finland were used in the crude oil and polycyclic aromatic hydrocarbon experiments. The amount of polycyclic aromatic hydrocarbon degradation genes was measured in all of the oil degradation experiments.

The results show how differences in bacterial community structure can be seen in the sea surface when compared to the subsurface waters. The mesocosm experiment demonstrated how diatom-bacteria interactions depend on other factors than diatom derived polyunsaturated aldehydes, which do not seem to have an effect on the bacterial community structure as has been suggested in earlier studies. The dominant bacterial groups in the diesel microcosms differed in samples taken from a pristine site when compared to a site with previous oil exposure in the Archipelago Sea area. Results of the study with sediment and iron-manganese concretions indicate that there are diverse bacterial communities, typical to each bottom type, inhabiting the bottoms of the Gulf of Finland capable to degrade oil and polycyclic aromatic hydrocarbon compounds.

Climate variability and extremes

Anna Rutgersson

Department of Earth Sciences, Uppsala University, Uppsala, Sweden (anna.rutgersson@met.uu.se)

1. Introduction

Situated in the extratropics of the Northern Hemisphere, the Baltic Sea region is be under the influence of air masses of arctic to subtropical origin. It is therefore a region of very variable weather conditions and far reaching teleconnections (i.e. BACCII; Rutgersson et al., 2014). The region is dominated mainly by two large-scale pressure systems over the northeastern Atlantic, the Icelandic Low and the Azores High, and a thermally driven pressure system over Eurasia (high pressure in winter, low pressure in summer). In general, there are westerly winds over the region, although any other wind direction is observed frequently. The climate of the Baltic Sea shows a strong seasonal cycle, but also large inter-annual to multidecadal variability. Long-term changes and variability of atmospheric parameters have large impacts on hydrological, oceanographic and biogeochemical processes in the region. The shallow and complex bathymetry of the semi-enclosed Baltic Sea makes the ecosystem very sensitive to any atmospheric changes. Precipitation and temperature control the river runoff to the Baltic Sea with a relation between atmospheric circulation patterns and sea-level, sea-ice, salinity and oxygen. The storm frequency clearly influences Baltic Sea mixing as well as marine ecosystems.

2. Large-Scale circulation patterns

The atmospheric circulation in the European/Atlantic sector plays an important role for the regional climate of the Baltic Sea basin. It can be described mainly by the North Atlantic Oscillation (NAO), the zonality of the atmospheric flow and the blocking frequency. The first mode of a principal component analysis (PCA) of winter sea-level pressure (SLP) variability is the NAO, which in winter shares a close correlation with atmospheric and marine state variables of the Baltic Sea region (where a positive index indicates mild and wet winters and a negative index indicates cold and dry winters). Fig. 1 shows the winter NAO index for 1823 to 2013. In a long term perspective, the behaviour of the NAO is rather irregular.

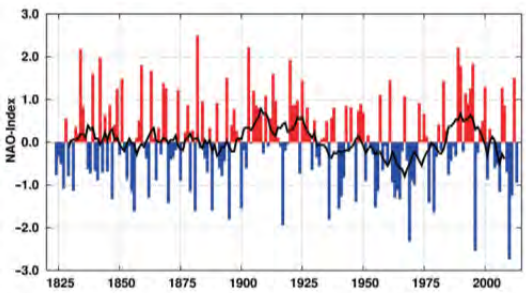

Figure 1. NAO index for boreal winters (DJFM) of 1823–2013. Black line: 11 yr running mean highlights decadal-scale variability. Bars: positive (red) and negative (blue) indices. From Rutgersson et al (2014).

For all weather types (zonal, meridional, or anticyclonic), an increase in persistence in the order of 2 to 4 d is found from the 1970s to the 1990s (BACCII). This increase in persistence may contribute to an increase in the occurrence of extreme events. Circulation changes in the Baltic Sea region may also be related to climate anomalies in other regions. Many authors discuss the cold temperatures of the winters 2009−2010 and 2010−2011 over large parts of Europe (including the Baltic Sea region). Overland and Wang (2010) point out a possible relationship of circulation changes in the Baltic Sea region to the loss of sea ice in the Arctic.

3. Wind climate

Variations in the wind climate are closely linked to the atmospheric circulation and cyclonic activity over the North Atlantic. Since 1958, the number of deep cyclones in winter reached a minimum in the early 1970s and clearly increased in the following decades, reaching their maximum around the last decade of the 20th century (Lehmann et al. 2011). At the same time, a continuous shift of North Atlantic storm tracks towards the north-east regionally increased the impact and number of storms over Northern Europe in winter and spring of recent decades, but decreased in autumn. Following the intensification of deep lows, a significant positive trend exists for storminess since the middle of the last century in reanalysis data over this region (Donat et al. 2011). However, Schmidt and von Storch (1993) did not find any long-term trend for the wind climate of 1876−1990. The absence of robust long-term trends was confirmed by numerous storm indices showing similar high storm levels during the 1880s as observed in the 1990s with a distinct minimum in the 1970s (see BACCII; Schenk and Zorita, 2012 for more details).

4. Surface air temperature

A quite significant surface air temperature increase have been observed in the Baltic Sea Region. The warming has partly continued up to the present (during summer in the southern parts and during autumn in the north), although some winters during the last decade have been relatively cold. The temperature increase is not monotonous but accompanied by large (multi-) decadal variations. Linear trends of the annual mean temperature anomalies during 1871–2013 were 0.10 K decade−1 north of 60° N and 0.08 K decade−1 south of 60° N in the Baltic Sea region. This is larger than the global mean temperature trend, which is about 0.06 K decade−1 for the period 1871–2005.

5. Precipitation

The amount of precipitation in the Baltic Sea area during the past century has varied between regions and seasons, with both increasing and decreasing precipitation and no general trend during the past 200 ys. A tendency of increasing precipitation in winter and spring was detected during the second half of the 20th century. However, as precipitation is highly variable trends depend very much on time frames, seasons and locations. Change in precipitation is also associated with an increase in the frequency and intensity of extreme precipitation events; the number of extreme precipitation days per year and the seasons in which they occur vary for the different catchment areas of the Baltic Sea. Wet periods with daily precipitation exceeding 1 mm have become longer over most of Europe by about 15 to 20% during 1950−2008 (Zolina et al. 2010). The lengthening of wet periods was not caused by an increase of the total number of wet days. Becoming longer, wet periods in Europe are now characterized by an increase in heavy precipitation. Heavy precipitation events during the last two decades have become much more frequently associated with longer wet spells and have intensified in comparison with the 1950s and 1960s (Zolina 2011), Fig. 2.

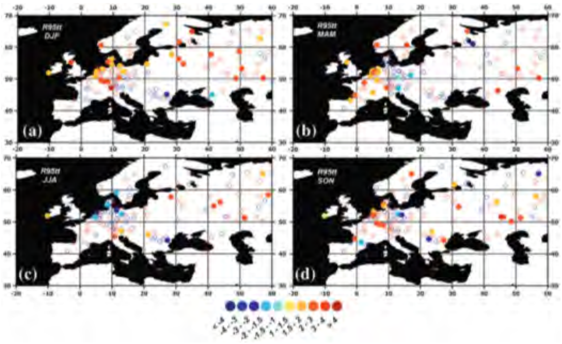

Figure 2. Linear trends (% per decade) in the R95tt index (fraction of total precipitation above 95th percentile of rain-day amounts) for a winter, b spring, c summer and d autumn for the period 1950–2000. Open circles show all trend estimates and closed circles denote locations where the trends are significant at 95 %. Blue indicates negative trends and red indicates positive trends (Zolina et al. 2009 reproduced in BACC II).

6. Extreme events

In terms of Natural disasters and weather related accidents it is the really rare events causing high-impact damages. During the past decades several such events have attained significant attention. In 2013 natural disasters worldwide were responsible for the death of more than 20,000 people and costs of more than $134 billion. In 1994 the ferry Estonia sank in heavy seas on her route from Tallinn to Stockholm, killing 852 persons. In 2005 a storm surge with record heights of 2.75m associated with storm “Gudrun” hit the Estonian coast, causing damages of approximately 0.7% of the annual Estonian GDP. In July 2011 a cloudburst in Copenhagen produced extreme precipitation of more than 150 mm in 2 hours, resulting in severe damage to critical infrastructure. As reliable in-situ data exists for less than 200 years, statistically significant knowledge on occurrence and trends of the most severe events are very limited. While climate change has received considerable attention in the scientific community for several decades now, the knowledge on changing extremes and their impacts is still fragmented, the confidence level of the knowledge of relation between climate change and flooding, heat waves and storms ranges from low to medium (IPCC, 2012), in particularly the confidence level reduces when approaching the local scale (IPCC, 2014).

7. Conclusions

Variations and trends of atmospheric parameters in the Baltic Sea region during the last 200–300 years can be summarised as follows. A northward shift in storm tracks and increased cyclonic activity have been observed in recent decades with an increased persistence of weather types. No long-term trend have been observed in annual wind statistics since the nineteenth century, but considerable variations on (multi-)decadal timescales have been observed. An anthropogenic influence cannot be excluded since the middle of the twentieth century. The pattern in wind and wave heights over the Northern Hemisphere with a NE shift of storm tracks appears to be consistent with combined natural and external forcing. Continued warming has been observed, particularly during spring and is stronger over northern regions than southern (polar amplification). Bhend and von Storch (2009) showed that the significant warming trends over the Baltic Sea region are consistent with future climate projections under increased greenhouse gas concentrations. No long-term trend was observed for precipitation, but there is some indication of an increased duration of precipitation periods and possibly an increased risk of extreme precipitation events.

References

BACCII, BACC II Author Team, Second Assessment of Climate Change for the Baltic Sea Basin, Regional Climate Studies, ISSN 1862-0248 ISSN 1865-505X (electronic). ISBN 978-3-319-16005-4 ISBN 978-3-319-16006-1 (eBook). DOI 10.1007/978-3-319-16006-1. Springer Cham Heidelberg New York Dordrecht London.

Bhend J, von Storch H (2008) Consistency of observed winter precipitation trends in northern Europe with regional climate change projections. Clim Dyn 31: 17−28

Donat M, Renggli D, Wild S, Alexander L, Leckebusch G, Ulbrich U (2011) Reanalysis suggests long-term upwardtrends in European storminess since 1871. Geophys Res Lett 38: L14703, doi: 10.1029/2011GL047995

IPCC, 2012: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, 582 pp.

IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Lehmann A, Getzlaff K, Harlaß J (2011) Detailed assessment of climate variability in the Baltic Sea area for the period 1958 to 2009. Clim Res 46: 185−196

Overland JE, Wang M (2010) Large-scale atmospheric circulation changes are associated with the recent loss of Arctic sea ice. Tellus A 62: 1−9

Rutgersson A, J Jaagus, F Schenk, M Stendel (2014) Observed changes and variability of atmospheric parameters in the Baltic Sea region during the last 200 years, Clim. Res, 60, 177–190

Schenk F, Zorita E (2012) Reconstruction of high resolution atmospheric fields for Northern Europe using analog upscaling. Clim Past 8: 1681−1703

Schmidt H, von Storch H (1993) German Bight storms analyzed. Nature 365: 791

Zolina O, Simmer C, Belyaev K, Kapala A, Gulev S (2009) Improving estimates of heavy and extreme precipitation using daily records from European rain gauges. J Hydro - meteorol 10: 701−716

Environmental constraints on the input of reactive organic carbon to the Baltic Sea

Ana Raquel Alves Soares

Department of physical geography and ecosystem sciences, Lund University, Lund, Sweden (ana.soares @nateko.lu.se)

1. Terrestrial organic carbon inputs in the Baltic Sea

Large quantities of terrestrial dissolved organic carbon (DOC) are exported with river runoff to the Baltic Sea (Humborg et al. 2010). The current view assumes that DOC reactivity should decrease during its transit from land to sea, but still this riverine DOC removes large amounts of dissolved oxygen while its degradation in coastal waters. Considering the sensitive environmental status of the Baltic Sea, a better understanding of DOC dynamics is essential for adequate coastal water management.

2. DOC as limiting nutrient in coastal areas

Besides being related to DOC concentrations, dissolved O2 concentrations in coastal waters are also related to the influx of inorganic nitrogen (N) and phosphorus (P) which promotes both primary productivity and bacterial respiration (Bianchi et al. 2010). Particularly heterotrophic bacterioplankton is affected by fluxes of N and P directly through resource regulation and indirectly through control on primary producers.

Figure 1. Relative impact (%) of additions of C, N and P, shown as the change in marginal mean (response of bacterial respiration adjusted for all other variables in the model). The nutrient enrichment experiments were performed on a total of 8 dates, and the results were interpolated for the whole period. Flow data was obtained from the Swedish national monitoring programme

However, consensus on whether heterotrophic bacteria respiration in aquatic systems is controlled by C or P is missing (Dorado-García et al. 2014). In this study was found that all three C, nitrogen (N) and P elements increased BR (Fig. 1), however C seems to be the main element limiting BR coastal areas during the studied period.

3. Nutrient stoichiometry in river systems

Measurements of total and bioavailable fractions of dissolved N, P, and organic C in 15 river systems in the Baltic Sea catchment revealed that total N and P pools are mainly organic. Nutrient ratios varied 10-fold higher C : N and 3-fold higher C : P ratios for the total nutrient fractions, compared with those of the bioavailable nutrient fractions. Although classical resource C : N : P stoichiometry suggests N limitation in several cases, our studies have showed that N had a systematically higher bioavailability and was never a limiting factor for bacterial respiration. Our studies also show that the degree of P limitation of bacterial metabolism tend to decrease with increasing concentrations of bioavailable P.

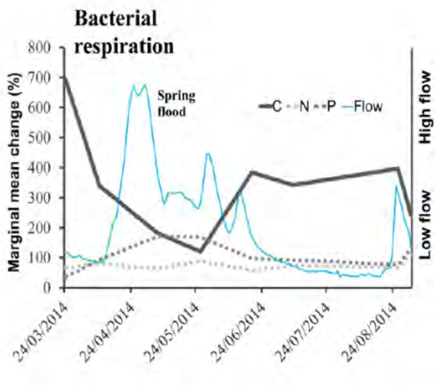

Figure 1. Relative impact (%) of additions of C, N and P, shown as the change in marginal mean (response of bacterial respiration adjusted for all other variables in the model). The nutrient enrichment experiments were performed on a total of 8 dates, and the results were interpolated for the whole period. Flow data was obtained from the Swedish national monitoring programme

References

Bianchi TS, DiMarco SF, Cowan Jr JH, Hetland RD, Chapman P, Day JW, Allison MA. 2010. The science of hypoxia in the Northern Gulf of Mexico: A review. Science of The Total Environment 408: 1471-1484.

Dorado-García I, Medina-Sánchez JM, Herrera G, Cabrerizo MJ, Carrillo P. 2014. Quantification of Carbon and Phosphorus Co-Limitation in Bacterioplankton: New Insights on an Old Topic. PLoS ONE 9: e99288.

Humborg C, Mörth CM, Sundbom M, Borg H, Blenckner T, Giesler R, Ittekkot V. 2010. CO2 supersaturation along the aquatic conduit in Swedish watersheds as constrained by terrestrial respiration,aquatic respiration and weathering. Global Change Biology 16: 1966-1978.

Arsenic speciation in the environment of southern Baltic Sea

Marta Szubska

Marine Chemistry and Biochemistry Department, Institute of Oceanology of Polish Academy of Sciences, Sopot, Poland (szubi@iopan.gda.pl)

1. Research project objectives

Arsenic is an ubiquitous element occurring in the environment, toxic to many marine organisms, and consequently via the food web it might create risk for fish consumers. Due to its complex biogeochemistry, and the fact that some of its forms are biologically inert, it is impossible to estimate its toxicity in the marine ecosystem by measurement of only total arsenic concentration. Therefore the need arises to study speciation of arsenic to assess the processes influencing its biogeochemical cycle and to relate existing data to a synthetic impact assessment of arsenic compounds on the baltic organisms and consequently the whole ecosystem.

Total arsenic concentration levels in Baltic Sea bottom sediments are differentiated and depend on the distance from arsenic source and its type, as well as on the type of sediments covering the bottom and environmental conditions. In marine environment arsenic occurs in different oxidation states, both in organic and inorganic compounds. Organic arsenic species are assumed to be less toxic than inorganic, and arsenic (III) compounds are the most toxic of all arsenic species present in the environment. The main aim of proposed study is the complex recognition of Baltic Sea exposure to different arsenic species and estimation of the impact of physico-chemical conditions occurring in sediments and water column on biogeochemistry of arsenic in marine environment. Under reducing conditions arsenic (III) is the dominant species while arsenic (V) is generally stable in oxygenated environments. For this reason changes in climate conditions can influence biogeochemical cycles, what could result in re-emission of heavy metals deposited in sediments, including arsenic. Eutrophication of the Baltic Sea may increase due to elongated growing season, what causes depletion in bottom waters. Anaerobic conditions foster the dissolution of iron and manganese oxides and oxyhydroxides, and release of adsorbed arsenic in its most toxic form into the water column, where it can be assimilated by organisms (Bissen and Frimmel 2003, Fauser et al. 2013). Eh values determine oxidation or reduction of arsenic species, type and chemical composition of sediments is related to bounding with sulfur, absorption on iron and manganese oxyhydroxides influences the cycle of arsenic between sediments and water column (Bissen and Frimmel 2003, Cullen and Reimer 1989). Measuring arsenic concentrations in bottom sediments will help to fill in the gaps in the present knowledge on the contamination of Baltic sea with arsenic compounds. An effort will be given to define the source of arsenic in particular areas of southern Baltic Sea. Arsenic speciation measurements in pore waters and bottom waters will enable to calculate the diffusion fluxes of individual arsenic species. The physico-chemical properties of sediment matrix influence the sorption of arsenicals thus can significantly influence bioavailability of arsenic in sediments and water column, what directly affects arsenicals transformations in trophic web.

2. Research methodology

In the first stage of the research, bottom sediments collected in Polish Exclusive Economic Zone along Polish coastline, will be analyzed for the total arsenic concentrations and principal sediment characteristics (including moisture, texture, organic matter content, concentrations of iron, aluminium and manganese, organic matter source and contamination with heavy metals). Total arsenic concentrations will be analyzed with the technique of Atomic Absorption Spectrometry with Hydride Generation (HG-AAS), concentrations of heavy metals will be determined with Inductively Coupled Plasma Mass Spectrometry (ICP-MS), origin of the sediment material will be assessed basing on the measurements of carbon stable isotopes with the use of CHN elemental analyzer coupled with Mass Spectrometry. Basing on the results on sediments contamination with arsenic from different sources further sampling areas will be chosen, where biological samples would be collected. Sampling will include organisms from different trophic levels: phytoplankton and macroalgae, zooplankton, benthic organisms and fish with different feeding strategies. Organisms will be analyzed for different arsenic forms concentrations with the use of ion-exchange chromatographic column (CF-Kit-As35) with the detection on ICP-MS. Basing on nitrogen and carbon stable isotopes analyses (CHN elemental analyzer coupled with MS) trophic level of each organism group will be established for bioconcentration and biomagnification rates calculations.

3. Expected impact of the research project for the development of science and for society

Arsenic is assumed to be toxic to plants, animals and human and is considered as a potential carcinogen. It disrupts enzymatic processes in cells, causes cell walls breakdown, inhibits mitochondria functions, affects proteins formation by its high affinity to sulfhydryl groups, inhibits phosphate insertion to DNA, affecting transmission of genetic information (Harkabusova et al. 2009, Bissen and Frimmel 2003, Nicholas et al. 2003, Niedzielski et al.2000). Chronic exposure to elevated arsenic concentrations can cause disturbance in nervous system and heart diseases. It is also believed that bladder and lung cancer may be caused by chronic arsenic poisoning. As fish and seafood is the main source of arsenic in human diet it is very important to investigate the marine environment for arsenic species and their concentrations. The most toxic inorganic arsenic (III) compounds can be fourfold more toxic to organisms than corresponding arsenic (V) compounds. Arsenic speciation in sediments and marine organisms will enable to determinate the levels of arsenic (III) and its transformations in Baltic Sea ecosystem.

Specificity of the Baltic Sea (steep salinity and temperature gradients, oxygen deficiency in deep basins and different sediment coverage) makes it unique in the global scale and especially susceptible for contamination. As a consequence it is impossible to compare the environment of Baltic Sea with oceanic ecosystems and the results of arsenic measurements described in literature. Therefore it is very important to recognize and understand transformations of this contaminant in this environment. Proposed research would be the first project concerning arsenic speciation in food web from the Baltic Sea ecosystems. The issue of arsenic speciation was already raised by other researchers, studying both marine and freshwater ecosystems. So far it was confirmed that arsenic is present in all aquatic organisms from different trophic levels and that biomagnification of arsenic in food chains of marine environments is very likely, whereas trends of arsenic biomagnifications in freshwater environments are unnoticeable. However so far there is no information on the behavior of arsenic species in marine waters with very low salinity - like the brackish waters of the Baltic Sea. Polak-Juszczak (2009) compared total arsenic concentrations, without speciation measurements, in muscle of carnivorous and herbivorous fish from Baltic Sea, and noticed no biomagnification trends of arsenic. Examinating a complete food chain from Baltic ecosystem could clearly show such trends or reject the hypothesis of biomagnification. Arsenic biosynthesis in not clarified precisely yet, however it is known that mostly the organisms living and feeding in sediments are impacted with the elevated arsenic concentrations. Rahman with coworkers (2012) in their publication about arsenic in aquatic food chains, indicated that significant differences occur between predominating arsenic species in organisms on the same trophic level from freshwater environments and from marine environments. Understanding the transport of arsenic species through the food chain and awareness of their concentrations in animals could be also useful for examination of marine biota potential usage as bioindicators of arsenic contamination.

References

Bissen M., Frimmel F.H. (2003) Arsenic – a Review. Part I: Occurrence, Toxicity, Speciation, Mobility, Acta hydrochim. Hydrobiol., Vol.31(1), pp.9-18

Cullen W.R, Reimer K.J. (1989) Arsenic Speciation in the Environment, Chemical Reviews, vol.89,pp.713-764

Fauser P., Sanderson H., Hedegaard R.V., Sloth J.J., Larsen M.M., Krongaard T., Bossi R., Larsen J.B (2013) Occurence and sorption properties of arsenicals in marine sediments, Environmental Monitoring and Assessment, vol.185, pp.4679-4691

Harkabusová V., Macharáčková B., Čelechovská O., Vitulová E. (2009) Determination of Arsenic in the Rainbow Trout Muscle and Rice Samples; Czech J.Food Sci., vol.27, pp.404-406

Nicholas D.R.,, Ramamoorthy S., Palace V., Spring S., Moore J.N., Roseznzweig R.F. (2003) Biogeochemical transformations of arsenic in circumneutral freshwater sediments, Biodegradation, vol. 14, pp. 123-137

Niedzielski P., Siepak M., Siepak J. (2000) Występowanie i zawartość arsenu, antymonu i selenu w wodach i innych elementach środowiska, Rocznik Ochrona Środowiska, vol.2, pp.317-341

Polak-Juszczak L. (2009) Temporal trends in the bioaccumulation of trace metals in herring, sprat and cod from the southern Baltic Sea in the 1994-2003 period, Chemosphere, vol. 76, pp.1334-1339

Rahman M.A., Hasegawa H., Lim R.P. (2012) Bioacummulation, biotransformation and trophic transfer of arsenic in the aquatic food chain, Environmental Research, vol. 116, pp.118-135

A multi-proxy study on the role of climate-driven processes in the open Baltic Sea during the Holocene

Falkje van Wirdum

School of Natural Science, Technology and Environmental Studies, Södertörn University, Huddinge, Sweden (falkje.van.wirdum@sh.se)

1. Introduction

Ever since the Baltic Sea Basin was deglaciated its history has been governed by the interplay between the isostatic rebound and the global sea-level changes (Björck, 1995; Andrén et al., 2011). This has resulted in several different development phases both weak brackish and lacustrine. From c. 10 000 yr BP, when the connection to the world's oceans was established through the Danish straits and Öresund, the Baltic Sea's water exchange has been driven by climate, both in terms of the amount of freshwater runoff through precipitation in the drainage area, and the large-scale atmospheric pressure gradient which influences the inflow of marine water (Gustafsson and Westman, 2002; HELCOM, 2007, 2013). Which of these processes are dominant, how they act on different time scales, and whether there are time lags or possible control by different phases of the North Atlantic Oscillation are not fully understood (Zillen et al., 2008).

Changes in the long-term nutrient record of the Baltic Sea are directly linked to changes in climate controlling marine water inflow, stratification, oxygen saturation, oxygenation of sea bottoms, sequestration of phosphorous in sediment, freshwater runoff, weathering rates in the catchment area and affecting the magnitude and extension of cyanobacterial blooms (HELCOM 2007, 2013). The role of climate change versus human impact in driving the eutrophication and hypoxia in the present Baltic Sea is not fully understood (Andrén et al., 2000; Conley et al., 2011), and needs to be disentangled, especially when global warming in the basin is projected to be 3-5 °C during the course of the 21st century (HELCOM 2007, 2013).

The prospect of reconstructing Holocene environmental variations with a high resolution as provided by laminated sediment archives will give unique new knowledge on how the anthropogenic unaffected BSB responded to climate-driven natural variability. Information on this long-term variability in the Baltic Sea ecosystem provides unique data for refining and validating future climate change models and improves predictions for this area. Knowledge of the past is crucial for understanding long-term natural dynamics and relatively recent changes caused by anthropogenic activity, and therefore a prerequisite for well-founded sustainable management of the present Baltic Sea ecosystem.

2. Main objectives

The overarching aim of this project is to disentangle natural variability in the Baltic Sea ecosystem in response to climate forcing and separate it from the effect of anthropogenic impact. This can be subdivided in three main objectives of this research project:

a. To determine the Holocene Baltic inflow history and implications for changing salinity

b. To identify triggers for high and low primary productivity events through the Holocene

c. To reconstruct responses in the Baltic Sea ecosystem to past climate change in order to get a better understanding of the ongoing climate change

3. Material

During International Ocean Discovery Program (IODP) 347, Baltic Sea Basin Paleoenvironment, sediments from different settings in the Baltic Sea Basin (BSB) spanning the last glacial-interglacial cycles have been retrieved (Figure 1). The Holocene sequence from the Bornholm Basin (M0065) and the extremely expanded laminated sequence from the Landsort Deep (M0063) will allow reconstructions of climate-driven natural variability in the Baltic Sea ecosystem.

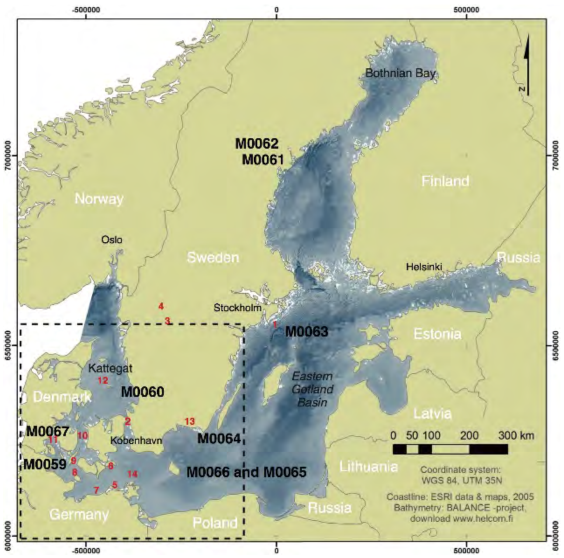

Figure 1. Geographic location of sites drilled during IODP Expedition 347. M0059 and M0067 = Little Belt, M0060 = Anholt, M0061 and M0062 = Ångermanälven River Estuary, M0063 = Landsort Deep, M0064 = Hanö Bay, M0065 and M0066 = Bornholm Basin.

4. Methods

This project will be carried out as a multi-proxy study in cooperation with the Science Party of IODP Baltic Sea Expedition 347. Collaboration with people working on other proxies and/or on other sites will lead to a comprehensive reconstruction of climate-driven processes during the Holocene in the Baltic Sea. By comparing responses to climate-driven variances at different sites, possible time lags can be established.

Furthermore, this project will also collaborate with the project UPPBASER, which has the aim to disentangle the influence of changed land-use on coastal waters the last 2000 years. By comparing data of the high resolution sediment archive of the Landsort Deep with coastal sites any synchronicity of environmental and climate change between sites will be investigated.

Based on these two unique high-resolution sediment cores from the Baltic proper, a Holocene diatom stratigraphy will be established, and paleoproductivity will be inferred using absolute diatom abundance, together with geochemical proxies (e.g. total organic carbon, stable nitrogen and carbon isotopes and biogenic silica) provided by the IODP 347 Science Party.

Changes in salinity, ice cover and nutrient availability will be inferred from changes in diatom assemblages. Age models of both sites will be provided by IODP 347 Science Party. By comparing results from different sites the time-lag between Bornholm Basin and Landsort Deep can be establishes.

High primary productivity events will be reconstructed by using the diatom stratigraphy together with absolute diatom abundance and detailed microfabric analyses of the laminations. Hypoxic or even anoxic conditions in the Baltic Sea can be recognized in Baltic Sea sediments as laminated intervals (Virtasalo et al., 2007), by studying the microfabric of these laminated sediments reconstructions of eutrophication history on a seasonal resolution can be established (Burke et al., 2002; Jokinen et al., 2015).

Variance partitioning on the diatom data will be performed in order to find the proportion of variance in the data that can be explained by climate variability through time.

References

Andrén, E., Andrén, T., Kunzendorf, H. (2000) Holocene History of the Baltic Sea as a background for assessing records of human impact in the sediments of Gotland Basin, The Holocene, 10, 6, 99. 687-702

Andrén, T., Björck, S., Andrén, E., Conley, D., Zillen, L., Anjar, J. (2011) The development of the Baltic Sea Basin during the last 130 ka. In: *The Baltic Sea Basin*, Eds. Harff, J., Björck, S., Hoth, P., Central and Eastern European Development Studies, Springer-Verlag Berlin Heidelberg, pp. 75-97

Björck, S. (1995) A review of the history of the Baltic Sea, 13.0 – 8.0 ka BP, Quaternary International, 27, pp. 19-40

Burke, I.T., Grigorov, I., Kemp, A.E.S. (2002) Microfabric study of diatomaceous and lithogenic deposition in laminated sediments from the Gotland Deep, Baltic Sea, Marine Geology, 183, pp. 89-105

Conley, D.J., Carstensen, J., Aigars, J., Axe, P., Bonsdorff, E., Eremina, T., Haahti, B.-M., Humborg, C., Jonsson, P., Kotta, J., Lännegren, C., Larsson, U., Maximov, A., Rodriguez Medina, M., Lysiak-Pastuszak, E., Remeikaite-Nikien, N., Walve, J., Wilhelms, S., Zillén, L. (2011) Hypoxia Is Increasing in the Coastal Zone of the Baltic Sea, Environmental Science & Technology, 45, pp. 6777-6783

Gustafsson, B.G., Westman, P. (2002) On the causes of salinity variations in the Baltic Sea during the last 8500 years, Paleocenography, 17, 3, pp. 1-14

HELCOM (2007) Climate Change in the Baltic Sea Area, Baltic Sea Environment Proceedings, 111, 51 pp

HELCOM (2013) Climate Change in the Baltic Sea Area, Baltic Sea Environment Proceedings, 137, 66 pp

IODP Expedition 347, Baltic Sea Paleoenvironment, http://www.eso.ecord.org/expeditions/347/347.php

Jokinen, S.A., Virtasalo, J.J., Kotilainen, A.T., Saarinen, T. (2015) Varve microfabric record of seasonal sedimentation and bottom flow-mediated mud deposition in the coastal northern Baltic Sea, Marine Geology, 366, pp. 79-96

UPPBASER, Understanding Past and Present Baltic Sea Ecosystem Response - background for a sustainable future, https://www.sh.se/p3/ext/content.nsf/aget?openagent&key=projekt_page_eng_1385474632927

Virtasalo, J.J., Kotilainen, A.T., Räsänen, M.E., Ojala, A.E.K. (2007) Late-glacial and postglacial deposition in a large, low relief, epicontinental basin: the northern Baltic Sea, Sedimentology, 54, pp. 1323–1344

Zillén, L., Conley, D.J., Andrén, T., Andrén, E. & Björck, S. (2008) Past occurrences of hypoxia in the Baltic Sea and the role of climate variability, environmental change and human impact, Earth Science Reviews, 91, pp. 77-92

Analysis and evaluation of agricultural land use impact on ecosystem of coastal lagoon by means of dynamic crop simulation models

Ligita Venckuviene

Klaipeda University, Lithuania (ligita.venckuviene@ku.lt)

Water, the very basis of life and the single most important feature of our threatened resource today. In rainfed areas, watershed management is the approach used for conservation of water and other natural resources as well as for sustainable management of natural resources. A watershed is a hydrologically defined area that is drained by a network of streams, which meet together in such a way that the water leaves through a common point. A watershed is made up of soil, vegetation and water along with the people and animals who are the integral part of the system (Wani et al., 2001).

Agriculture is the main nutrients source, which affect the lagoon ecosystem. It is therefore very important to create a unified complex of dynamic models, which includes agro-ecosystem productivity, development and lagoon basin hydrological dynamic models that repeating interaction of the aforementioned ecological systems.

Integrated agricultural systems modeling represents an effective research tool to meet the evolving challenges facing agricultural production and environmental quality. An integrated, process-based model was developed to simulate the impacts of the changing environment and different water and farming management practices on the hydrology, water quality, and crop growth and yield for artificially drained cropping systems (Negm et al., 2014). Such an integrated modelling system will enable a more detailed analysis and assessment of hydrological and biogeochemical cycles change, depending on the agricultural land use change (Lithuania).

Agro simulation models (such as SWAT, Agrotool, DSSAT) are increasingly used for analyzing the impact of agriculture on water bodies. SWAT default soil parameters are compatible with Canadian and US Government soil survey databases (Kiniry at al., 2008). Model calibration for Lithuanian soils could be made more accurate by using Crop growth and development information modeling system DIASPORA created by Lithuanian Institute of Agriculture and University of Klaipeda in 1994-2000.

DIASPORA has its own database AgroWin, which has field testing and agrometeorological data from various Lithuanian fields from the time period 1971-1998 (Juščenko et al., 2001). This data was used for DIASPORA imitational dynamical model parameter identification and functioning. Accumulated KU IK agro-ecological modeling experience and research shows that the most reliable simulation results typically require complete time series of meteorological inputs.

Scientist or organization that will be involved in this work:

Supervisor: Prof. dr. Vitalij Denisov – dean of Klaipeda university Nature and mathematics science faculty, – one of the main Diaspora model developer;

Advisor: Dr. Natalija Juščenko - Agrowin DB and Diaspora model developer;

- Lithuanian Institute of Agriculture – where are going agroecological fields experiments and where can get some experimental data;
- Agro physical institute in Sankt-Petersburg – Agrotools and integration tolls with Apex developers. Take part in many internationals projects, related with impact on ecosystem or her behavior in various situation modeling.
- Marine Science and Technology Centre (MARSTEC) scientists - is an interdisciplinary center of Klaipeda University that offers open access research facilities, resources and services for maritime research and technological development;

Short work plan

The first year:

- Analysis of literature
- Meteorological and agro-meteorological data order /purchase of Lithuanian hydro-meteorological services.
- SWAT analysis modeling system (data input accuracy);

The second year:

- Selection and analysis of Agroecosystem simulation model (literature);
- Development of integration method (SWAT, Agrotool, Diaspora, DSSAT);
- Application regression analysis and neural networks approach for data reconstruction, its evaluation;

The third year:

- Implementation of models integration methodology;
- Validation of the simulation results, correction of method;

The fourth year

- Assessment of the obtained results, impact analysis;
- Evaluate the possibility to visualize the result date in three-dimensional format.

Climate change effects on the Baltic Sea hydrodynamics and water quality

Guillaume Vigouroux

Land and Water Resources Engineering, KTH, Stockholm, Sweden (gvig@kth.se)

1. Background

The Baltic Sea is a large semi-enclosed brackish water body, in the northern Europe, and it plays an important socioeconomic and ecological role. Its semi-enclosed characteristic and high residence time makes it particularly vulnerable to anthropogenic pollution. Moreover, due to the limited and complex water exchanges with the North Sea, climate change is likely to modify the hydrodynamic properties of the Baltic Sea.

The hydrodynamics of the Baltic Sea have been intensively studied, but due to its complex bathymetry and exchanges with the North Sea, further research is still needed for some processes, such as vertical mixing and inflows from the North Sea as stated by Reissmann (2009). Moreover, further work is needed to model the effect of the climate change on the physical properties of the Baltic Sea and to study the salinity dynamics, which is part of the Grand Challenges.

In the past century, the Baltic ecosystem has changed significantly, mostly due to anthropogenic pressures. An example is the increase in eutrophication over the past decades is, which is considered a serious problem and measures are taken to lessen this process. However, this is a global problem, which cannot be treated without considering the nutrient transport, both due to currents and vertical mixing. Moreover, Johannesson (2006) shows that the repartition of species in the Baltic Sea is highly dependent of the salinity and therefore, it is crucial to assess salinity changes to study the ecosystem transformation.

2. Aim

The aim of the study is to deepen the understanding of the consequences of the climate change on the hydrodynamic properties of the Baltic Sea and to assess the effects on the Baltic ecosystem, mainly through the study of water quality and eutrophication. This will be done through large scale (Baltic Sea) and medium scale (sub-basins) modelling over a short and medium term time period (up to 30 years).

3. Objectives

The objectives can be divided in two categories. The primary objectives focus on understanding the climate change effects on the Baltic Sea hydrodynamics and ecosystem while the secondary objectives aim to apply this research to create a framework for an efficient assessment of the future eutrophication situation, based on policy making scenarios.

Primary objectives:

- Model the hydrodynamics of the Baltic Sea and its sub-basins and assess their changes and changes in salinity under different climate change scenarios.
- Model the nutrient and algae transport in the Baltic Sea and its sub-basins using the hydrodynamic model of the Baltic Sea. Study the different vertical mixing processes and their relative influence to increase surface nutrient availability, with possibility of downscaling to understand their role in creating area with high biomass production.
- Assess the water quality and ecosystem changes in the Baltic Sea, as consequences of the climate, hydrodynamic, salinity and nutrient load variations, by implementing a biological module in the hydrodynamic model.
- Related topics:
- Define the nutrient loads and river discharges in the Baltic Sea by studying and using model of the Baltic Sea catchment area.
- Continue to develop the PyWQM, box model use to study water quality, by coupling it to the data from the hydrodynamic model and by implementing new models and compare it biological module of the hydrodynamic model.

4. Methodology

This research work will be integrating three main approaches:

- Collection and analysis of data for hydrodynamic modelling, for hydrologic modelling and for the definition of ecological model and parameters.
- Numerical simulations using COHERENS for the hydrodynamic and water quality modelling of the Baltic Sea, PCRaster for the hydrological modelling of the catchment area and a Python Water Quality Model for a box modelling of the water quality of the Baltic Sea.
- Modelling work to improve existing or implement new water quality and ecosystem model, using the COHERENS biological module and the PyWQM.

The different objectives are also linked to each other. In a first time, the data to set up the hydrodynamic model on COHERENS, such as meteorological forcing, bathymetry, coast line, monitoring data, will be collected and the hydrodynamic model will be implemented. In the same time, the hydrological model, using PCRaster can also be implemented, using data such as DEM, soil cover, soil types, meteorological forcing.

From the implementation of these models, after defining the climate change scenarios and collection of the needed data, the effect of climate change on the hydrodynamics can be studied. The vertical mixing processes will also be studied, possibly by using nested grids to downscale the model to be able to seize the processes of different scale and assess their importance.

From those results, the transport of nutrients can be assessed by modelling them as a tracer in COHERRENS and a water quality and eutrophication model will be implemented using the COHERENS biological module.

In parallel of those tasks, improvements of the PyWQM will also be carried out, by coupling it to the COHERENS hydrodynamic data, modifying the water quality model used and resolution methods to make it more performant. The model will also be compared to the COHERENS biological module.

Assessment of biogeochemical changes in the sediments of the eastern part of the gulf of finland due to invasion of polychaete *marenzelleria* spp.

Ekaterina Voloshchuk

Russian State Hydrometeorological University, Sankt-Petersburg, Russia. (ketrin492006@mail.ru)

Polychaete species of the genus *Marenzelleria* spp. by 2009 became the dominant component of the soft-bottom zoobenthos of the Eastern part of the Gulf of Finland. During their vital activity those polychaetes burrow the sediments deeper than the native species of the Baltic sea, leading to the intensification of metabolic processes on the sediment-water interface. Intensive bioturbation and bioirrigation activity of worms comes to the improvement of oxygen conditions in the deeper layers of the sediments. Emerging iron oxyhydroxides adsorb phosphates on its surface and this complex is buried below the bioirrigation zone. *Marenzelleria* spp. activity in the sediments also might lead to suppression of the development of blue-green algae through nitrogen/phosphorus ratio increase.

Estimation of nitrogen and phosphorus stores and understanding of their income sources is actual goal in conditions of the deteriorating state of the Baltic sea due to eutrophication.

Comparative analysis of biogeochemical changes in the sediments was held for 2 groups of stations: with high and low *Marenzelleria* spp. population. Differences in distribution of various substances in the pore water (ΣPO_4^{3-}, NO_3^-, NH_4^+ and ΣSO_4^{2-}) and in the sediments (Fe^{3+}) were found.

For quantitative assessment of worm's activity contribution to benthic layer changes diagenetic sediment model was applied. The simulation results show that in 5 years there might be lower stores of phosphates (in 2.6 times), ammonium (1.5 times), as well as higher stores of sulphate (1.5 times) in pore water and iron in the sediments (7 times) in station with high abundance of polychaetes compared to the station with low population of *Marenzelleria* spp. The stores of nitrates in two stations are practically the same. Thus in conditions of high and low abundance of invasive species different mechanisms are working in the ecosystems; in future it might lead to significant alterations in these systems.

Those assessments of *Marenzelleria spp*. invasion impact will be taken into account in high-resolution eco-hydrodinamic model of the Baltic Sea (SPBEM) which is constructed for ecosystem changing investigation with consideration of joint effect of climate change and biological communities in this region. Very important, that those assessments will also allow to decrease prediction uncertainties for the Baltic Sea ecosystems.

Summer bloom dynamics in coastal marine ecosystems: a trait-based model study

Changjin Zhao

Institute of Costal Research Helmholtz-Zentrum Geesthacht, Germany (changjin.zhao@hzg.de)

1. Research Background

With growing human populations living adjacent to the sea, coastal seas and their ecosystems have become a hotspot of human interference at ever-increasing rates. Among the most apparent and relevant features of near-shore ecosystems, we recurrently observe algal blooms. However, coastal blooms are ephemeral. Their appearance greatly vary both in time and space which has been documented for many estuaries and coastal seas, such as Chesapeake Bay, San Fransisco Bay, the Bohai Sea, and coastal areas of the North Sea. Algal blooms are of crucial importance in most temperate aquatic ecosystems for driving food web dynamics, energy transformation and matter cycling, but also for economic impacts. Yet, origin and decay dynamics of blooms are poorly predicable, which reflects the various interactions of biological and physical factors (Wirtz & Sommer,2013). It is thus a major challenge in environmental science and management to connect the observed variability in bloom dynamics with our current understanding of control mechanisms, and to develop model systems for accurate hindcast or forecast and mechanistic analysis. However, increasing availability of high quality real-time observations for ecosystem states remotely sensed Chl-a, or from Ferry box) and changing physical forcings (e.g., tides, wind, precipitation and river run-off) as well as improved representation of biological processes within recently developed ecosystem models should substantiate the basis for a quantitative assessment of phytoplankton blooms.

In our group, integrated data-modeling (former Ph.D project) on control mechanism of spring blooms, revealed that the suspended particulate matter (SPM) concentration and related under water light density acts as an important trigger for spring blooms (Tian et al., 2009). Tian et al could also interpret inter-annual variations in the timing and intensity of blooms as being determined by atmospheric and hydrographical drivers (Tian et al., 2010). These works revealed a high sensitivity of the ecosystem dynamics not only to meteorological and hydrographic variability, but also to the internal state of primary producers. For example, species composition and the physiological state of cells as represented by the chlorophyll-a to carbon (Chl:C) ratio were found to explain unresolved features in bloom dynamics (Tian et al., 2010). This result underlined the need for a realistic representation of algal communities and, more specifically, phytoplankton traits to improve such predictions (Smith et al. 2014). Phytoplankton and zooplankton traits such as body size, selectivity, or energy partitioning strategies critically determine all relevant interaction functions such as photosynthesis or nutrient and prey uptake (e.g., Merico et al 2009). Trade-offs in traits (e.g., small cells grow faster but are also grazed faster) and related optimal compromise solutions (adaptation) thus control the endogenous dynamics of plankton community as well as their response to changing environments. Identifying and simulating the important traits not only could help to explain species coexistence, diversity and shifts of community structures. This approach could also quantify the relative and variable importance of the mechanisms that underlay the algal growth patterns observed in situ, especially during the summer period where the interplay between zooplankton grazing, nutrient replenishment from sediments and bottom water, and ongoing species succession complicates the analysis. Due to trait variations in time and space, ecosystem dynamics becomes partially decoupled from physical and chemical forcing, which may explain part of the multi-scale variability observed for coastal algal concentration. This can be inferred from predecessor studies using existing trait-based models in 0D (e.g., Wirtz & Pahlow 2010), but has not been studied in a 3D coastal ocean so far. Model simulations of multi-scale physical features of the German Bight were recently made available by high resolution runs of the state-of-the-art hydrodynamic model GETM (Staneva et al 2009).

Most importantly, a plankton ecosystem model description that is coupled to a realistic 3D physical model and based on adaptive traits defines a central milestone for reliable scenarios of how algal blooms and ecosystem dynamics respond to multiple anthropogenic and natural stressors. This coupled model can be expected to generate more reliable simulations and explanations of macro- and meso-scale features of coastal and marine environments.

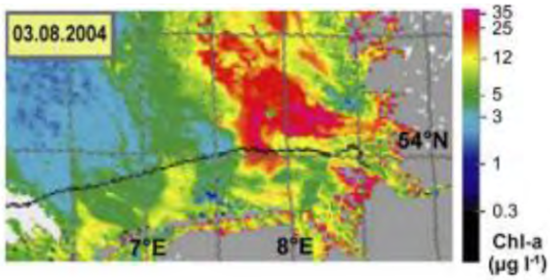

Figure 1. Algal bloom in the German Bight on 3rd August 2004: standard algal concentration for coastal waters derived from remote sensing images (1200 m spatial resolution) taken by MERIS.(Petersen et al ,2008)

2. Research Objectives

- To assess the degree of physical and biogeochemical control of summer algal blooms in the GB
- To explore how variable plankton traits respond to those environmental forcings.
- To quantitatively understand how GB summer blooms depend on physical forcing AND internal trait dynamics at seasonal and interannual scales
- To extrapolate the findings to past and future long-term environmental changes

3. Experimental Methods

- Build a 2D-box transect representation of the GB based on 3D high resolution GETM results; Analyze and compare physic-chemical forcings and observed ecosystem dynamics (time-series data) with focus on summer phytoplankton blooms
- devise a simple (non-trait)ecosystem model (e.g., Fasham model under the Framework for Aquatic Biogeochemica lModels, FABM,) and conduct simulation studies to quantify model skills and to reveal the importance of resuspended nutrients and zooplankton grazing on summer blooms. Extend the model by “internal degrees of freedom” (plankton traits) to represent adaptation at the community level; assess the effect of trait dynamics Run in 3D and extend to spatial statistical analysis using satellite and Scanfish data from COSYNA
- Conduct numerical experiments to identify key mechanisms in controlling spatio-temporal variability at the season scale
- Extend the findings to reconstruct long-term

4. Proposed Timetable

- Months 1-5 Introduction to the scientific background and modelling tools needed for the subsequent work.
- Months 6-7 Data integration and summary of regular patterns in summer blooms
- Months 7-11 2D transect representation of the GB implementation of an existing Fasham-type ecosystem model and validation.
- Months 11-15 Model analysis such as on the quantitative importance of grazing and physically driven nutrient replenishment (possible first paper)
- Months16-23 Implementation of a trait-based approach to represent adaptation at the community level; renewed validation study and quantified effect of trait dynamics on oscillation phenomena (second paper)
- Months 24-36 Trait-based reconstruction and analysis of summer blooms at the GB scale (3D) with special emphasis on (i) mesoscale variability and (ii) interannual variations (third, perhaps fourth paper)
- Months 37-39 Sensitivity experiments and scenarios; elaboration of mechanistic (conceptual) models . (basis for an optional future paper)
- Months 40-42 preparations of the thesis and defense.

References

Wirtz, K. W., & Sommer, U. (2013). Mechanistic origins of variability in phytoplankton dynamics. Part II: analysis of mesocosm blooms under climate change scenarios. Marine biology, 160(9), 2503-2516.

Tian, T., Merico, A., Su, J., Staneva, J., Wiltshire, K., Wirtz, K., (2009). Importance of resuspended sediment dynamics for the phytoplankton spring bloom in a coastal marine ecosystem. J. Sea Res. 62 (4), 214-228

Tian Tian.(2010). Spring bloom dynamics in a coastal marine ecosystem: identification of key processes. Faculty of Mathematics and Natural Sciences at Kiel University

Tian, T., Su, J., Flöser, G., Wiltshire, K., & Wirtz, K. (2011). Factors controlling the onset of spring blooms in the German Bight 2002–2005: light, wind and stratification. Continental Shelf Research, 31(10), 1140-1148.

Smith, S. L., Merico, A., Wirtz, K. W., & Pahlow, M. (2014). Leaving misleading legacies behind in plankton ecosystem modelling. Journal of Plankton Research, 36(3), 613-620.

Merico, A., Bruggeman, J., & Wirtz, K. (2009). A trait-based approach for downscaling complexity in plankton ecosystem models. Ecological Modelling, 220(21), 3001-3010.

Wirtz K.W. & Pahlow M. (2010) Dynamic CHL and nitrogen-carbon regulation in algae optimizes instantaneous growth rate. Marine Ecology Progress Series 402, 81-96.

Stanev EV, Schulz-Stellenfleth J, Staneva J, Grayek S, Seemann J, Petersen W (2011): Coastal observing and forecasting system for the German Bight – estimates of hydrophysical states. Ocean Science, 7, 569-583.

Petersen, W., Wehde, H., Krasemann, H., Colijn, F., & Schroeder, F. (2008). FerryBoxand MERIS–Assessment of coastal and shelf sea ecosystems by combining in situ and remotely sensed data. Estuarine, Coastal and Shelf Science,77(2), 296-307.

The climate over the past 2000 years

Eduardo Zorita

Institute for Coastal Research, Helmholtz-Zentrum Geesthacht, Germany (eduardo.zorita@hzg.de)

1. Background

The climate of the Late Holocene is more similar to today's climate than other periods in the past. The understanding of its variability and of the influence of the external drivers that cause climate changes can provide useful insights about the amplitude of natural climate variations and help estimate the climate change brought about by anthropogenic factors.

In general terms, the global climate over the past 2000 years underwent a series of warm and cold phases. A warm phase during Roman times was followed by a colder period in the Dark Ages that lasted until around year 1000. The Mediaeval Warm Period then lasted until about 1400, followed by the Little Ice Age that terminated in the present warming phase since about 1850.

This succession of cold and warm periods provide a natural laboratory to test the same climate models that are used to predict future climate and to understand which are the mechanisms that give rise to climate variability.

2. Reconstructing past climates from proxy archives

We will give a brief overview of the most important proxy records used to reconstruct the climate of the Late Holocene, mainly, recorded in tree-rings and lake sediments. We will also look at those proxy records that are needed to reconstruct the most important external climate drivers, greenhouse gases, solar irradiance and volcanism. The reconstructions of those external forcings is essential to obtain the information needed to drive the climate models and simulate the past climate.

All reconstructions are burdened from uncertainties, since the proxy records are not exact measuring devices. In addition, we have to assume that the link between the local climate and a proxy record remains unchanged back through time. We will also explore the consequences of these assumptions and illustrate methods to estimate the uncertainty in the reconstruction of past climates.

There exists several reconstructions of the global or north hemispheric surface temperature covering the past millennium, and continental-scale reconstructions of surface temperature over the past two millennia. We will interpret these reconstructions and summarize the main conclusions that can be derived from them.

3. Climate simulations over the past 2000 years

The Climate Model Intercomparison Project includes simulations with several climate models over the past millennium. In addition, more recent simulations covering this period are now available , including a recent large ensemble of simulations with the CESM model and one long simulation with the model MPI-ESM. We will review the main commonalities and main differences among these simulations, explore the magnitude of the externally forced and internally generated climate variability, and provide a general picture about the agreement between simulations and proxy-based reconstructions

4. Combining proxies and simulations

The reconstructed past climate may be used to reduce the uncertainty in climate projections. This may be achieved by using a Bayesian framework, in which the ensemble of simulations covering the past millennium and this century are compared to climate reconstructions. The simulations that are closer to the reconstructions are given more confidence and weighted more strongly than those that show larger disagreements with the reconstructions. This set-up can be applied to many other situations with uncertainties in the models and in the observations, but where predictions under uncertainty are nevertheless required.

References

Fernández-Donado L. et al. (2013) Large-scale temperature response to external forcing in simulations and reconstructions of the last millennium. Climate of the Past 9, 393-421.

George, S.St, and Ault T.R.. (2014) The imprint of climate within Northern Hemisphere trees. Quaternary Science Reviews 89, 1-4.

Hegerl, G., Luterbacher, J., González-Rouco, F., Tett, S. F., Crowley, T., & Xoplaki, E. (2011). Influence of human and natural forcing on European seasonal temperatures. Nature Geoscience, 4(2), 99-103.

Mann, M. E., et al. (2009). Global signatures and dynamical origins of the Little Ice Age and Medieval Climate Anomaly. Science, 326(5957), 1256-1260.

PAGES 2k Consortium Continental-scale temperature variability during the past two millennia (2013) Nat. Geosciences 6, 339-346

Schmidt, G. A.,et al. (2011). Climate forcing reconstructions for use in PMIP simulations of the last millennium (v1. 0). Geoscientific Model Development, 4, 33-45.

Smerdon, J.E. (2012) Climate models as a test bed for climate reconstruction methods: pseudoproxy experiments." Wiley Interdisciplinary Reviews: Climate Change 3, 63-77.

Success and limitations of current climate models

Eduardo Zorita

Institute for Coastal Research, Helmholtz-Zentrum Geesthacht, Germany (eduardo.zorita@hzg.de)

1. Background

Increases in anthropogenic greenhouse gases (GHG) in the atmosphere must lead to surface warming. This statement is not based on climate models, but on established physical theories.

However, to estimate the precise level of global warming caused by a given increase of GHG and to predict changes in other variables like precipitation and wind, requires climate models that compute the effect of that external forcing, the reactions of the subsystem of the Earth's climate and their mutual interactions. These computations are very complex, require strong simplifications of the real climate system and thus are burdened by limitations and uncertainties.

Latching on the presentations by Erik Kjellström, we will overview evaluate how good are climate models at simulating the present climate, where are the major uncertainties in predicting future climates and explore the uses and misuses of climate model output for impact studies.

2. Internal versus external climate variability

When comparing climate simulations with observations, it is crucial to understand that climate variations may originate from two main sources: those attributable to variations of the external forcing factors, like solar irradiance, GHG, volcanoes, etc, and those caused internally by the climate system itself and which do not require external drivers and which evolve quasi randomly

A well know example of these is El Niño, phenomenon but internal variations do occur at all spatial and temporal scales. The internal variability realized in different climate simulations and in the observations are different, and thus climate simulations and observations must to some extent disagree even if the climate models were prefect.

3. The Climate Model Intercomparison Project CMIP

All major climate modelling centers agreed to produce sets of climate simulations with comparable settings that could be used to by the Intergovernmental Panel for Climate Change for its climate predictions. The data from these simulations are publicly available and constitute a very valuable set to have a handle on the uncertainty due to deficiencies of the climate models.

These sets of simulations comprise a fairly large number, including simulations for the Last Glacial Maximum, the Mid-Holocene, the past millennium, the recent centuries, and the future scenarios, among other more specific set-ups. Researchers aiming at estimating the impact of future climate change and past climate variations should be acquainted with the use of these data. We will give a brief overview of the scope of these data sets and how to access these data.

4. Ensembles of simulations

Since no particular climate model can be considered perfect, studies about future climate should include results from different climate models. However, only very few of these models will be 'correct' and the rest of models will turn out to be 'wrong' - e just do not know yet which ones. Several epistemological questions arise from this state of things. Why are some models wrong when all are based on the same physical principles ? Although the number of models in the CMIP ensemble is about 50., this number cannot comprise 'all possible' models ? How do we know that these ensemble contains the 'truth' ? How to interpret the range of available simulations and translate it into probabilistic climate predictions predictions ?

This a situation not unique to climate research. In other areas of environmental science and even social-economics , models often deliver distinct and contradicting predictions that have to be summarize to produce useful information for policy makers.

References

Curry J., and Webster P.J. (2011) Climate science and the uncertainty monster. Bulletin of the American Meteorological Society 92, 1667-1682.

Edwards P. N. (2011) History of climate modeling. Wiley Interdisciplinary Reviews: Climate Change 2, 128-139.

Hargreaves J. (2010) Skill and uncertainty in climate models. Wiley Interdisciplinary Reviews: Climate Change 1, 556-564.

Hargreaves J. Annan J (2014) Can we trust climate models ? WIREs Clim Change 2014, 5:435–440.

Knutti R. (2010) The end of model democracy? Climatic change 102, 395-404.

Masson D. and Knutti R. (2011) Climate model genealogy. Geophysical Research Letters 38..

Mauritsen T., et al. (2012), Tuning the climate of a global model, J. Adv. Model. Earth Syst., 4, M00A01, doi:10.1029/2012MS000154.

Räisänen J..How reliable are climate models? (2007) Tellus A 59, 2-29.

Participants

Akstinas, Vytautas	Lithuanian Energy Institute, Kaunas, Lithuania vytautas.akstinas@lei.lt
Andersson, Agneta	Umeå University, Sweden agneta.andersson@emg.umu.se
Åstrand Capetillo, Nastassja	Baltic Sea Centre, Stockholm University, Sweden nastassja.astrand.capetillo@su.se
Binczewska, Anna	University of Szczecin, Poland anna.binczewska@gmail.com
Blenckner, Thorsten	Stockholm University, Sweden thorsten.blenckner@stockholmresilience.su.se
Brander, Keith	Technical University of Denmark, Charlottenlund, Denmark kbr@aqua.dtu.dk
Bulskaya, Ina	Brest State University named after A.S. Pushkin, Belarus inabulskaya@gmail.com
Čerkasova, Natalja	Klaipeda University, Lithuania natalja.cerkasova@gmail.com
Chen, Yuanying	Royal Institute of Technology (KTH), Stockholm, Sweden yuanying@kth.se
Conley, Daniel	University of Lund, Sweden daniel.conley@geol.lu.se
Ehrnsten, Eva	Baltic Sea Centre, Stockholm University, Sweden eva.ehrnsten@su.se
Eilola, Kari	Swedish Meteorological and Hydrological Institute, Västra Frölunda, Sweden kari.eilola@smhi.se
Elmgren, Ragnar	Stockholm University, Sweden ragnar.elmgren@su.se
Friedrich, Jana	Helmholtz-Zentrum Geesthacht, Germany jana.friedrich@hzg.de
Hinners, Jana	University of Hamburg, Germany jana.hinners@uni-hamburg.de
Humborg, Christoph	University of Stockholm, Sweden christoph.humborg@itm.su.se

Inàcio, Miguel	Leibniz Institute for Baltic Sea Research, Warnemuende, Germany miguel.inacio@io-warnemuende.de
Jokinen, Sami	University of Turku, Finland sami.jokinen@utu.fi
Kjellström, Erik	Swedish Meteorological and Hydrographic Institute, Norrköping, Sweden Erik.Kjellstrom@smhi.se
Labuce, Astra	Latvian Institute of Aquatic Ecology, Riga, Latvia astra.labuce@lhei.lv
Lubiene, Irma	Klaipeda University, Lithuania irma.lubiene@apc.ku.lt
Meier, Markus	Swedish Meteorological and Hydrographic Institute, Norrköping, Sweden markus.meier@smhi.se
Nilsson, Jenny	University of Gothenberg, Sweden gusnjenn03@student.gu.se
Omstedt, Anders	University of Gothenberg, Sweden anom@gvc.gu.se
Reckermann, Marcus	Helmholtz-Zentrum Geestacht, Germany marcus.reckermann@hzg.de
Reunamo, Anna	University of Turku, Finland anna.reunamo@utu.fi
Rutgersson, Anna	Uppsala University, Sweden anna.rutgersson@met.uu.se
Smith, Benjamin	University of Lund, Sweden ben.smith.lu@gmail.com
Soares, Ana	Lund University, Sweden ana.soares @nateko.lu.se
Szubska, Marta	Institute of Oceanology of Polish Academy of Sciences, Sopot, Poland szubi@iopan.gda.pl
Undeman, Emma	University of Stockholm, Sweden emma.undeman@su.se
Van Wirdum, Falkje	Södertörn University, Huddinge, Sweden falkje.van.wirdum@sh.se
Venckuviene, Ligita	Klaipeda University, Lithuania ligita.venckuviene@ku.lt

Vigouroux, Guillaume	Royal Institute of Technology (KTH), Stockholm, Sweden gvig@kth.se
Voloshchuk, Ekaterina	Russian State Hydrometeorological University, Russia ketrin492006@mail.ru
Zhao, Changjin	Helmholtz-Zentrum Geesthacht, Germany changjin.zhao@hzg.de
Zorita, Eduardo	Helmholtz-Zentrum Geestacht, Germany eduardo.zorita@hzg.de

International Baltic Earth Secretariat Publications

ISSN 2198-4247

No. 1 Programme, Abstracts, Participants. Baltic Earth Workshop on ”Natural hazards and extreme events in the Baltic Sea region”. Finnish Meteorological Institute, Dynamicum, Helsinki, 30-31 January 2014. International Baltic Earth Secretariat Publication No. 1, 33 pp, January 2014.

No. 2 Conference Proceedings of the 2nd International Conference on Climate Change - The environmental and socio-economic response in the Southern Baltic region. Szczecin, Poland, 12-15 May 2014. International Baltic Earth Secretariat Publication No. 2, 110 pp, May 2014.

No. 3 Workshop Proceedings of the 3rd International Lund Regional-Scale Climate Modelling Workshop ”21st Century Challenges in Regional Climate Modelling”. Lund, Sweden, 16-19 June 2014. International Baltic Earth Secretariat Publication No. 3, 391 pp, June 2014.

No. 4 Programme, Abstracts, Participants. Baltic Earth - Gulf of Finland Year 2014 Modelling Workshop ”Modelling as a tool to ensure sustainable development of the Gulf of Finland-Baltic Sea ecosystem”. Finnish Environment Institute SYKE, Helsinki, 24-25 November 2014. International Baltic Earth Secretariat Publication No. 4, 27 pp, November 2014.

No. 5 Programme, Abstracts, Participants. A Doctoral Students Conference Challenges for Earth system science in the Baltic Sea region: From measurements to models. University of Tartu and Vilsandi Island, Estonia, 10 - 14 August 2015. International Baltic Earth Secretariat Publication No. 5, 66 pp, August 2015.

No. 6 Programme, Abstracts, Participants. International advanced PhD course on Impact of climate change on the marine environment with special focus on the role of changing extremes. Askö Laboratory, Trosa, Sweden, 24 - 30 August 2015 International Baltic Earth Secretariat Publication No. 6, 61 pp, August 2015.

For a list of International BALTEX Secretariat Publications (ISSN 1681-6471), see www.baltex-research.eu/publications

International Baltic Earth Secretariat Publications
ISSN 2198-4247