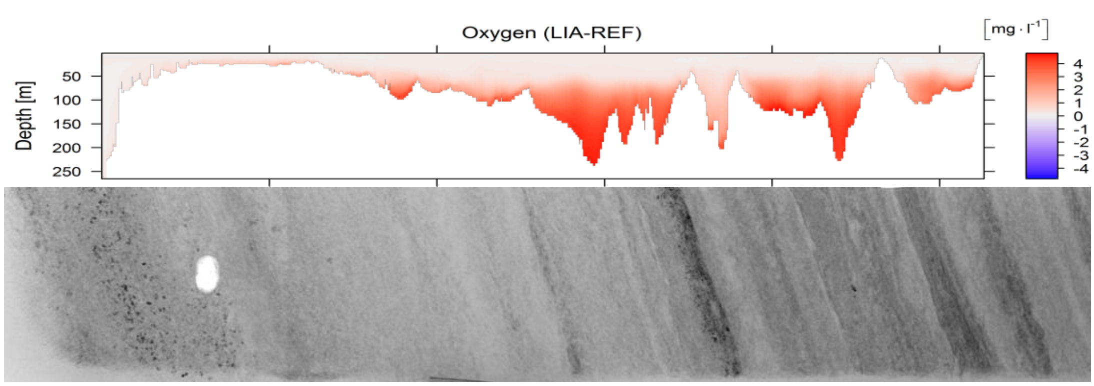
INFLOW Interim Report No. 7

# INFLOW :
# ANNUAL REPORT 2010




BONUS
Baltic Organisations Network for Funding Science EEIG

<table>
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<tr><td colspan="2">Key words<br><br>INFLOW-project, BONUS- research program, Baltic Sea, Palaeoenvironment, marine sediments, Holocene</td></tr>
</table>

GTK = Geological Survey of Finland, Espoo, Finland
IOW = Leibniz Institute for Baltic Sea Research Warnemünde, Germany
GEUS = Geological Survey of Denmark and Greenland
Lund = Department of Earth and Ecosystem Sciences – Division of Geology, Lund University, Sweden
SMHI = Swedish Meteorological and Hydrological Institute
Szczecin = Faculty of Earth Sciences, Department of Paleooceanology, University of Szczecin
BCCR = Unifob AS, Bjerknes Centre for Climate Research, Norway
VSEGEI = A. P. Karpinsky Russian Geological Research Institute, St. Petersburg, Russia
Helsinki = Department of Geosciences and Geography, University of Helsinki, Finland

This report should be cited as:
Kotilainen, A. et al., 2011. INFLOW Annual Report 2010. INFLOW Interim Report No 7 Espoo: GTK. 31 p. Electronic publication. Available at http://projects.gtk.fi/inflow/index.html .

# Project acronym: INFLOW - Holocene saline water inflow changes into the Baltic Sea, ecosystem responses and future scenarios

## Reporting period: 2010

## Project Partners

INFLOW (2009-2011) (http://projects.gtk.fi/inflow/index.html) is one of the BONUS research programme (http://www.bonusportal.org/) projects and it is funded by national funding agencies, the EU Commission and participating institutes. Geologian tutkimuskeskus (GTK) coordinates the INFLOW project that has nine partners in seven countries of the Baltic Sea Region:

Germany: **Leibniz Institute for Baltic Sea Research Warnemünde - IOW**,

Denmark: **Geological Survey of Denmark and Greenland - GEUS**,

Sweden: **Department of Earth and Ecosystem Sciences – Division of Geology, Lund University,** and **Swedish Meteorological and Hydrological Institute – SMHI**,

Poland: **Faculty of Earth Sciences, Department of Paleooceanology, University of Szczecin**,

Norway: **Unifob AS, Bjerknes Centre for Climate Research - BCCR**,

Russia: **A.P Karpinsky Russian Geological Research Institute – VSEGEI**,

Finland: **GTK, and Department of Geosciences and Geography, University of Helsinki**

Table 1. Institutes, persons and persons months of INFLOW Project 2010. PS = Principal Scientist.

| Institute | Person | Acronym | Person month | |
|---|---|---|---|---|
| GTK | | | **14** | |
| | Aarno Kotilainen | ALE | 4 | Coordinator |
| | Joonas Virtasalo | JVV | 10 | Post-doc |
| IOW | | | **27** | |
| | Karoline Kabel | KKA | 12 | PhD student |
| | Thomas Leipe | TLE | 1 | Senior scientist |
| | Matthias Moros | MMO | 6 | Senior scientist |
| | Thomas Neumann | TNE | 2 | PS |
| | Christian Porsche | CPO | 6 | PhD student |
| GEUS | | | **7** | |
| | Antoon Kuijpers | AKU | 3 | PS |
| | Niels E. Poulsen | NEP | 3 | Senior scientist |
| | Jens Peter Rasmussen | JPR | 0.5 | Senior scientist |
| | Kaarina Weckström | KW | 0.5 | Post-doc |
| Lund | | | **13** | |
| | Bryan Lougheed | | 12 | PhD student |
| | Ian Snowball | | 1 | PS |
| SMHI | | | **10.6** | |
| | Helen Andersson | | In kind | Senior scientist |
| | Kari Eilola | | In kind | Senior scientist |
| | Robinson Hordoir | | 6.9 | Senior scientist |
| | Markus Meier | | In kind | PS |
| | Gustav Strandberg | | 3.7 | Senior scientist |
| Szczecin | | | **15** | |
| | Andrzej Witkowski | AWI | 3 | PS |
| | Slawomir Dobosz | SDO | 12 | PhD student |
| BCCR | | | 3.2 | |
| | Eystein Jansen | EJA | 1 | PS |
| | Björg Risebrobakken | BRI | 2.2 | Post-doc |
| VSEGEI | | | **36.5** | |
| | Timofev Bodryakov | TBO | 10 | PhD student |
| | Andrey Grigoriev | AGR | 5.5 | Senior scientist |
| | Juriy Kropatchev | JKR | 0.5 | |
| | Elene Nesterova | ENE | 0.5 | |
| | Daria Ryabchuk | DRY | 5 | Senior scientist |
| | AlexanderSergeev | ASE | 2 | Student |
| | Mikhail Spiridonov | MSP | 6 | PS |
| | Vladimir Zhamoida | VFH | 7 | Senior scientist |
| Helsinki | | | **13.5** | |
| | Laura Arppe | LAR | 12 | Post-doc |
| | Mia Kotilainen | MKO | 1 | Senior scientist |
| | Juha Karhu | JKA | 0.5 | PS |
| **Total person months used** | | | **133.6** | |

## General

During 2010 altogether 33 scientists and students participated in the INFLOW –project (Table 1), with total used resources of 133.6 person months. The INFLOW Project has been continued more or less as planned in the Full Research Plan with laboratory and modeling work.

Due to prolonged contractual negotiations between the Danish Natural Research Council (FNU) and the BONUS EEIG management, an official (financial) start of GEUS activities (e.g. dinoflagellate studies) was delayed. Consortium Agreement between BONUS EEIG and Project Partners was signed finally (25th January 2011).

## Introduction

INFLOW uses sediment multi-proxy studies and modeling to identify the forcing mechanisms of palaeoenvironmental change of the Baltic Sea over the past 6000 years and to provide selected scenarios of the future Baltic Sea.

INFLOW studies ongoing and past changes in both surface and deep water conditions (e.g. saline water inflow, hypoxia and temperature) and their timing by means of multi-proxy studies combined with state-of-the-art modelling approaches. INFLOW uses sediment proxy data from key sites along a transect from the marine Skagerrak to the freshwater dominated northern Baltic Sea. The focus of the project will be the Late Holocene. The validated ecosystem models can provide simulated data for extreme natural climatic conditions over the past thousands of years (e.g. Medieval Warm Period, Little Ice Age). Proxy reconstructions will be compared with results from model simulations to investigate the relationship between natural variability and human impact. Validated models will be used to provide scenarios of the Baltic Sea ecosystem state at the end of the 21st century for selected IPCC climate change scenarios. That information produced by the INFLOW project can form the scientific basis for political strategies adapting to future climate change. INFLOW will provide policy makers with valuable information on how humans have been affected in the past 6000 years. This may shed some light on the possible impacts of future climate change.

This report focuses on activities of INFLOW project during 2010. The timing of different work packages (WP) and tasks are shown in table 2. Deliverables due during the reporting period (2010) were:

Deliverable (D1.2) "***High resolution age model for the past 6000 years"*** was due month 18.

Deliverable (D2.1) "***Forcing data for time slice experiments"*** was due to month 24.

Table 2. The timing of different Work packages and Tasks of INFLOW Project.

| | | 2009 | | | | 2010 | | | | 2011 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| **WP1 – Sediment proxy studies** | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| Task.1.1. Key-site selection & sampling | | ▒ | ▒ | ▒ | | | | | | | | | |
| Task.1.2. Chronostratigraphy | | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | | | | | | |
| Task.1.3. Reconstr. of deep water condit. | | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | | | |
| Task 1.4. Reconstr. of surface water condit. | | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | | | |
| **WP2 - Modelling approach** | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| Task: 2.1. Forcing function | | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | | | | | | |
| Task: 2.2. Time slice experimensts | | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | | |
| **WP3 – Synthesis** | | | | | | | | | | ■ | ■ | ■ | ■ |
| Task: 3.1. Model validation | | | | | | | | | | ▒ | ▒ | ▒ | |
| Task: 3.2. Link to North Atlantic | | | | | | | | | | ▒ | ▒ | ▒ | ▒ |
| Task: 3.3. Future Scenarios | | | | | | | | | | | ▒ | ▒ | ▒ |
| **WP4 – Training and Education** | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Task: 4.1. Floating University | | | ▒ | | | | | | | | | | |
| Task: 4.2. Workshops | | ▒ | | | | | | | ▒ | | | | ▒ |
| Task: 4.3. Outreach | Presentations in conferences | ▒ | | | | ▒ | | ▒ | | ▒ | | | ▒ |
| | Raising public awareness | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ |
| **Project meetings** | | ▒ | | ▒ | | | ▒ | | ▒ | | ▒ | | ▒ |
| **Publications** | | | | | | | | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ |
| **Final reports** | | | | | ▒ | | | | ▒ | | | ▒ | ▒ |

Note, due to the known (contract) delay in the GEUS time/work schedule, GEUS post doc contribution to Task 1.4 (surface water reconstruction) will consequently also be delayed. The duration of Task 1.4 might then extend to mid 2011 (2/2011).

## Activities and results

### Work package WP1. Sediment proxy studies

Participating Institutes: GTK, IOW, GEUS, GBSCL, Szczecin, BCCR, VSEGEI, Helsinki.

Multi-proxy sediment studies will be used to understand the natural elasticity of the ecosystem. We have studied ongoing and past changes in both surface (temperature, salinity, sea-ice) and deep water (oxygen, salinity) conditions and their timing. Sediment studies will provide needed data for modelling approaches (WP2). Sediment proxies have been studied from key-sites along a transect from the marine Skagerrak to the freshwater dominated northern Baltic Sea. Work in the WP1 was divided into the following tasks:

#### Task 1.1.: Key-site selection and sediment sampling – Activities 2010:

The key-site selection and sediment sampling was mainly realized already during 2009 (see INFLOW Annual Report 2009). The field investigations of the INFLOW project in 2010 concentrated on the northern Baltic Sea and the Russian waters of the eastern Gulf of Finland. Two cruises were organized.

June 2010, the Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Germany, organized R/V Prof. Albrecht Penck cruise (07PE1012) to the Northern Baltic Sea (Fig. 1). During the cruise fresh surface and multi-corer material were collected from central and northern Baltic for TEX-86 measurements, proxy calibration and XRF-scanning.

A.P Karpinsky Russian Geological Research Institute (VSEGEI) organized the field expedition to the Russian waters of the eastern Gulf of Finland in the summer 2010. R/V Ladoga and R/V Risk field work in the Russian waters included:

- side-scan sonar profiling in the Vyborg Bay for the study of configuration of the local basins characterizing by recent silty-clayey sedimentation;
- sampling of soft silty-clayey sediments by Niemisto corer (3 stations) (Vyborg Bay) for study of sedimentation rate within local sedimentation basins;
- seismo-acoustic profiling (using complex “Geont-Shelf”) in the sampling areas of 2009 (R/V Ladoga) for the study of litho-stratigraphic boundaries.

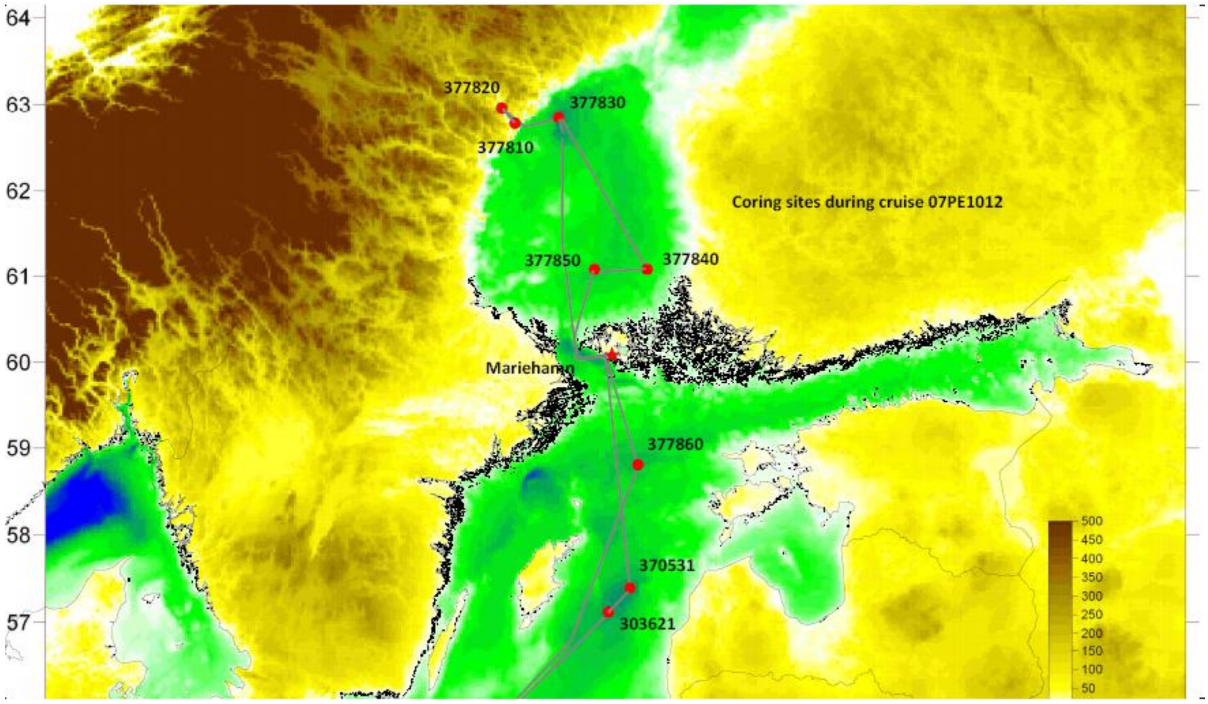



**Fig. 1.** Cruise track and coring sites of R/V "Prof. A. Penck" cruise (07PE1012) in June 2010.

In addition to that INFLOW Partners (BLO, JVV) participated in the R/V Maria S. Merian "BONUS Baltic Gas project" cruise to the northern Baltic Sea. Cruise was organized by the IOW.

**Task 1.2.: Chronostratigraphy - Activities 2010:**

**Palaeomagnetic dating and Mineral Magnetic Analyses of sediment cores (Lund, IOW, GTK)**

Based on measurements of cores made in 2009 the following sediment cores were selected for detailed palaeomagnetic and mineral magnetic analyses in Lund:

- Core 370530 (Gotland Deep): Rotational remanent magnetization, anhysteretic remanent magnetization and saturation isothermal remanent magnetization of discrete samples. Magnetic susceptibility of discrete samples.

- Core 370540 (Gotland Deep): Rotational remanent magnetization, anhysteretic remanent magnetization and saturation isothermal remanent magnetization of discrete samples.

- Core 370520 (North Central Basin): Anhysteretic remanent magnetization of discrete samples.

Additional measurements made during 2010 include Core MSM16/1 where magnetic susceptibility and natural remanent magnetization of discrete samples were measured, and Core 367270 where samples were prepared for grain size analyses (in coop. with Matthias Moros, IOW).

Measurements were done also from the Eastern Gulf of Finland (F40 site) core MGML-2009-5 where bulk magnetic susceptibility, natural remanent magnetization, anhysteric remanent magnetization and saturation isothermal remanent magnetization of discrete samples were measured in GTK

Palaeomagnetic age/depth modeling carried out for cores 370530 and 370540 using statistical sequence slotting. These age-depth models require verification with isotopic dating techniques and results are only preliminary. Modelled palaeomagnetic secular variation curves are derived from global models.

**Isotope dating** (BCCR, GEUS, GTK, IOW, Lund)

AMS$^{14}$C dating

The dating results of many samples submitted for radiocarbon dating analysis were received in December 2010 and January 2011. Currently, these results are being evaluated and additional material will be submitted at the end of January 2011. The parallel dating of benthic foraminifers and TOC fractions is necessary due to unknown reservoir ages and admixing of old carbon in the Baltic Sea Basins.

- Multi-cores:
    - Picking and submission of benthic foraminifer samples from Kattegat/Skagerrak to Poznan Radiocarbon Laboratory and Kiel Radiocarbon laboratory (IOW)
- Long cores from key-sites:
    - Gotland Basin sites (370530, 372740) Time-consuming picking of foraminifers (IOW)
    - Skagerrak / Kattegatt: Picking and submission of benthic foraminifer samples to Poznan Radiocarbon Laboratory and Kiel Radiocarbon laboratory (results back in Dec. 2010)
    - Bornholm Basin: submission of selected shell samples to Poznan Radiocarbon Laboratory (results February 2011)

  - Gotland Basin, Northern Central Basin, Gulf of Finland: submission of samples for bulk, two fraction (base residue, humic acid fraction) radiocarbon dating Poznan Radiocarbon Laboratory (results December 2010)

Pb210/Cs137 dating

- Samples from 12 multi-cores (3 Skagerrak, 2 Kattegat, 1 Bornholm Basin, 4 Gotland Basin, 2 Northern Central Basin) have been selected and submitted for dating to University of Copenhagen (results are expected in January 2011) – IOW, Lund

**OSL dating (Helsinki**)

Testing of the OSL-samples has been continued at Helsinki University in close co-operation with the Nordic Laboratory for Luminescence Dating (NLL), Department of Earth Sciences, University of Aarhus, Risø National Laboratory, Roskilde, Denmark.

Laboratory work included e.g. opening and sampling of the cores for OSL-dating (Geological Survey of Finland) February-March 2010; chemical pre-treatment of the OSL-samples in Kumpula (University of Helsinki, Dating Laboratory) April-June 2010; final chemical etching, acid treatment ($H_2SiF_6$) of the samples and measuring the luminescence signal in the NLL July 2010 (MKO visit to NLL 9.-23.7.2010).

**Task 1.3.: Reconstruction of deep water conditions – Activities 2010:**

Various sediment proxies have been used to reconstruct deep water conditions. Laboratory analysis continued in 2010 including e.g.

- Benthic foraminifera studies of samples from Kattegat/Skagerrak and central Gotland basin cores, including counting, stable (δ18O and δ13C) and strontium (87**Sr**/86**Sr**) isotope, as well as Mg/Ca analyses (BCCR, IOW, HU). Stable isotope studies included measurements of oxygen and carbon isotopes on surface sediment cores MUC372610 and MUC 372680. Samples from long sediment core GC372610 are picked, and are waiting for measuring time on the mass spectrometer to get the data finished (BCCR).
- sedimentary-fabric analysis integrating sedimentologic and ichnologic methods was carried out on digital images and X-radiograph of the following cores: 367270 and 367280 (Kattegat), 370530-6 and 303620-3 (Gotland Deep), 349140 (North Central Basin), 370510-5 (Western Gulf of Finland, JML), and MGML-2009-5 (Eastern Gulf of Finland, F40) (GTK).

- grain size analysis of the Skagerrak core 372610 and the eastern Gulf of Finland cores MGGL-2009-4 (506 samples) and 09-BI-3 (10 samples) (VSEGEI, IOW).

**Task 1.4.: Reconstruction of surface water conditions - Activities 2010:**

To reconstruct surface water conditions during the past we have utilized extensive studies of surface sediments and long sediment cores. Laboratory analysis continued in 2010 including e.g.:

- sediment biomarker TEX-86 SST (sea surface temperature) measurements in NIOZ Texel (IOW) :
  - Trap series one year monthly (2007/2008)
  - 27 surface samples covering the whole Baltic
  - 6 multi-corer, davon 2 NCB (370520; 377860), 4 Gotland Basin (370540, 303600N, 370540N, 370531)
  - 2 gravity cores: 370530 (high-resolution), 303600 (low-resolution) – Gotland Basin, 370520 (low-resolution) – Northern Central Basin
- diatom analyses of surface sediment samples and long sediment cores (Szczecin)
  - 100 surface samples have been analyzed, and next 100 surface samples are ready to microscopic work. Samples from the upper 240 cm of the Gotland Deep core (370530) have been prepared and 150 cm examinated.
- dinoflagellate analyses of sediment samples from the Bornholm Basin were carried out in GEUS. The samples used for dinoflagellate studies were prepared at the University of Szczecin, and partly in GEUS.
- Br analyses of the eastern Gulf of Finland cores MGML-2009-4 (Site F40) (102 samples) and 09-BI-3 core (48 samples) (VSEGEI);
- preparation and tests of sediment samples for alkenone and $IP_{25}$ study (GEUS).

For Tasks 1.3. and 1.4.: Geochemical analysis such as XRF–scanning, TOC/TIC/TC/S/N (IOW, GTK, VSEGEI), biogenic opal (IOW), P, Ca/Mn, Sr-isotope measurements (Helsinki, GTK). These geochemical studies cannot be solely linked to surface or deep water processes, but which are essential to characterize the status of the ecosystem (such as redox stage). Activities 2010 included:

Loss on ignition (LOI) data of 6 cores, TOC/TC/N measurements (IOW, GTK).

XRF scanning (University of Cologne) of 4 multi-core halves (IOW).

Laboratory work for 87Sr/86Sr analyses included: pretreatment trials including MS runs for C- and O-isotopes; Sr ion chromatography tests; preparation of foraminifer samples, Sr-chemistry, MC-ICP-MS & TIMS-measurements from cores 372680 and 372610; sampling, preparation, Sr-chemistry and TIMS runs of $Mn(Ca)CO_3$ layer and shell samples (LA/Helsinki).

Palynological (pollen) analysis of MGML-2009-4 (Site F40) core (VSEGEI).

Following the geochemical study of core 211630-9 from the Bornholm Basin described in the 2009 GEUS Annual Report, an additional core (211660-1), which was retrieved from the Gotland Basin, has been investigated by modified energy-dispersive X-ray fluorescence (EDX) techniques using radio-isotopes for characteristic X-ray excitation. This work by GEUS (AKU**)** has been carried out together with Helmar Kunzendorf (Institute of Geography and Geology, Copenhagen University).

Preparation of mini-icefinger samples at GTK Finland in May-June and October-December 2010 (Katharina Häusler, Diploma student IOW – Diploma Thesis in 2011). The ice-finger samples were impregrated with epoxy, following the water–acetone–epoxy exchange method. X-radiographs of the samples were produced in order to permit detailed structural analysis of the surface sediments.

**WP1 Results**:

*Chronostratigraphy and mineral magnetic studies (LU, IOW, GTK, Helsinki)*
Palaeomagnetic age/depth models have been established for cores 370530 and 370540. A tentative age-depth model based on radiocarbon has been established for core 370530 (which has been compared with the palaeomagnetic based model).

Mineral magnetic analyses indicate that single-domain magnetic particles are responsible for the high concentrations of magnetic minerals in the laminated sections of cores from the Baltic Proper. The precise origin of these particles remains to be determined, but they are most likely authigenic/diagenetic and related to the precipitation of iron oxides by anaerobic (possibly magnetotactic) bacteria as a result of organic matter decomposition during time of anoxia/hypoxia. There is a clear relationship between palaeomagnetic directions and the presence of laminations, which complicates the application of palaeomagnetic age modeling. Preliminary palaeomagnetic analyses of sediment cores from the Bothnian Bay suggest that the influx of detritus with a higher magnetic mineral concentration leads to a better palaeomagnetic signal in this region.

Problems with poor NRM recording occurred in "marine" clay and very strong laminations. NRM recording in weakly laminated sediment and clays from Bothnian Bay (non-marine) was relatively good.

As expected, bulk radiocarbon dates are unreliable due to the unknown radiocarbon reservoir effect in the Baltic, which varies in time and space. In an effort to provide an estimate for this reservoir we attempted radiocarbon 'wiggle-matching' using high-density 14C dates obtained on foraminifera picked from core 370530. These dates span a well-dated palaeomagnetic feature and an anomaly in the 14C calibration curve. 10 samples were submitted to ETH-Zurich (CH), which uses direct-gas injection into a mass spectrometer. Despite the advance in technique, the results obtained in December 2010 indicate that many of the samples were too small to obtain sufficiently precise ages for wiggle matching. However, the individual ages can be calibrated and compared with the calendar year age of the palaeomagnetic feature to obtain a reservoir correction. (Lougheed et al. in prep).

A detailed discussion of age models results will be performed at INFLOW Annual Meeting early February 2011 in Sweden. Multi-corer Pb210/Cs137 results will be compared with those from AMS14C dating for reservoir age estimation in Skagerrak and Kattegatt. After the meeting age-models should be available for all key-sites.

As a part of the dating package, we are in the process of developing a chronology based on optically stimulated luminescence (OSL) dating. For OSL dating it is essential that any prior OSL signal is well zeroed or bleached before final deposition. This is known to be true in the Arkona Basin in the southern Baltic Sea, and is likely to apply at our sampling site F40 at the outer Neva estuary (water depth 38 m). This location is thought to record continuous sedimentation and a relatively high accumulation rate. The 4.54 m long sediment core was recovered by the piston coring during R/V Aranda cruise in August 2009. The sediment consists mainly of bioturbated silty mud with laminated intervals.

The thermo luminescence (TL) signals IR50 and pIRIR225 from polyminerals of 12 samples were demonstrating that the sediment grains have electrons (emitted as light) trapped in them and that the signals also formed a sensible smooth succession according to the depth suggesting proper bleaching prior to sedimentation. Hence the outer Neva estuary fine grained marine sediment is suitable for luminescence dating. The optically stimulated luminescence was measured from 5 samples using the SAR procedure and fine-grained quartz grains. The limited number of samples was unavoidable since the purity test of the samples proved that all the polymineral samples were not pure quartz after 3 days of acid treatment ($H_2SiF_6$). However, the OSL signal of the measured samples was offset compared with IR50 and pIRIR225, probably due to thermal transfer. This problem has to be solved by preparing more samples and running more measurements. The dose rate determination is also essential before the measured signals can be transformed into ages. The sample preparation for the dose rate determination for all the 12 samples was completed, and one preliminary result received. The dose rate in the area seems to be rather high (reducing the age estimate). The water content of the sediment is very high too, which alters the interaction (by amplifying the age estimate). Eventually, both the OSL and TL signals are giving too old ages at this stage.

The length of the visit, or more precisely, the limited time, was affecting the laboratory work substantially. The most characteristic feature of the luminescence technique is, that it is time-consuming: getting the results require laboratory time rather months than weeks. It is evident that this technique works for marine sediments and can be used as an independent dating method for INFLOW sediments, but more work is required for finalised results.

Mineral magnetic properties were studied also from the Eastern Gulf of Finland (F40 site) core MGML-2009-5 In the SIMR acquisition, all the samples were saturated (over 95 %) in low fields (<300 mT), which shows that the dominating magnetic mineral is the most likely pseudo-single-domain magnetite. The S-ratio is below –0.6 in the sediments underlying the erosional horizon at 190 cm, while the ratio reaches –0.4 or even higher above the erosional contact (Fig. 2). This indicates the presence of a higher coercivity mineral such as hematite as a minor component in the overlying sediments. Furthermore, the SIRM/K ratio decreases significantly just above the erosional horizon, indicating a higher magnetic grain size, but the increasing SIRM/K ratio indicates that the magnetic grain size decreases upward (Fig. 2).

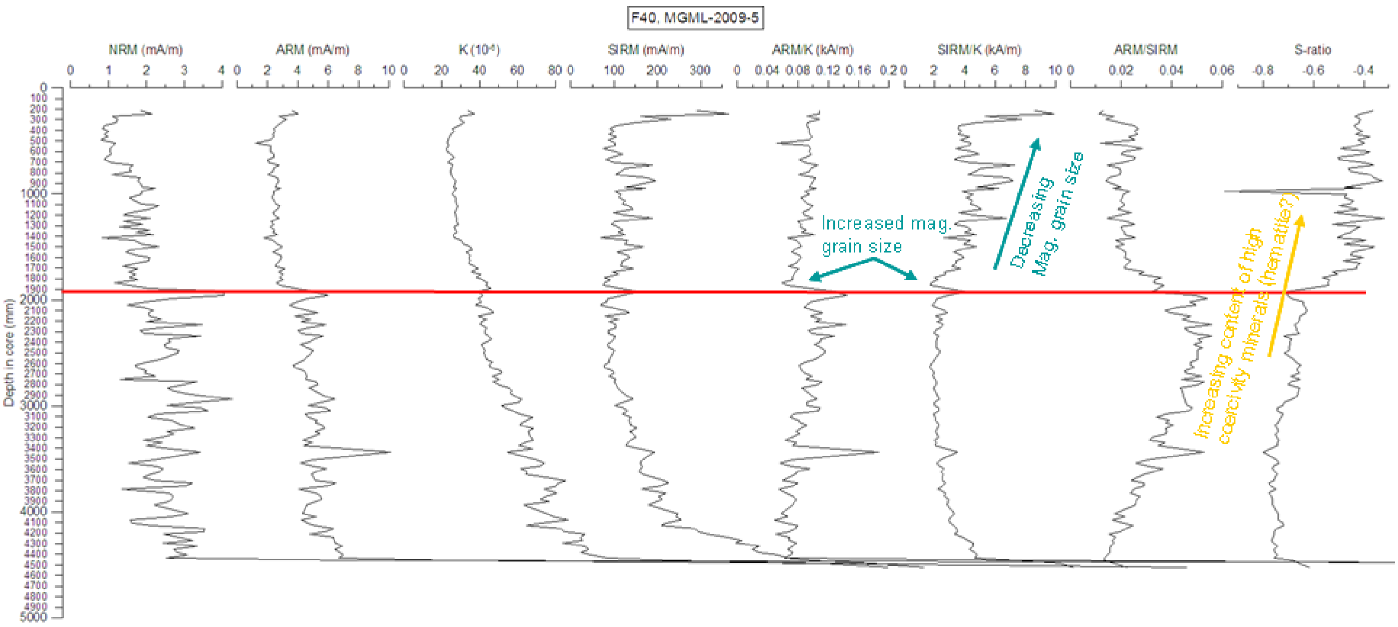



**Fig. 2.** Mineral magnetic parameters determined for the core MGML-2009-5 from the Eastern Gulf of Finland (F40 site). The red line indicates the erosional horizon at 190 cm.

*Sedimentary fabric analysis (GTK)*

The cores from Gotland Deep, North Central Basin and Western Gulf of Finland are characterized by alternating thinly-laminated, biodeformed and burrow-mottled fabrics (Fig. 3). These fabrics record anoxic, transient low-oxygen and oxic seafloor conditions, respectively. For details and discussion on the fabrics, see Virtasalo et al. (2011).

The cores from Kattegat are intensely bioturbated with the occurrences of bivalve biodeformational structures and worm-produced burrows (*Planolites* and *Arenicolites*/*Polykladichnus* trace fossils). A characteristic feature of these cores is the sporadic occurrence of *Scolicia* trace fossils (Fig. 4) that are produced by sea urchins (echinoids). At present, the echinoid *Echinocardium cordatum* inhabits the northern Great Belt, but the species does not survive the lower salinities further south. The *Scolicia* trace fossils, therefore, may represent times of increased salinity and temporary southward expansion of the echinoid communities (Werner, 2002).

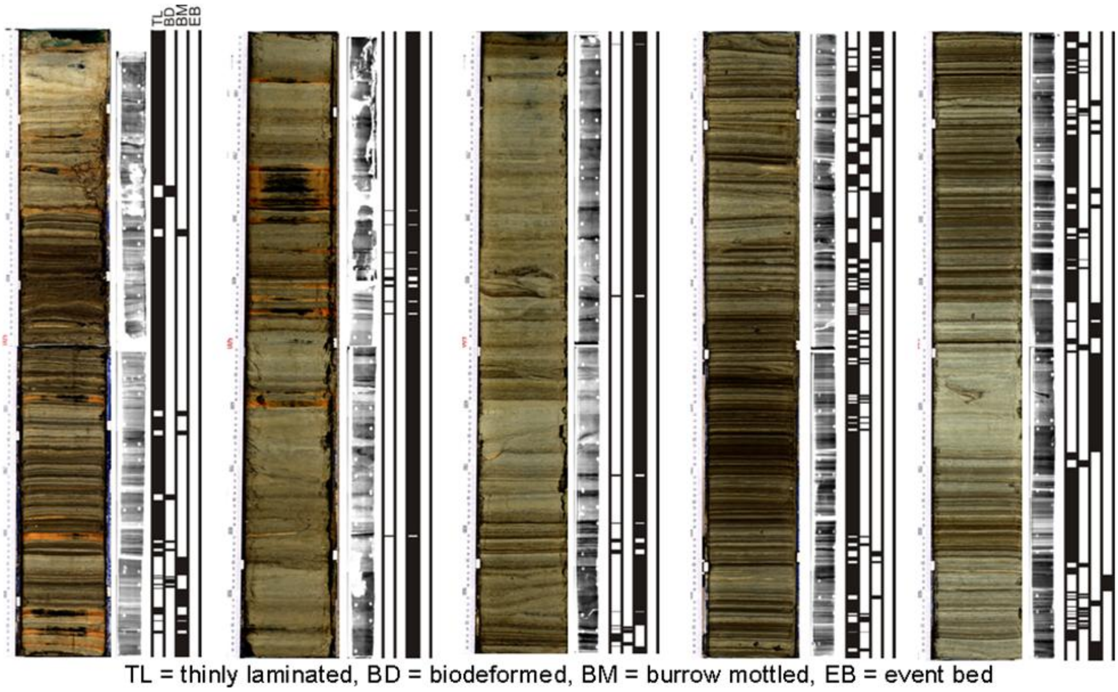



**Fig. 3.** Digital images, X-radiographs and sedimentary-fabric interpretation for the core 370530-6 from the Gotland Deep GB1 site.

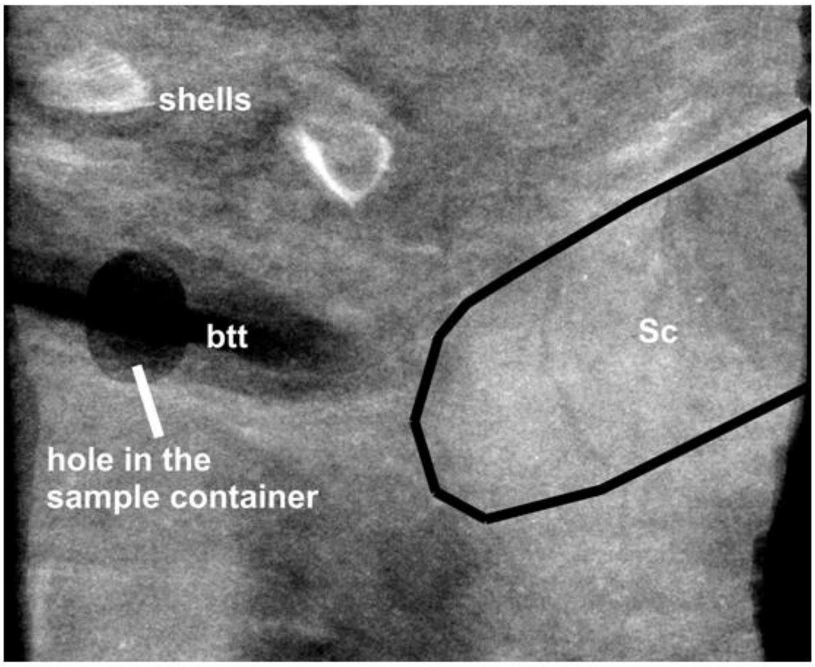



**Fig. 4.** X-radiograph from the core 367270 from Kattegat. The black line outlines a Scolicia trace fossil (Sc) with sub-vertical crescent-shaped lamination. A thick-walled burrow is seen on the left hand side (btt). Figure width is 5 cm.

The core from the Eastern Gulf of Finland is strongly bioturbated, but few thin laminated intervals are present (Fig. 5). The sediments below a strong erosional horizon at 190 cm are characterized by occasional small worm-burrows that are typically <1 mm in diameter, while above the erosional contact also burrows up to 3 cm in diameter occur as well as rare bivalve biodeformational structures (Fig. 6). The appearance of larger burrows and bivalve-produced structures indicates higher benthic diversity and improved living conditions.

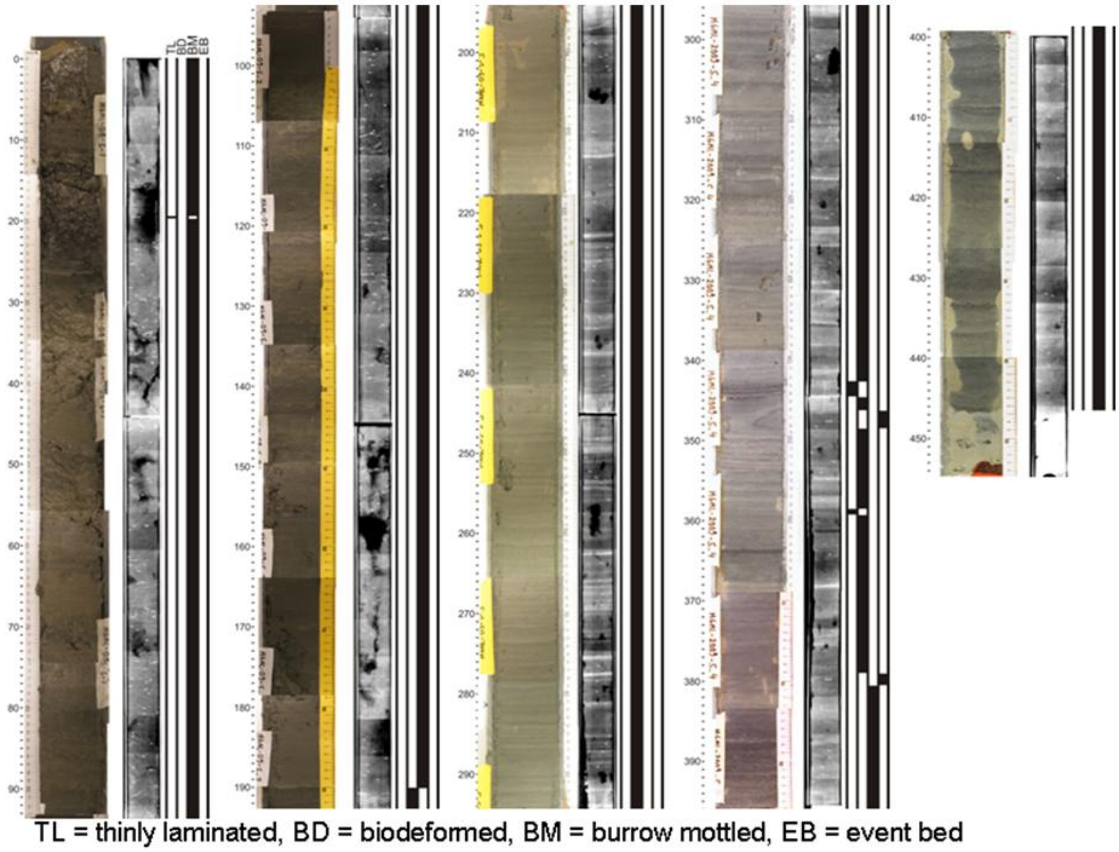



**Fig. 5.** Digital images, X-radiographs and sedimentary-fabric interpretation for the core MGML-2009-5 from the Eastern Gulf of Finland. Note the erosional horizon at 190 cm.

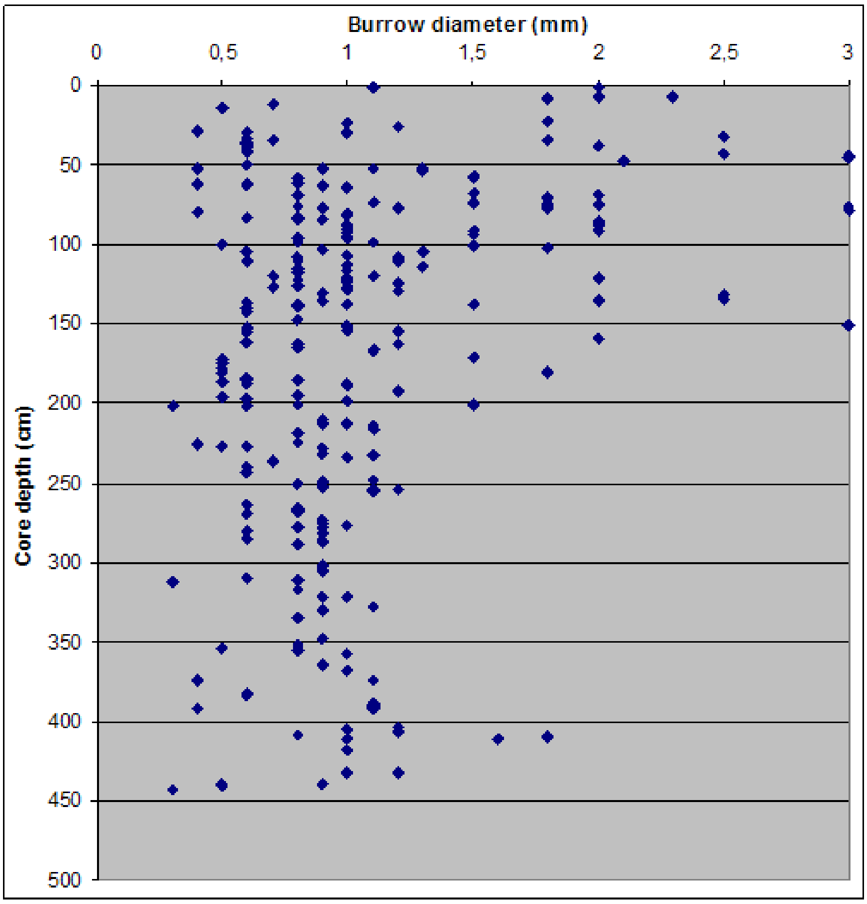



**Fig. 6**. Distribution of worm-burrow diameters in the core MGML-2009-5 from the Eastern Gulf of Finland. The burrow size increases above 190 cm.

*Benthic foraminiferas (IOW)*

Benthic foraminifer counting results (Master Thesis, Jentzen 2010 – IOW) reveal a close link of the bottom water properties in Skagerrak and Kattegatt to the so-called "Matthäus-curve" of major Baltic saline water inflows. A decrease in frequency of the major Baltic inflows from the 1980s is parallel a depleting of oxygen in bottom waters of Skagerrak and Kattegatt. This evidences a close link of Baltic Sea inflow changes to variations observed in Skagerrak area.

*Stable isotope studies of benthic foraminifers (BCCR)*

Benthic $\delta^{18}O$ data from Skagerrak, so far representative of the last 710 $^{14}C$ years BP, are produced. The $\delta^{18}O$ anomaly, relative to the mean of the measured time interval, has been calculated. According to instrumental records, bottom water salinities at the site are rather constant at 35‰, leaving the $\delta^{18}O$

signature primarily to represent temperature changes in the Skagerrak bottom water. From approximately 710-350 $^{14}$C years BP, the area was dominated by cold temperature anomalies. The recorded amplitude of the cold anomalies is to some degree dependent on the species used (approximately 0.1-0.3‰, or about 0.4-1.3°C). At approximately 350 $^{14}$C years BP, a switch toward dominating warm anomalies occurred. As for the cold anomalies, the amplitude of the variability depends on the species (0.1-0.4‰, or 1.7°C). The benthic $\delta^{13}$C anomalies indicate a contemporaneous shift towards a higher flux of organic matter after approximately 350 $^{14}$C years BP.

In the Kattegat area, the last 820 $^{14}$C years BP are represented by the MUC and hence the measurements done so far. At a preliminary stage, assuming constant salinities, the benthic $\delta^{18}$O data indicates predominantly warm anomalies, interrupted by quasi-periodic cold anomalies. Salinities are presently lower in the Kattegat area than in the Skagerrak area, and are also supposed to be slightly more variable than in Skagerrak. Hence, the role of salinity at this site must be better checked. Comparable to the Skagerrak record, a shift in benthic $\delta^{13}$C occurs approximately in the middle of the MUC, indicating a stronger flux of organic matter to the sea floor during the youngest part of the record.

*$^{87}$Sr/$^{86}$Sr studies (Helsinki)*

Trials of automated ion chromatograph (IC) separation of Sr revealed problems related to throughput. Tests with sample solutions of known Sr concentration indicated a mean yield of only 15%. The problem is most likely related to a modification of the eluent, which was necessary to produce sample solutions compatible with inductively coupled plasma mass spectrometer (ICP-MS) isotopic measurements. In view of the small size of the intended samples for $^{87}$Sr/$^{86}$Sr analyses, the automated IC-elution approach was abandoned.

The foraminifer $^{87}$Sr/$^{86}$Sr measurements on the lately acquired ICP-MS at the Geological Survey of Finland (GTK) indicated problems within the instrument. Replicate runs carried out using thermal ionisation mass spectrometry (TIMS) at GTK showed significant discrepancies in resulting $^{87}$Sr/$^{86}$Sr values between the two instruments. Standard material and sample comparisons indicate that the ICP-MS results are suspect, the instrument producing erratic offsets from expected values. The factors responsible for the problems in Sr analytics with the ICP-MS instrument are as of yet unknown, and under investigation. Further, the ICP-MS analyses suggest possible problems associated with the leakage of Sr-spec resin from the microcolumn into the sample, causing Sr retention onto the resin. Due to these problems, all current $^{87}$Sr/$^{86}$Sr work is performed on the TIMS instrument.

The Sr isotope analyses of benthic foraminifers from cores 372680 and 372610 suggest that the $^{87}Sr/^{86}Sr$ ratios of the biogenic calcite do not solely reflect the Sr isotopic composition of the bottom water. Further, the Sr-salinity model performs best for waters with salinities <10‰. Within the salinity range characteristic for Kattegat, where foraminifers are present in the sediment cores in sufficient abundance for TIMS analyses, the salinity model has a poor precision of 7-16‰. Thus, the decision was taken to explore the potential of $MnCO_3$-rich layers and bivalve shells, present in cores from less saline waters, for Sr-isotope salinity investigations. First results on the $MnCO_3$ precipitates indicate the presence of Sr not derived from Baltic bottom waters. Further investigation will reveal the usefulness of the $MnCO_3$ precipitates as Sr-salinity records.

*Sea-surface temperature (TEX-86 SST), central Baltic Sea (IOW)*

For the first time, biomarker TEX-86 based SST studies have been successfully applied on Baltic Sea sediments during a Diploma Thesis (IOW, Adolphi 2010) in collaboration with Prof. Jaap Sinninghe Damsté. PhD Kabel (IOW) continued measurements on multi-corers from Northern Central Basin and Gotland Basin, and on key-long cores 370530 (Gotland Basin, 243 m water depth) and 303600 (Gotland Basin, 170 m water depth) at NIOZ on Texel during summer 2010 (3 months stay). Currently, the calibration of TEX-86 method is being improved for application in Baltic. Hereby, TEX-86 measurements on a set of the Baltic Sea surface samples, multi-corer and trap material will be calibrated using instrumental data available for the last 50 years (collaboration with PhD Porsche, IOW). The new calibration will then be applied on the multi-corer and long core data. However, with applying the new calibration, just the absolute values will change slightly and not the trends/ temperature gradients. The likely summer temperature reflecting data (Adolphi 2010) reveal a clear change of 3-4°C between the cold Little Ice Age phase and the Medieval Warm Period (not shown) and Modern Warm Period, respectively (Fig.7). Please note the parallel appearance of lamination in the Gotland Basin sediments.

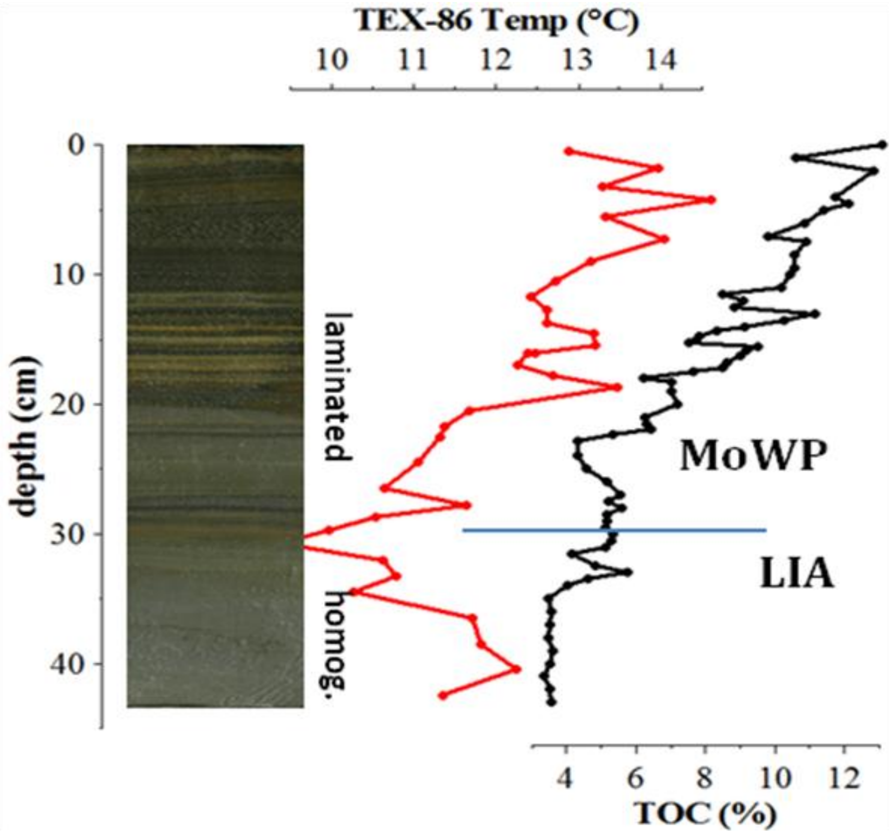



**Fig 7.** TEX-86 SST temperatures, TOC content, photo vs. depth of multicore 370531.

Loss on ingnition (LOI) measurements on multi-corer and long cores from about 40 sites (IOW: Kattegatt, Mecklenburgian Bight, Arkona Basin, Bornholm Basin, Gotland Basin, Northern Central Basin, western Gulf of Finland; GTK: eastern Gulf of Finland) were finished in 2009 and 2010. Parallel total organic carbon (TOC) measurements were performed to allow a conversion LOI to TOC. The results of the Gotland Basin cores are shown in Fig. 8. Note the nice similar pattern in all cores.

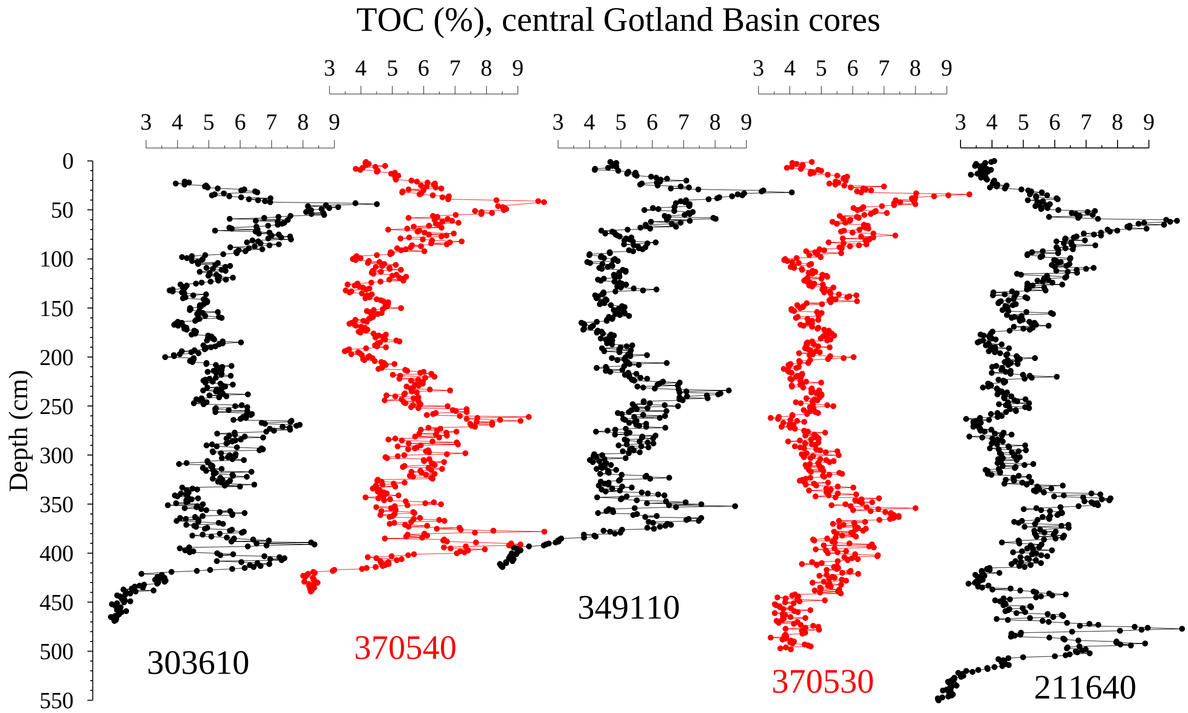



Fig. 8. TOC (%) versus depth from selected the central Gotland Basin cores.

*Diatom analyses (Szczecin)*

Preparation of transfer function (IKM) has been completed. Tests of the method are in progress.

*Eastern Gulf of Finland studies (Ryabchuk, D., Zhamoida, V., Grigoriev, A., Spiridonov, M., Sergeev, A., Sivkov, V., Dorokhova, E., VSEGEI)*

Detailed study of core 09-BI-3, recovered from the local sedimentation basin in Vyborg Bay ($60^0$17,506 N, $28^0$03,405 E, depth 40 m) has a great importance for understanding of the Late Pleistocene – Holocene geological history of the region. Visual description of the core enabled to distinguish three major lithostratigraphic units: brownish-grey badly laminated clay corresponded to the Baltic Ice Lake period (the core depth of 129-246 cm), grey, sometimes black, silty clay with black micro-inclusions of amorphous iron-sulphides presumably formed during the Ancylus Lake period (the core depth of 104-129 cm), and laminated, olive-grey, silty-clayey sediment accumulated during Littorina and Post Littorina stages (the core depth of 96-0 cm). At the core depth of 96-104 cm there is a very special sediment layer called “blue clays”, which is rarely observed in the sediment sequence of the Eastern Gulf of Finland, and it is poorly studied from palaeoenvironmental point of view. The upper core interval (6-0 cm) is represented by unsorted clayey-silty-sandy sediment containing spheroidal Fe-Mn concretion up to 2 cm size. According to our previous investigations of concretions growth rate the age of spheroidal concretion of 2 cm diameter is in the range 650-820 years. Accordingly silty-clayey sedimentation was changed in this area for non-sedimentation conditions at least 650-820 years ago. Grain-size and chemical analyses allowed receiving information on sediment dynamics and water salinity in the north-western sedimentation basin of the Russian part of the Eastern Gulf of Finland (Fig.9). In particular our data suggest four significant salinity maxima during the Littorina Sea - Post Littorina stages including initial Littorina transgression.

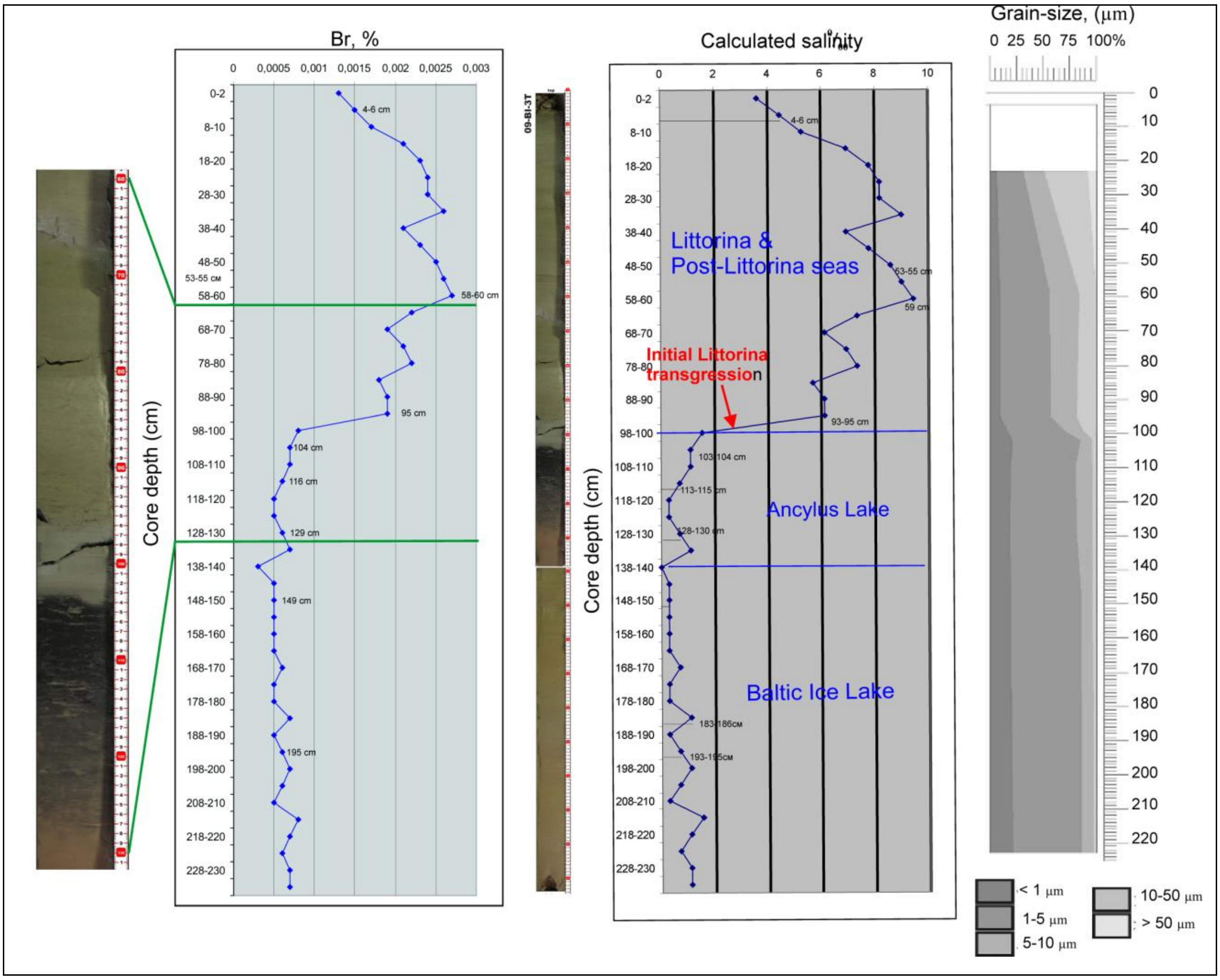



Fig. 9. Preliminary results of proxy study of the sediment core 09-BI-3 (the eastern Gulf of Finland).

The preliminary surface sediment dating analysis of Site F40 core (one of INFLOW key-sites) allowed establishing the most significant events of Middle and Late Holocene history of the eastern Gulf of Finland. Distribution of Br concentration (which will be recalculated to salinity values, after analyses of organic matter concentration) and grain-size distribution have shown such events as

- beginning of the Littorina transgression;
- six sub-cycles (transgression-regression) within Littorina Sea;

- the onset of the Neva Riva;
- Medieval warming;
- Little Ice Age (Fig.10).

The preliminary dates of these events were estimated using linear sedimentation rates. The joint study of VSEGEI data together with the laboratory results of the other INFLOW partner's studies will permit to define date these events correctly.

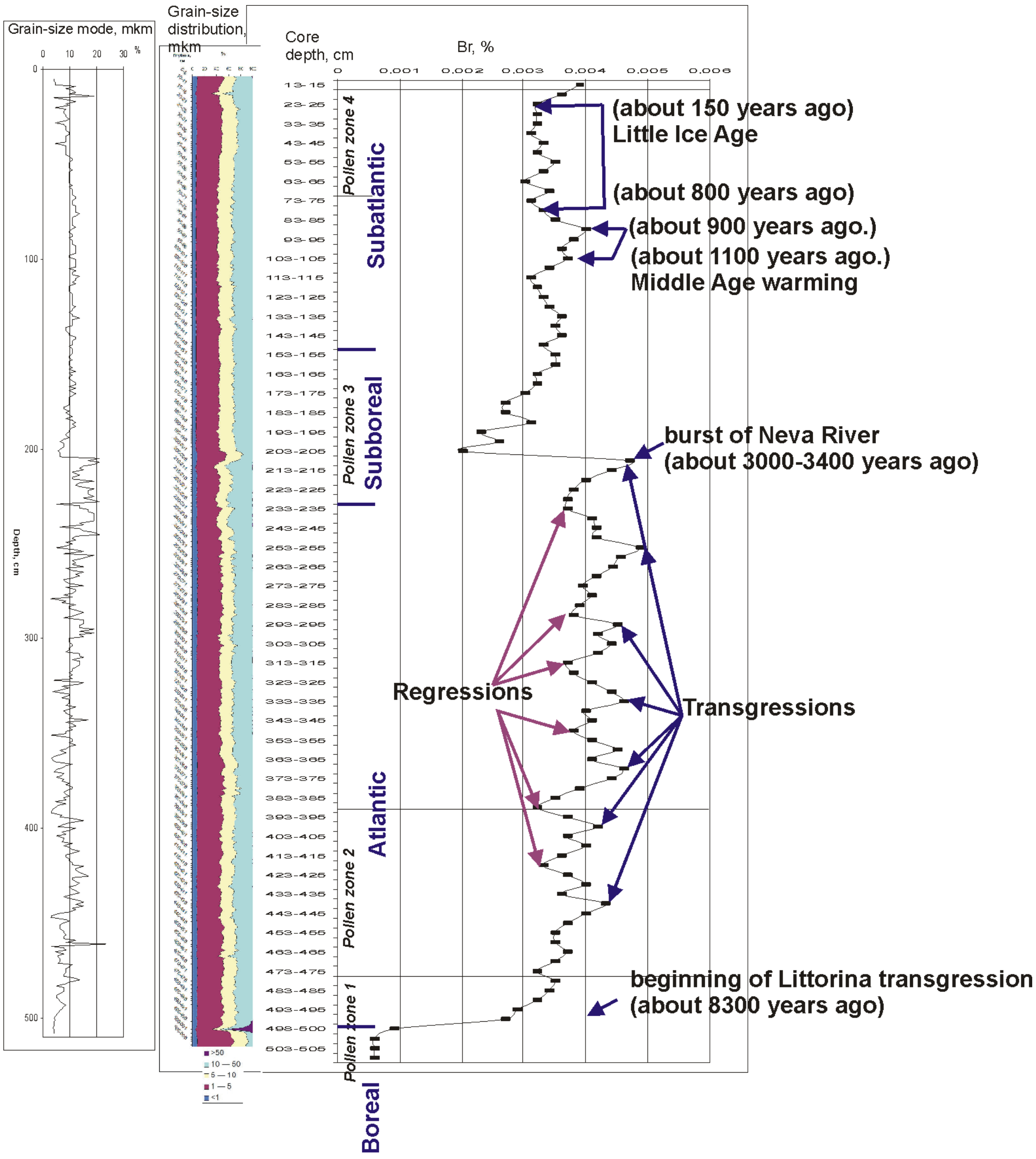



Fig.10. Preliminary results of F40-core analysis.

Upper unit of the core (0-50 cm) is represented by dark olive grey clayey silt (the average content of clay particles is 47.3%, silt particles – 52.6%). There is no sand except of upper horizons (5-7 cm), where sand particles value reaches 1.62%. The next sediment unit (50-205 cm) consists of laminated olive gray clayey silt, bioturbated in the interval 148-167 cm. The average content of clay is 44%, silt - 46%, sand – 0.004%.

At the core depths of 205-212 cm there is a layer which upper part differs from the lower part of sequence by grain-size distribution. Coarse particle content increases to 63.4% for silt, and 0.44% for sand.

Sediment unit at the core depths of 212-249 cm is represented by dark olive grey laminated clayey silt with average content of clay particles 45.1% and silt particles 54.9%. Within upper (212-221 cm) and lower (242-249 cm) subunits there are no sand particles, but in the middle part average sand content grows to 0.35%.

Within the unit of laminated very dark olive grey clayey silt from the core interval of 249-391 cm, average clay content is 47.6%, silt – 52.3%, sand – 0.13%. The next unit at the core depths of 391-495 cm is represented by dark olive grey partly laminated clayey silt (48.5% of clay, 51.4% of silt, 0.13% f sand).

The unit at the core depths of 495-500 cm characterizes the "border" between Littorina Sea and Ancylus Lake. The content of clay particles decreases from the top of the unit to the bottom of the unit from 50.9% to 32,7%, silt - from 47,6% to 26,5%, content of sand particles increases from 2.45% at the depth 4.95-4.96 m to 40.8% at the depths 4.99-5.00 m). Thus the average contents of clay, silt and sand are 45.0%, 41.2%, and 13.8%, respectively.

Sediments of Ancylus Lake (down 9 cm of the core - interval 500-509 cm) differ from the Littorina and postLittorina deposits, as they are represented by brownish grey silty clays with 65.5% of clay particles and 35.5% of silt, and with no sand.

Analyses of grain-size (hydraulic size) mode (left graph, fig.10) have shown that sediments of Ancylus Lake were formed without active hydrodynamics impact. Sedimentation environment during forming the deposits between the core depths of 205-500 cm was active and variable. During the deposition of sediments at the core depths between 40 and 205 cm, hydrodynamic conditions were much calmer. The upper part of the sediment core was formed under the influence of near-bottom currents again.

The most interesting results were received using analyses of the trend of Br-concentration changing (right graph, fig.10). It will be recalculated to near-bottom water salinity using the results of organic matter content. The trend of Br concentration shows a drastic change (increase) of water salinity at the depth 495-500 cm, which is interpreted as the onset of the Littorina transgression. Six distinct alterations of Br-concentration occurred in the interval of 205-495 cm, which can possibly be interpreted as the transgressions and regressions of the Littorina Sea. This data will be analyzed and validated together with the results of the other INFLOW partners.

At the depth 205-212 cm there is a drastic significant decrease of Br-content, which can be interpreted as the onset of the Neva River (see also the results of mineral magnetic and sediment fabric analyses shown in figures 2 and 6). In the post-Littorina sediment sequence it is possible to find peaks that can be explained as Medieval Warming and Little Ice Age.

The dates of events were preliminary estimated using the linear sedimentation rate between modern surface (the strong increase in the $^{137}$Cs activity in the sediment core at the depth of 6 cm corresponds to the fallout of the Chernobyl nuclear power plant accident of the year 1986, pers comm. Henry Vallius/GTK) and the onset of the Littorina transgression that was estimated approximately 8300 years ago. Later these dates will be corrected according to 14C and OSL-dating.

Received results have a great importance for palaeogeography of the Eastern Gulf of Finland as there is no uniform opinion about time and number of Littorina transgression.

As for the timing of the onset of Neva River, according to many scientists (Sevastianov et al., 2001) it is still one of the most interesting and unclear questions of Holocene geological history in spite of many research and publications (Kvasov, 1979; Saarnisto, 1996; Subbeto et al., 1998). According to most part of scientists, this event took place in Middle or Late Holocene, 4000-4500 years ago according to A.Yakovlev and U.Ailio (1926), 2000 years ago according to O.Znamenskaya et al. (1970), 2300-1300 years ago according to D.Kvasov (1979), and 3100 years ago according to M.Saarnisto (1970; 1996). Besides there is another point of view, supported by some specialists (Verzilin et al., 2003) the Neva is much “older” and formed in Pleistocene. It should be mentioned that all data for these hypotheses were received on-land. Sediments of the Eastern Gulf of Finland have never studied from this point of view.

Results received in the range of the INFLOW project will help to solve the problem of the onset of the Neva Riva, and the palaeoenvironmental history of the Gulf of Finland

*Geochemical (EDX) studies of the Gotland Deep cores (GEUS)*

Results show, amongst others, peak values in the concentration of both the element Cu and Mo during the Medieval Climate Anomaly (MCA) with a drastic drop in level at near AD 1200. Elevated Cu values suggest enhanced (wind-induced, local upwelling) algal productivity during the MCA, whereas the maximum in Mo concentration may indicate post-springbloom nutrient (e.g. P) availability favouring cyanobacterial summer blooming in the Gotland Basin. The results agree with the 2009 findings for the Bornholm Basin (core 211630-9) revealing here enhanced marine influence and productivity (element Br) during the MCA until ca. AD 1200 when compared with the following 'Little Ice Age' interval.

Deliverable (D1.1) *High resolution age model for the past 6000 years* was produced as planned in FRP

References:

Saarnisto, M. Shoreline displacement of Lake Ladoga - new data from Kilpolansaari // Hydrobiologia. – 322. – 1996. – P. 205–215.

Sevastianov D.V., Subbeto D.A., Sikatzkaya E.D., Stepochkina O.E. Peculiarities of evolution of hydrographic network of Ladoga Lake basin in Holocene// Vestnik St. Petersburg University, 2001, series 7 (Geology, Geography), N 1 (in Russian).

Subbeto D.A., Davydova N.N., Rybalko A.E. Contribution to the lithostratigraphy and history of Lake Ladoga// Palaeogeography, Palaeoclimatology, Palaeoecology. 1998. Vol.140.

Verzilin N.N., Kalmykova N.A. Features and reasons of the water level change in Ladoga Lake during Holocene// Vestnik St. Petersburg University, 2000, series 7 (Geology, Geography), N 1, pp. 15-22 (in Russian).

**Work package WP2. Modelling approach**

Participating Institutes: IOW, SMHI

In the WP2 hydrographical and biogeochemical condition for historical time slices, a contemporary time slice, and future scenarios will be simulated. The ecosystem models will be forced with the climate of extreme conditions from the past 6000 years. These model experiments will give insight into what extent the ecosystem responds to past natural climate variability and environmental change. Comparison with the simulated contemporary and future status allows relating the expected changes to conditions in historical times.

**Task 2.1.: Forcing function – Activities 2010:**

*Forcing data for time slice experiments*

- Based on the delta-change approach a forcing data set for the LIA (Little Ice Age, Maunder minimum from 1657 to 1704) has been reconstructed.
- In co-operation with the BONUS-ECOSUPPORT project transient simulations have been performed for a future climate (1960-2099) using RCAO/ECHAM5-A1B_3, RCAO/ECHAM5-A1B_1, RCAO/ECHAM5-A2 and RCAO/HadCM3-A1B.
- The downscaling of ECHO-G data using RCA3 for the Baltic Sea Region for 950-1849 has been finalized.
- A statistical model has been developed to calculate runoff and sea level data from the output of the regional climate model for both future scenario simulations and and the long past climate simulation.

**Task 2.2.: Time slice experiments:**

*Simulation of the Baltic Sea ecosystem*

- Both involved ecosystem models for the Baltic Sea, RCO-SCOBI and ERGOM have been set up for the simulations.
- Calibration and validation of the model systems have been finished.
- A sensitivity study has been performed to assess the model's response to changing forcing.
- Simulations for a future climate are in progress in a common effort with the BONUS-ECOSUPPORT project.

**WP2 Results**:

The validation of the model was done by the comparison of the reference model results with instrumental data for the time period of 1961 to 2007. The instrumental data sets consist of up to 4 million single values depending on the particular parameter (fig. 11a), which were adapted to the model's spatial and temporal resolution. Results of the validation are shown in figure 11b. The data were standardized before analysing. The spearman rank correlation coefficient of phosphate, oxygen, salinity, and temperature is in the range of about 0.8 and 0.95. For these parameters, the ratio of the standard deviation is nearly one or something less and the deviation in the centred RMS is about one half of the standard deviation.

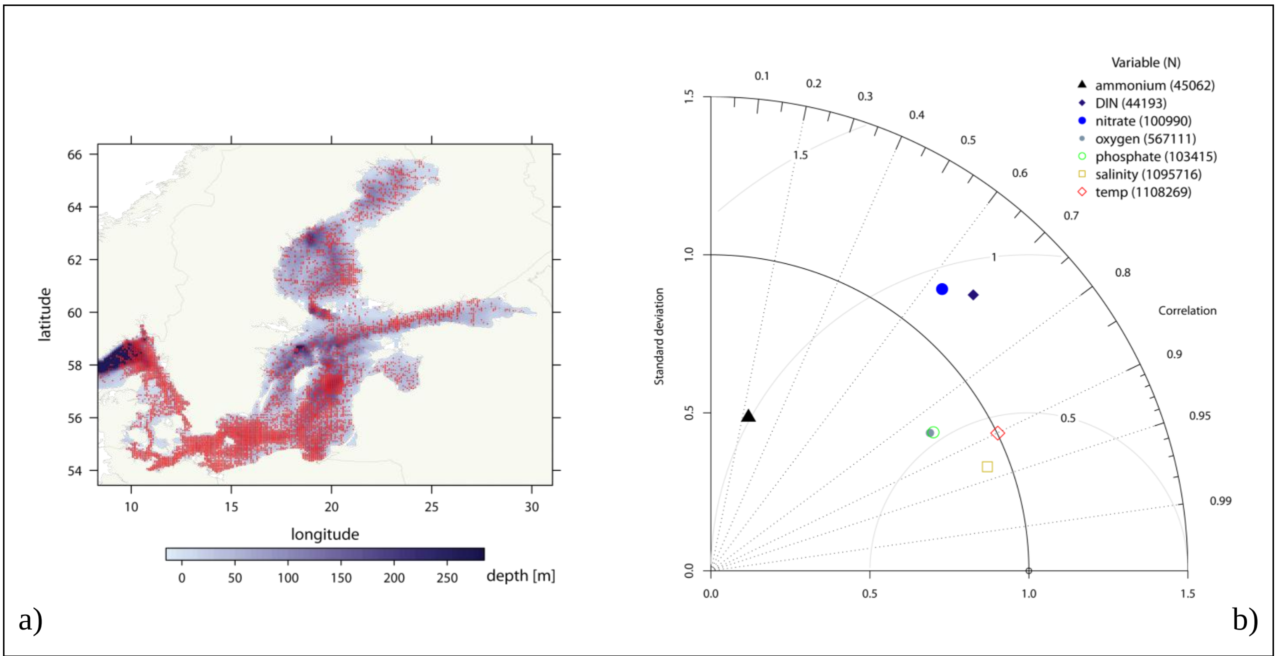
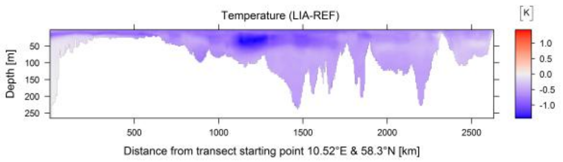



Figure 11. a) Location of the salinity measurements. b) Taylorplot, showing a summary of some statistical results.

For the Little Ice Age period (Maunder minimum from 1657 to 1704) an ensemble simulation with 4 members has been performed. Change signals for several model variables along a transect (see fig. 13) are shown in figure 12. The water temperature decreased according to the reduction of the atmospheric temperature while the salinity increased about one PSU in the whole Baltic Sea. The oxygen concentration increased up to 4 ml · $l^{-1}$ in depths greater than 50 m, which is likely a result of the lower temperature and the reduced nutrient loads. In the deeper parts of the Baltic Sea ammonium is reduced while nitrate increases. This reflects the oxygen conditions in the deeper part of the Baltic Sea. Phosphate is reduced in the whole Baltic Sea, especially in the deeper areas.

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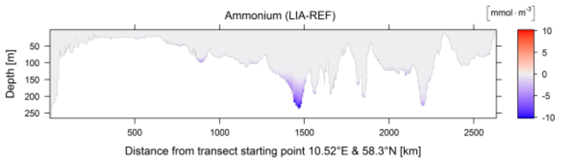


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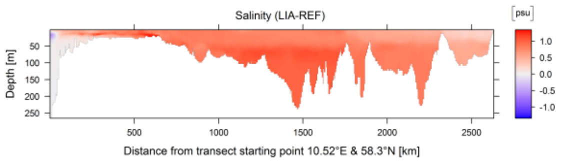


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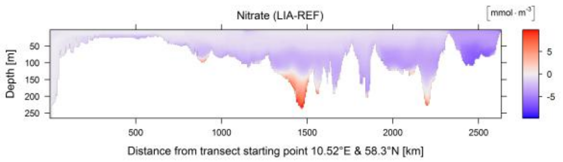


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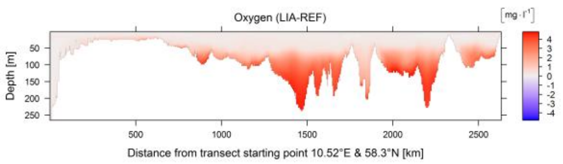


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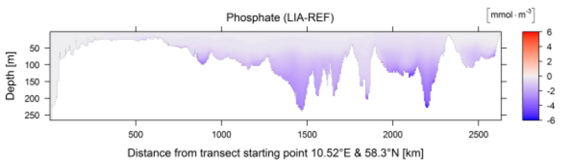


f)

Figure 12. Change signals estimated from the ensemble mean of a) temperature, b) salinity, c) oxygen, d) ammonium, e) nitrate, and f) phosphate along a transect through the Baltic Sea (see fig. 13)

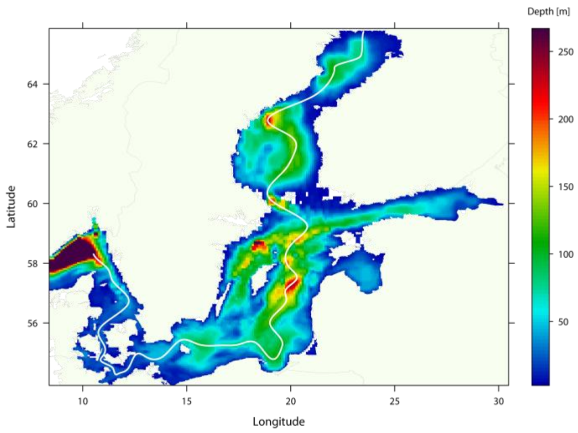


Figure 13. Map of the Baltic Sea model topography. The white line shows the transect, which was chosen for statistical analysing.

Future scenario simulations for 1961-2099 have been performed (Meier et al., 2011). Results for temperature changes from RCO-SCOBI are shown in Figures 14. Independently of the applied model we found the largest temperature changes in the Bothnian Bay and Bothnian Sea during summer. The increased water temperatures cause decreased oxygen concentrations in the entire water column (not shown) because the oxygen saturation concentration decreases with increasing water temperature. As the bottom water is ventilated by surface water on a decadal time scale, also the bottom oxygen concentrations will decrease in future climate with up to 2 ml/l in a A1B scenario. However, the bottom oxygen concentration will not decrease in areas where the stratification is decreasing due to increased freshwater supply from the rivers. These areas are for instance regions where the permanent halocline hits the topography in present climate.

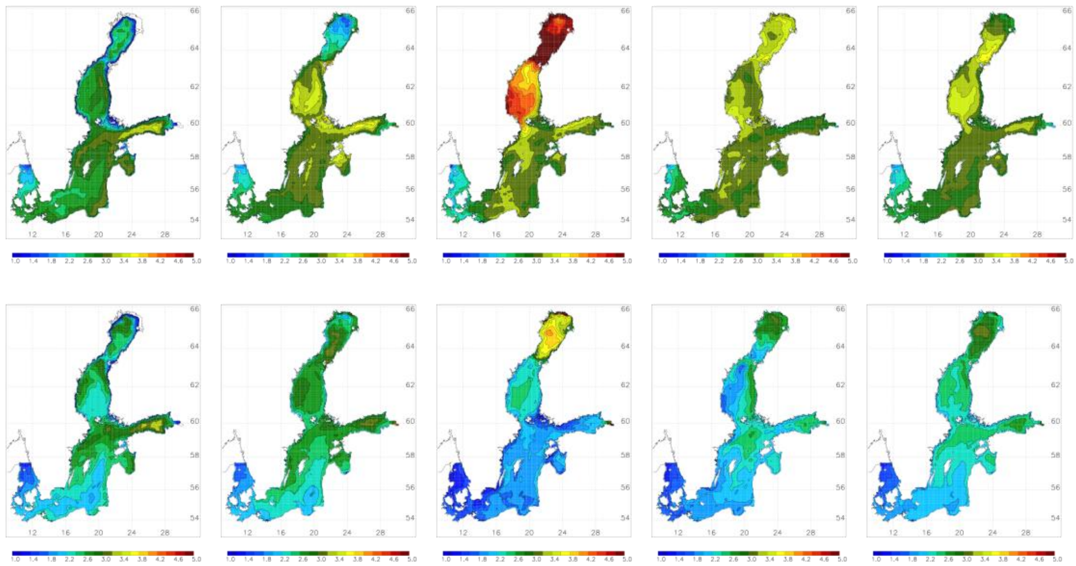

Figure 14. Annual and seasonal mean sea surface temperature changes (in°C) between 2070-2099 and 1969-1998 in RCO-SCOBI forced with RCAO-HadCM3_ref A1B_3 (upper panels) and RCAO-ECHAM5 A1B (lower panels). The columns show from left to right winter (December through February), spring (March through May), summer (June through August), autumn (September through November) and annual mean changes, respectively.

First steps have been made towards an uncertainties assessment of climate projections for the Baltic Sea. In figure 15, the sea surface temperature based on a 3 member ensemble for the A1B scenario is shown. The ensemble members are based on one Baltic Sea model forced with different combinations of global and regional atmospheric climate models. As seen from Fig 15 the strongest changes can be expected in summer in the northern Baltic similar to the findings indicated in Fig 14. The lower panels in Fig 16 show the range of the ensemble simulations, that means the difference between the maximum and minimum of the ensemble realisations. Largest uncertainties appear in summer in the northern Baltic.

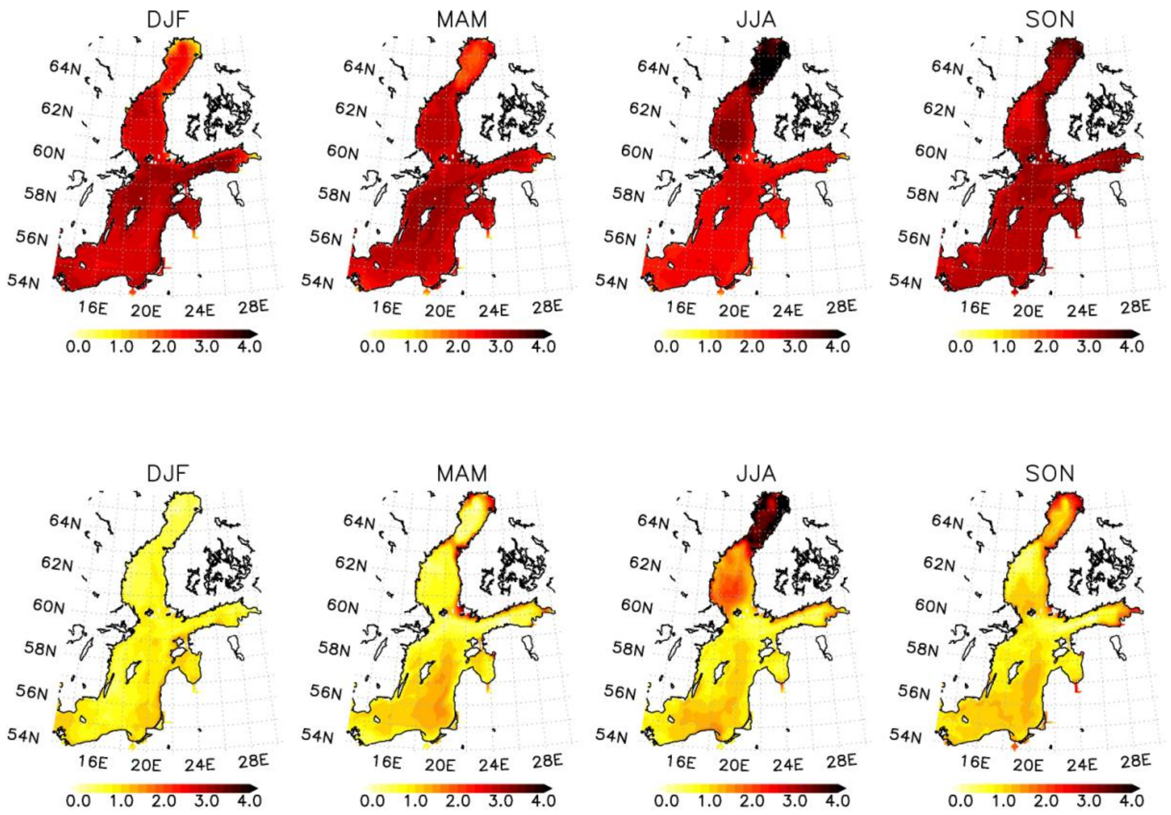


Figure 15. Upper panels show the sea surface temperature change between 2070-2100 and 1970-2000 based on an ensemble simulation of 3 members for the A1B scenario. In the lower panels the range of the ensemble simulation is shown. Each column of the figure represents a season.

The model results for future climate will be compared with model results from the Medieval Warm Period and the Little Ice Age. For this purpose a dynamical downscaling approach has been performed to generate atmospheric and hydrological forcing fields for the two coupled physical-biogeochemical models of the Baltic Sea, RCO-SCOBI and ERGOM. Using the regional atmosphere model RCA3 with a horizontal resolution of 50km data of the global model ECHO-G have been downscaled for the Baltic Sea Region for the period 950-1849. This very long simulation was finalized during 2010. Further, a statistical model has been developed to calculate monthly runoff and daily sea level elevation from the output of the regional climate model RCA3 for 950-1849. Results for air temperature and precipitation averaged over Sweden are shown in Figure 16. During the Medieval Warm Period, especially winter mean air temperature and winter mean precipitation are significantly higher compared with corresponding values during the Little Ice Age.

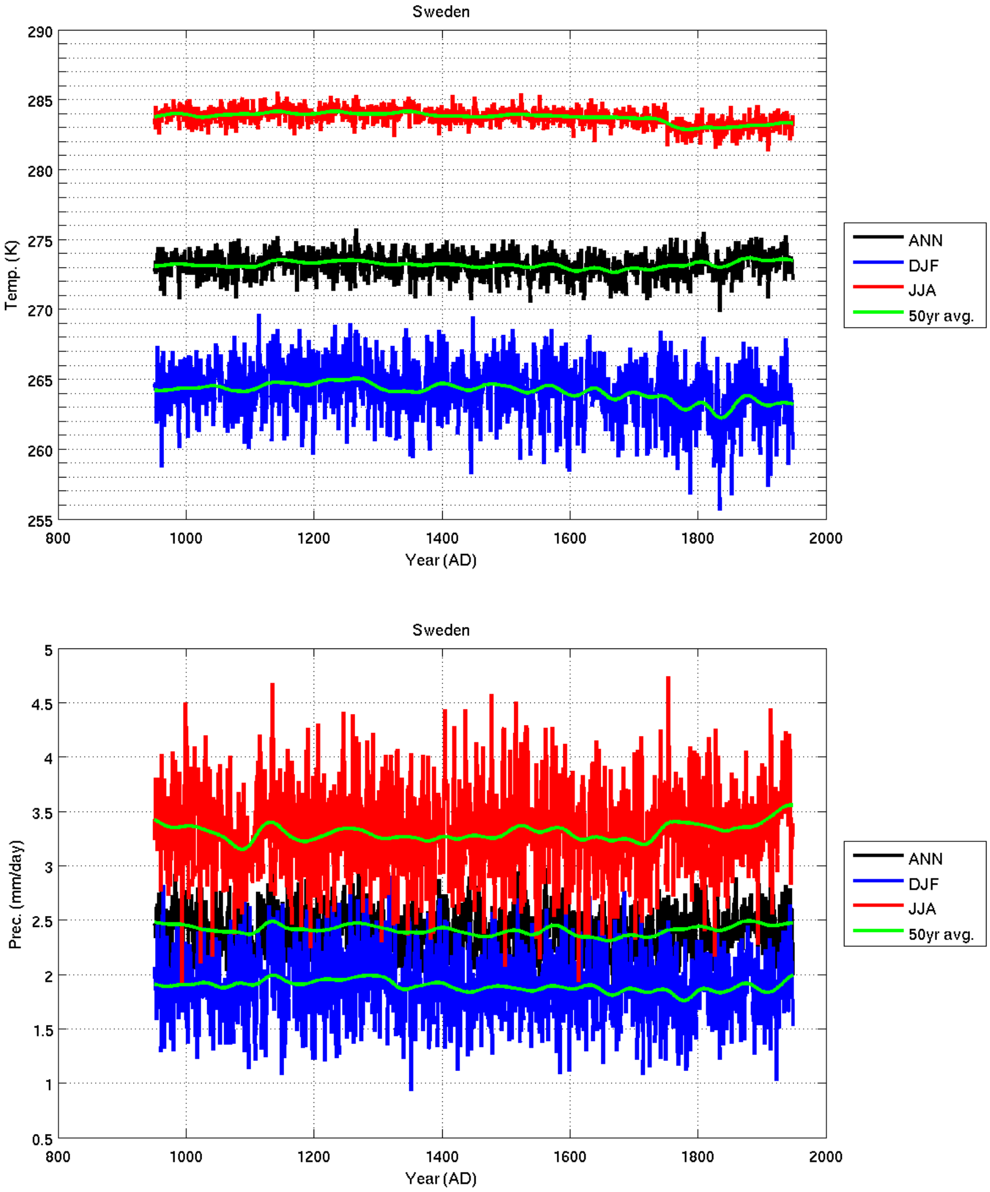


Figure 16. Area averaged 2m air temperature (in K, upper panel) and precipitation (in mm/day, lower panel) over Sweden for 950-1849: annual mean (black), summer mean (July through August, red) and winter mean (December through February, blue). The 50year running mean curves are shown in green.

Deliverable (D2.1.) *"Forcing data for time slice experiments"* was procuded as planned in FRP.

**Work package WP3. Synthesis**

Participating Institutes: all Partners.

Work will start early 2011 (see table 1).

**Work package WP4. Training and education.**

Participating Institutes: all Partners.

WP4 aims to educate students/researchers scientific knowledge, understanding, and multidisciplinary international cooperation in the Baltic Sea environmental issues for tomorrow's needs.

**Task 4.1.: Floating University**

Floating University was organized during the RV Aranda SEDU 2009 Cruise 22.-29.4.2009. For more detailed information see INLOW Interim Reports 1 (Kotilainen et al. 2009) and 2 (Ryabchuk and Kotilainen 2009).

**Task 4.2.: Workshops**

Altogether three workshops were organized in 2010:

- INFLOW Annual Meeting (and workshop), Vilnius, Lithuania, 19$^{th}$ January 2010 (GTK)
- INFLOW workshop, Małkocin, Poland, 18$^{th}$ – 20$^{th}$ June 2010 (Szczecin University)
- INFLOW workshop in the range of 10$^{th}$ Baltic Marine Geological Conference, St.Petersburg, Russia, 27$^{th}$ August 2010 (VSEGEI).

**Task 4.3.: Outreach**

INFLOW Partners disseminated the project actively during 2010. Altogether 12 articles were published. In addition to that altogether 27 conference and seminar presentations as well as invited lectures were given.

**Articles/publications:**

Arppe, Laura._Interviewed by "X-Veikkauksen asiakaslehti" about research within the INFLOW project. "Alkueliön jäljillä", X-Veikkauksen asiakaslehti 1/2010, pp. 36-37.

Grigoriev A., Zhamoida V., Spiridonov M., Sharapova A., Sivkov V., Ryabchuk D. Late-glacial and Holocene palaeoenvironments in the Baltic Sea based on a sedimentary record from the Gdańsk Basin. Climate Research, Special Issue. Environmental change and socio-economic response in the Baltic region Editors: Andrzej Witkowski, Jan Harff, Eduardo Zorita (accepted).

Dellwig, O., Leipe, T., März, C., Glockzin, M., Pollehne, F., Schnetger, B., Yakushev, E. V., Böttcher, M. E., Brumsack, H.-J., 2010. A new particulate Mn-Fe-P-shuttle at the redoxcline of anoxic basins. *Geochimica et Cosmochimica Acta*, 74, 2010, 7100-7115.

Kotilainen, A., Kotilainen, M., Neumann, T., Snowball, I., 2010. INFLOW - Towards understanding the forcing mechanisms of environmental changes of the Baltic Sea and future scenarios. BONUS in Brief, November 2010, p. 8.

Leipe, T., Tauber, F., Vallius, H., Virtasalo, J., Uscinowicz, S., Kowalski, N., Hille, S., Lindgren, S., Myllyvirta, T.,2010. Particulate organic carbon (POC) in surface sediments of the Baltic Sea. *Geo-Marine Letters* doi:10.1007/s00367-010-0223-x

Meier, H.E.M., A. Höglund, R. Döscher, H. Andersson, U. Löptien and E. Kjellström, 2011. Quality assessment of atmospheric surface fields over the Baltic Sea from an ensemble of regional climate model simulations with respect to ocean dynamics. Oceanologia, accepted.

Neumann, T., 2010. Climate-change effects on the Baltic Sea ecosystem: A model study, Journal of Marine Systems, 81, 213-224, doi:10.1016/j.jmarsys.2009.12.001

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Rößler, D., Moros, M., Lemke, W.. 2010. The Littorina transgression in the southwestern Baltic Sea: new insights based on proxy methods and radiocarbon dating of sediment cores. *Boreas*, doi: 10.1111/j.1502-3885.2010.00180

Virtasalo, J, Kotilainen, A., 2010. Hienosedimenttien kerrostumisesta ja pohjaeläinyhteisöjen toiminnasta Itämeren syvänteissä. Yhdistetyn sedimentologisen ja iknologisen analyysin mahdollisuuksia. Geologi 62, 140-146.

Virtasalo, J.J., Leipe, T., Moros, M., Kotilainen, A.T., 2011. Physicochemical and biological influences on sedimentary-fabric formation in a salinity and oxygen-restricted semi-enclosed sea: Gotland Deep, Baltic Sea. Sedimentology, doi: 10.1111/j.1365-3091.2010.01166

Virtasalo, J.J., Löwemark, L., Papunen, H., Kotilainen, A.T., Whitehouse, M.J., 2010. Pyritic and baritic burrows and microbial filaments in postglacial lacustrine clays in the northern Baltic Sea. Journal of the Geological Society 2010; v. 167; p. 1185-1198

**Conference abstracts/presentations:**

Grigoriev A., Zhamoida V., Spiridonov M., Sharapova A., Sivkov V., Ryabchuk D. New data of the Gdansk Basin in the Late Pleistocene – Holocene according the result of investigations of the core-section #303700-7 (r/v Poseidon cruise) // Joint Baltic Sea Research Programme Annual Conference. Abstract volume, p.45. Vilnus, 2010.

Kotilainen, A., Arppe, L., Dobosz, S., Jansen, E., Kabel, K., Karhu, J., Kotilainen, M., Kuijpers, A., Lougheed, B., Meier, M., Moros, M., Neumann, T., Ryabchuk, D., Snowball, I., Spiridonov, M., Virtasalo, J., Witkowski. A., 2010. INFLOW: State of the art - high-resolution sediment cores covering the past 6000 years. In: Joint Baltic Sea Research Programme Annual Conference 2010, 19-21 January, 2010, Vilnius, Lithuania. Programme and Abstracts. 12.

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Kotilainen A.T., Ryabchuk D., Arppe L., Dobosz S., Jansen E., Kabel K., Karhu J., Kotilainen M., Kuijpers A., Lougheed B., Meier M., Moros M., Neumann T., Porsche C., Poulsen N., Risebrobakken B., Snowball I., Spiridonov M., Virtasalo J., Witkowski A., Zhamoida V., 2010. INFLOW project – providing new information on the development of the Baltic Sea over the past 6 ka and future scenarios. In: The Baltic Sea Geology – 10. The 10th International Marine Geological Conference. 24 – 28 August 2010, VSEGEI, Dt. Petersburg, Russia. Abstract volume, 56-57.

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Kuijpers, A., Seidenkrantz, M.-S., Knudsen, M.F., Jacobsen, B.H., Malmgren, B.A. (2010). Multidecadal to centennial North Atlantic SST fluctuations and NW European winter climate – colder in the coming 2-3 decades ?. Abstract Nordic Marine Science Conference, Strömstad, Sverige, 13-16 September 2010

Meier, H.E.M., Andersson, K. Eilola, R. Hordoir, and A. Höglund, 2010. New scenario simulations of the Baltic Sea ecosystem to support decision making. EUTRO 2010, Nyborg, Denmark, 14 - 18 June 2010.

Neumann, T., 2010. Climate change effects on the Baltic Sea ecosystem: a model study.
ICES ASC, 20-24 September 2010, Nantes, France.

Poulsen, N.E., 2010. Preliminary note on dinoflagellate cysts from the Bornholm Basin in the Baltic Sea. Joint Baltic Sea Research Programme, Baltic Organisations Network for Funding Science EEIG (BONUS), Annual Conference 2010, January 19th – 20th, Vilnius, Lithuania. (poster & abstract published in the Conference Proceedings www.bonusportal.org/files/635/Abstract_Booklet_Web.pdf)

Poulsen, N., Kuijpers, A., and Kunzendorf, H., 2010. INFLOW: Dinoflagellate preservation and saline bottom water inflow activity (past 2000 years) in the Bornholm Basin The Baltic Sea Geology-10, 24-28 August 2010, VSEGEI, St. Petersburg, Russia. Abstract volume p. 102

Ryabchuk D., ZhamoidaV., Grigor'ev A., Sergeev A., Spiridonov V., Kotilainen A., Virtasalo J., Vallius G., 2010. INFLOW project – the first results in the Gulf of Finland – detailed investigations of the bottom sediment cores. In: XI International Environmental Forum "Baltic Sea Day" : thesises collection. 22.-24.3.2010, St. Petersburg.

Ryabchuk, D., Zhamoida, V., Spiridonov, M., Leont'ev, I., Kolesov, A., 2010. Holocene and modern climate changes in the coastal zone of the Eastern Gulf of Finland - problems and first results of INFLOW project// Joint Baltic Sea Research Programme Annual Conference. Abstract volume, p.24. Vilnus, 2010.

Virtasalo, J.J., Leipe, T., Moros, M., Kotilainen, A.T., 2010. Formation of sediment fine structure in the Baltic Sea deep areas. In: Joint Baltic Sea Research Programme Annual Conference 2010, 19-21 January, 2010, Vilnius, Lithuania. Programme and Abstracts. 50.

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Witkowski, A., Dobosz, S., 2010. Towards a diatom-based transfer function for the Baltic Sea: I. Analysis of sediment-surface diatom assemblages." – poster presentation. JOINT BALTIC SEA RESEARCH PROGRAMME Annual Conference 2010, Abstracts book.

Witkowski A., Dobosz S., Changes in species composition of planktonic diatom assemblages along the salinity gradient of the Baltic Sea and its significance for paleoreconstructions. 21st International Diatom Symposium, 2010 St. Pauli, Minnesota, USA, Abstract book.

**Reports:**

Kotilainen, A., Virtasalo, J., Kabel, K., Leipe, T., Moros, M., Neumann, T., Porsche, C., Kuijpers, A., Poulsen, N., Rasmussen, J.P., Snowball, I., Lougheed, B., Meier, M., Strandberg, G., Dobosz, S., Witkowski, A., Jansen, E., Risebrobakken, B., Bodryakov, T., Grigoriev, A., Sergeev, A., Ryabchuk, D., Spiridonov, M., Zhamoida, V., Arppe, L., Kotilainen, M., Karhu, J., 2010. INFLOW Annual Report 2009. INFLOW Interim Report No 5 Espoo: GTK. 27 p. Electronic publication. Available at http://projects.gtk.fi/inflow/index.html .

Ryabchuk, D., Spiridonov, M., Zhamoida, V., Grigoriev, A., Sergeev, A., Kropatchev, Y., Kotilainen, A., 2010. INFLOW Cruise Report, FYTO 2009, the RV Ladoga 4.-7.7.2009. INFLOW Interim Report No. 6. St.Petersburg: VSEGEI. 14 p. Electronic publication. Available at http://projects.gtk.fi/inflow/index.html

**Lectures (and workshop presentations):**

Kabel, K., 2010. Reconstruction of Baltic Sea surface temperatures using Tex86 paleothermometry. Baltic Sea research Institute Seminar, 25.11.2010, Rostock, Germany.

Kabel, K. and INFLOW partners, 2010. The BONUS project INFLOW and planned foraminiferal research in the Skagerrak-Kattegat region. Workshop at Aarhus University, 2.2.2010-4.2.2010, Aarhus, Denmark (oral presentation).

Kotilainen, A., 2010. Marine geological research and mapping in Finland - a submarine view to the Gulf of Finland. Gulf of Finland Trilateral Meeting, 7.-8.12.2010, Helsinki, Finland.

Meier, H.E.M., A. Höglund, R. Döscher, H. Andersson, U. Löptien and E. Kjellström, 2010. Quality assessment of atmospheric surface fields over the Baltic Sea of an ensemble of regional climate model simulations with respect to ocean dynamics. BONUS+ program cluster workshop on "Uncertainties of scenario simulations", Norrköping, Sweden, 14 October 2010.

Meier, H.E.M., 2010. Impact of changing hydrography on biogeochemical cycles in future climates of the Baltic Sea (invited presentation). International workshop on ``Effects of climate change on the marine environment" organized by the Nordic Council of Ministers, Copenhagen, Denmark, 9-10 March, 2010.

Moros, M., 2010. The Baltic Sea as a recorder of Holocene climatic changes in the North Atlantic region. Australian National University Nov. 2010, Canberra. Australia. (talk)

Leipe T. and Moros, M., 2010. Sediments and Seabeds as archives of the Baltic Sea. 35$^{th}$ DEUQUA Conference Sept. 2010, Greifswald (oral presentation).

Leipe, T., Moros M., Tauber F., 2010. Sediments and seabeds as archives of the Baltic Sea history. In Eislandschaften in Mecklenburg-Vorpommern editors: Lampe R and Lorenz S., Excursion guide. 35$^{th}$ DEUQUA Conference Sept. 2010, 164pp.

Ryabchuk, D., 2010. Lecture to the students of Russian State Hydrometeorological University (RSHU)

Sławomir D., 2010. Presentation of Phd thesis assumption in frame of Faculty of Geoscience Council meeting. University of Szczecin, November 2010.

**Finalized Master / Diploma Thesis within INFLOW**

Adolphi, Florian, 2010. Holocene temperature reconstruction in Baltic Sea sediments for the last 2000 years, using the biomarker TEX86. Diploma Thesis, The faculty for Geosciences, Geoengineering, and Mining, Technical University Bergakademie Freiberg. 92pp.

Alenichev, Alexey, 2010. Paleoreconstruction of sedimentation environment in the Eastern Gulf of Finland during Late Pleistocene – Holocene. Baccalaurean thesis. The Geological Faculty, Department of Marine Geology, St. Petersburg State University, Russia.

Jentzen, Anna, 2010. Benthic foraminifera-based reconstruction of Palaeoenvironmental changes in Skagerrak and Kattegat during the last 500 years. Master Thesis. Ernst-Moritz University Greifswald, Institute of Geography and Geology, Greifswald. 94pp.

**Other**

Crown prince of Denmark visit in October 2010 (see INFLOW homepage) – news and brochure

Lougheed has constructed and maintained an online Baltic Sea Radiocarbon Database, information accessible via:
**http://www.geol.lu.se/inflow/**

**Collaboration with other BONUS projects**

- ECOSUPPORT: close co-operation in modelling
- BALTIC GAS:
  - The INFLOW Partners (BLO, JVV) participated in the R/V Maria S. Merian "BONUS Baltic Gas project" cruise to the northern Baltic Sea in July-August 2010. Cruise was organized by the IOW
  - Providing expertise for Site selection (ALE, JVV)
- HYPER: key-core samples were measured at Lund University for biogenic opal (D. Conley)

**Summary:**

Year 2010 was busy and INFLOW Partners have continued sediment proxy studies and modelling work. Despite the fact that we are just starting the last year of the INFLOW project; several important results have been achieved. Top 3 highlights of 2010 for the project are:

- Sediment biomarker TEX-86 based sea surface temperature estimates reveal a clear change of 3-4°C between the cold Little Ice Age (LIA) phase and the Medieval Warm Period (MWP) and Modern Warm Period (MoWP), respectively. This natural temperature variability is much higher than expected, but also recorded in instrumental data since the 19th century.

- Atmospheric models suggest that during the MWP especially winter mean air temperature and winter mean precipitation are significantly higher compared to corresponding values during the LIA. For the LIA period (Maunder minimum from 1657 to 1704, delta change of 1K only) simulation shows decreased water temperature while the salinity increased about one PSU in the whole Baltic Sea. The oxygen concentration increased up to 4 ml $\cdot$ $l^{-1}$ in depths greater than 50 m, which is likely a result of the lower temperature and the reduced nutrient loads. This model experiment is validated by the sediment texture. In contrast to laminated sediments during the MWP and MoWP, burrow-mottled sediments were deposited during LIA, demonstrating healthier benthos in terms of higher species richness and functional complexity. In the deeper parts of the Baltic Sea, ammonium is reduced while nitrate increases. This reflects the oxygen conditions in the deeper part of the Baltic Sea. Phosphate is reduced in the whole Baltic Sea, especially in the deeper areas.

- Future scenarios were done in strong co-operation with the BONUS-ECOSUPPORT project. These scenario simulations for 1961-2099 (Meier et al., 2011) indicate the largest temperature changes in the Bothnian Bay and Bothnian Sea during summer. The increased water temperatures cause decreased oxygen concentrations in the entire water column because the oxygen saturation concentration decreases with increasing water temperature. As the bottom water is ventilated by surface water on a decadal time scale, also the bottom oxygen concentrations will decrease in future climate with up to 2 ml/l in an A1B scenario. However, the bottom oxygen concentration will not decrease in areas where the stratification is decreasing due to increased freshwater supply from the rivers. These areas are for instance regions where the permanent halocline hits the topography in present climate.

INFLOW Partners disseminated the project actively during 2010. Altogether 12 articles were published. Project partners have participated in several international and national conferences and workshops where altogether 27 presentations as well as lectures were given.

During the year 2010 one Diploma Thesis (Florian, A.: Technical University Bergakademie Freiberg, Germany), one Master Thesis and (Jentzen, A.: Ernst-Moritz University Greifswald, Germany) and one Bachelor thesis (Sergeev, A.: St. Petersburg State University, Russia) was finalized in the frame of the INLFOW project.

**This report is a product of the ”INFLOW” project.**

INFLOW (Holocene saline water inflow changes into the Baltic Sea, ecosystem responses and future scenarios) –project studies ongoing and past changes in both surface and deep water conditions and their timing by means of multi-proxy studies combined with state-of-the-art modelling approaches. INFLOW uses sediment proxy data on a transect from the marine Skagerrak to the freshwater dominated northern Baltic Sea. The validated ecosystem models can provide simulated data for extreme natural climatic conditions over the past thousands of years (e.g. Medieval Warm Period, Little Ice Age). Proxy reconstructions will be compared to results from model simulations. These evaluated models will be used to provide predictions of the Baltic Sea ecosystem state at the end of the 21st century for selected IPCC climate change scenarios. Those scenarios of the future development of the Baltic Sea can form the scientific basis for political strategies adapting to future climate change.

INFLOW (2009-2011) is one of the BONUS research programme (http://www.bonusportal.org/) projects and it is funded by national funding agencies (e.g. Academy of Finland) and the EU Commission. Geologian tutkimuskeskus (GTK) coordinates the INFLOW project that has 9 partners in 7 countries of the Baltic Sea Region: Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Germany; Geological Survey of Denmark and Greenland (GEUS), Denmark; Lund University, Sweden; Swedish Meteorological and Hydrological Institute, Sweden; University of Szczecin, Poland; Unifob AS, Bjerknes Centre for Climate Research, Norway; A.P Karpinsky Russian Geological Research Institute (VSEGEI), Russia; Department of Geosciences and Geography, University of Helsinki, Finland.

**The INFLOW Report Series included following reports on 30th of January 2011:**

INFLOW Interim Report No. 1 “INFLOW Cruise Report, SEDU 2009, the RV Aranda 22.-29.4.2009”.

INFLOW Interim Report No. 2 “Floating University Report, the RV Aranda 22.-29.4.2009”.

INFLOW Interim Report No. 3 “INFLOW Cruise Report, FYTO 2009, the RV Aranda 3.-10.8.2009”.

INFLOW Interim Report No. 4 “High-resolution sediment cores covering the past 6000 years”.

INFLOW Interim Report No. 5 “INFLOW Annual Report 2009”.

INFLOW Interim Report No. 6 “INFLOW Cruise Report, the RV Ladoga 4.-7.7.2009”.

INFLOW Interim Report No. 7 “INFLOW Annual Report 2010”.

For more information on INFLOW –project see (http://projects.gtk.fi/inflow/index.html).