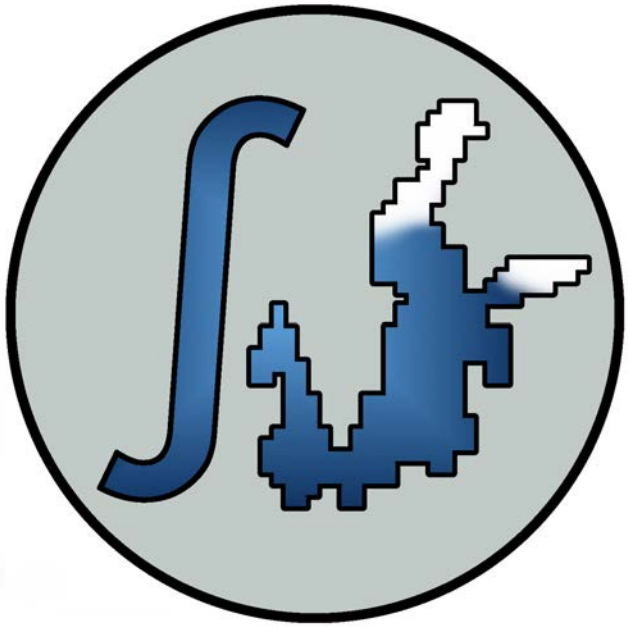
1 Project data

BONUS INTEGRAL

Integrated carboN and TracE Gas monitoRing for the bALtic sea



First Annual Report

Reporting Period: July 1st, 2017 to June 30th, 2018

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Partners: Leibniz Institute for Baltic Sea Research Warnemünde (IOW),
University of Uppsala (UU),
Finnish Meteorological Institute (FMI),
Institute of Oceanology of the Polish Academy of Sciences (IOPAN),
Tallinn University of Technology (TTU),
GEOMAR Helmholtz Centre for Ocean Research Kiel (GEOMAR),
Swedish Meteorological and Hydrological Institute (SMHI),
University of Exeter (UNEXE)

2 Scientific and technological results achieved during the reporting period

A.) INTRODUCTION

Several European nations are investing in the Integrated Carbon Observation System (ICOS). Finland, Sweden, and Germany are already partners of the ICOS ERIC with established infrastructure, while other countries like Poland and Estonia are currently in the process of developing their strategy. Although the overall aim of ICOS is to provide European-wide carbon dioxide and other greenhouse gas (GHG) concentration and flux data, an integration for the Baltic Sea region has not been pursued, and the added value of ICOS and related infrastructure for the Baltic Sea ecosystem assessment has not been exploited at all.

Within BONUS INTEGRAL, we will

- Integrate the different data streams of ICOS and related infrastructure in the pan-Baltic area,
- Provide better charts of seasonal carbon dioxide and GG flux over the Baltic Sea, including advanced remote sensing approaches,
- Integrate the carbon system into a high resolution 3D-model, which will contribute to a better description of the biogeochemical coupling of eutrophication and deoxygenation,
- Demonstrate the added value for a better biogeochemical ecosystem status description of the Baltic Sea,
- Advise the implementation of ICOS in the southeastern countries of the Baltic, and actively promote components strengthening the value for Baltic Sea ecosystem status assessment,
- Develop, in close interaction with stakeholders, strategies for a better, cost efficient monitoring approach for the Baltic Sea by integration of ICOS and related data.

The work plan is subdivided into 7 work packages. WP's 2-6 are related to the R&D program, WP1 to management of the project, and WP 7 to dissemination and outreach: WP1 Coordination and Management; WP2 Data mining, assimilation, integration; WP3 Infrastructure and observation amendments; WP4 Greenhouse Gas data integration, WP5 Flux parameterization and estimates; WP6 Carbon-based ecosystem assessment; WP7 Dissemination and outreach.

B .) WORK PACKAGE 1 - ORGANIZATION AND MANAGEMENT (Lead: IOW)

General Management and Work towards **Deliverable 1.1 (Web Pages), 1.2 (First Periodic Report), and 1.7 (Communications Plan)**

The BONUS INTEGRAL Kick-Off meeting took place from Sept. 5th to 7th, 2017 at the IOW, with representatives from all institutions present.

Over the first months of the project, key personnel was hired, or existing staff personnel resources were allocated for the project. Information about the staff involved in the project can be found on the project's web page under:
https://www.io-warnemuende.de/integral-partner.html

At the IOW, two PostDoc positions were filled (Dr. Anja Eggert, Dr. Jens D. Müller), both with some months delay. This delay was due to the fact that they were the most promising candidates, but had to fulfil some preceding job obligations, or finalize the last steps of the PhD-work. Both staff members already worked for BONUS INTEGRAL before being officially hired with project resources. An additional PhD-thesis (M.Sc. Erik Jacobs) was started at the beginning of the project to also avoid delay with respect to the work plan. The position will be complementarily funded by in-house resources of the partner IOW as an in kind contribution to the project. At UU PhD student Lucia Guiterrez Loca was hired in September 2017 (co-

funded by Uppsala University). Post-docs Gaelle Parard, and Shuping Zhang are hired with their jobs starting August 2018 (co-funded by the Swedish National Space Board). Professor Anna Rutgersson (PI) and research engineer Marcus Wallin are involved in the project, but paid by other funding sources (in kind).

FMI hired PhD-student Martti Honkanen to work part-time in the project in January 2018 after he was accepted in the Doctoral Programme of Atmospheric Sciences by the University of Helsinki. In addition, senior scientist Heidi Pettersson, PhD-student Jan-Victor Björkqvist, R&D engineer Sami Kielosto, senior scientist Milla Johansson and FMI PI Lauri Laakso have participated in the Bonus Integral project. At IO PAN, PostDoc Beata Szymczycha was hired at the beginning of the project, with a strong focus on WP2. PostDoc Przemysław Makuch was also hired part time at the beginning of the project; he is mainly involved in WP3. PI Karol Kulinski was also partly funded by the project. At TTU, the project personnel was hired among the research staff of the Department of Marine Systems by signing the amendments to their employment contracts where the share of time to be devoted monthly for the project was defined. Such amendments were signed by Villu Kikas (PhD), Germo Väli (PhD) and Natalia Fateeva (PhD). Professor Urmas Lips (PI) and PhD student Nelli Rünk are involved in the project but paid from other funding sources (in kind). GEOMAR has hired Post Doc Dr. Annette Kock from the beginning of the project. However, during the first year of the project Dr. Kock was on parental leave from September 10th, 2017 - May 16th, 2018. To avoid too much delay in the work plan, PhD-student Xiao Ma was hired with BONUS INTEGRAL resources from October 1st, 2017 - March 31st, 2018.

SMHI mainly uses personnel resources to compensate for the effort of in house staff members Dr. Kristin Andreasson, Anna Willstrand Wranne, and Johanna LInders.

The UNEXE hired Dr. Tom Holding (an early career researcher) as a junior post-doctoral researcher; Dr. Holding started work on February 5th, 2018.

The webpage of the project **(Deliverable Report 1.1)** was launched in October, and will be updated according to progress of the project. Frequent communication between the partners assured information and clarification at interfaces between the duties of different partners.

The advisory board was recruited with international experts renowned for their competence in fields representing the different aspects of the project. Vivi Fleming-Lehtinen from SYKE is a specialist on eutrophication and long-term changes in the Baltic Sea, with experience in the development of indicators and assessments as basis for decision making and management. She is vice chair of the HELCOM State & Conservation Working Group, and Chair of the HELCOM intersessional network on eutrophication (IN Eutrophication).

Annika Grage is responsible for eutrophication and nutrient assessment at the Bundesamt für Seeschifffahrt und Hydrographie, (BSH), which is the institution in charge of environmental monitoring in the Baltic and North Sea.

Werner Kutsch is Director General of the Integrated Carbon Observation System (ICOS), a European Research Infrastructure. He is by nature informed about all ICOS-related activities, and can advise many aspects of BONUS INTEGRAL, including management and dissemination strategies, potential synergies with ICOS or the related EU project RINGO (Readiness of ICOS, coordinated by Werner Kutsch). His scientific background is in greenhouse gas fluxes and underlying processes from terrestrial ecosystems

Mario Tamburri is professor at the University of Maryland and Director of the Alliance for Coastal Technologies and the Marine Environmental Resource center. As a “trained” marine biologist, he is now an expert for coastal instrumentation, technology transfer, and dialogue between scientist, technology developers, and stakeholders.

The first annual meeting of BONUS INTEGRAL took place in Helsingor from June 9th to 10th, 2018, organized by partner IOW as a pre-meeting of the 2nd Baltic Earth conference. The meeting showed a remarkable progress, which is reflected by a wealth of project-related

presentations given at the conference (see also Chapter 4). The meeting was also used to explain the work flow and decide on internal deadlines towards the 1st annual report **(Deliverable 1.2.).** It became apparent that all deliverables due in the first year of the project could be met before submission of the first annual report.

BONUS INTEGRAL did not foresee a Dissemination and Communication Plan **(Deliverable 1.7)**, which was requested by the BONUS EEIG after the negotiation phase, due to consistency considerations with the other funded projects. The Deliverable, with a somewhat flexible due date, was submitted in month 13, as several pursuable plans became clearer over the course of the first year. Notably, the project has an own Work Package (WP7) dedicated solely to dissemination and knowledge transfer.

C.) WORK PACKAGE 2 (Lead IO PAN)

The overall objective of WP2 is to identify and evaluate the quality of existing data on greenhouse gases (CO_2, CH_4 and N_2O) as well as on the carbonate system (AT, CT, pH) in the Baltic Sea. All the identified and quality-controlled data are to be published in the form of meta-data on the BOOS data platform, with easy-access links to the repositories of the real data.

Deliverable 2.1: Report on the existing data sets

The data on GHGs and accompanying carbon system parameters in the Baltic Sea has been identified within different activities running around the Baltic Sea. The compiled information on the data sources was prepared in the form of a metadatabase. Most of the existing data is stored in the databases like: MEMENTO, ICOS, COPERNICUS, SOCAT. Important data sources are also past BONUS projects like Baltic-C or Baltic Gas. Part of the data is available through the scientific literature, where the corresponding author is usually indicated.

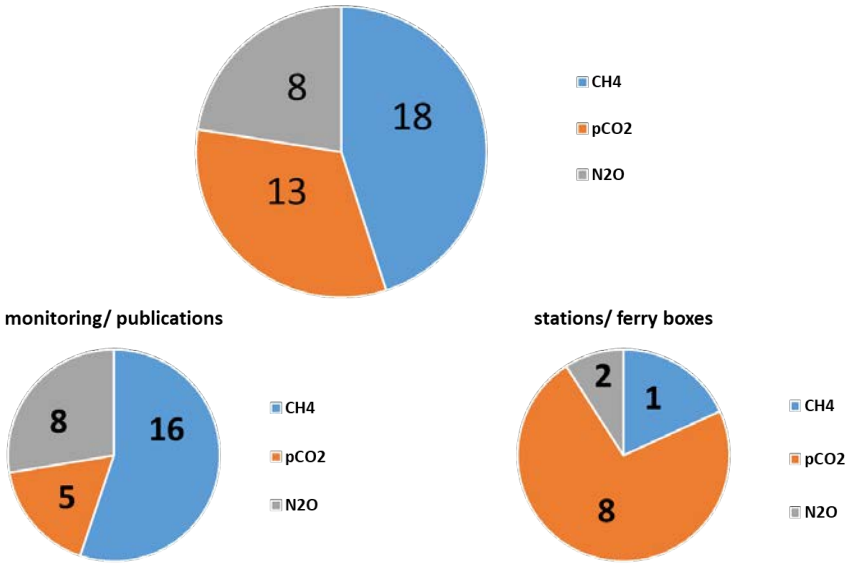

Figure 1: *Metadata files characterization. Upper panel presents compilation of all files. Lower left one refers to the non-continuous measurements (individual studies/publications or monitoring cruises), while the lower right to the continuous measurements on VOS lines or at monitoring stations.*

Altogether 33 metadata files were created (Figure 1). They can be approached either via the report from deliverable 2.1 submitted to the BONUS EPSS or via the online map (see deliverable 2.2). Each file contains information on:

- general description of the data set,
- data creation,
- last update of the data,
- keywords,
- study area,
- spatial extension,
- main parameters,
- auxiliary parameters,
- data location,
- data owner,
- contact person,
- data quality (only first assessment has been completed so far, the full assessment will be carried out within the BONUS INTEGRAL deliverable 2.3),
- data completeness,
- analytical method used for measurements,
- bibliographic data in the case of scientific papers.

A single file can have information on one or two or three GHGs and, if available, accompanying carbon system parameters (Figure 1). Most of the files (18) characterize CH_4 concentration in the surface water and water column, 13 files refer to pCO_2 in both atmosphere and surface water (some data include several depths in the water column), 8 files contain information about N_2O in seawater. Interestingly, only a few sites located in the Baltic Sea continuously monitor GHGs. This is performed with main focus on pCO_2. The vast majority of GHGs measurements are non-continuous events. They mostly refer to the related scientific cruises. Some of them are part of monitoring activities. However, the continuity of these activities in the future is not certain. Based on the evaluation of the existing data the conclusion can be drawn that there is a big lack of long-term measurements of GHG concentrations and fluxes in the Baltic Sea.

All the prepared metadata files have been delivered to the SMHI (BONUS INTEGRAL partner), who prepare for publishing the data on the BOOS platform, including a map search interface within deliverable 2.2.

Deliverable 2.2: Data identified and verified in the project published as meta-data on the BOOS- platform

To get an overview of the existing data on GHG and carbon measurements in the Baltic Sea, data has been identified and mined within the ICOS and ICOS-related activities running around the Baltic Sea. In addition, the mining was performed among the partners of the former BONUS and pre-BONUS projects such as Baltic-C or Baltic Gas, and within the MEMENTO database. We have also identified further potential data sources by reviewing both the existing literature published in scientific journals and the grey literature, such as technical or projects reports. We have also mined the data directly from the research and monitoring institutions, which might gather the data on GHG and/or carbon system locally in the Baltic Sea in the framework of their statutory activities or as part of small national funded projects. More information under the description of Deliverable 2.1.

The BOOS portal: BOOS (Baltic Operational Oceanographic System) is the Baltic branch of EuroGOOS, European Global Ocean Observing System, (http://eurogoos.eu/). EuroGOOS brings together 42 members from 19 different European countries that provide operational

oceanographic services and marine research. EuroGOOS coordinates five regional systems in Europe (Regional Operational Oceanographic System; ROOS), where BOOS is one of them. For the Baltic region, the BOOS collaboration is of importance to gather information and meta-data concerning oceanographic research and monitoring performed in the area in one place. The near real time in situ data acquired via the EuroGOOS members is channelled to Copernicus Marine Environmental Service (CMEMS) to be stored in a database. Copernicus is the EU initiative for space technology and the implementation of its policies, with three components: space, in situ, and services. Copernicus in situ relies on data from in situ monitoring networks (e.g. maps, ground-based weather stations, ocean buoys, and air quality monitoring networks) to provide robust integrated information, and to calibrate and validate the data from satellites.

The Copernicus in situ component is branched into CMEMS in situ TAC (Thematic Assembly Center for marine in situ observations within the Copernicus Marine Service), which integrates thousands of observing systems to provide a global picture of the 3D ocean state and ocean variability at different spatial and temporal scales. Collecting data in a database requires strong format standard definition and quality control procedures that are implemented by CMEMS in situ TAC.

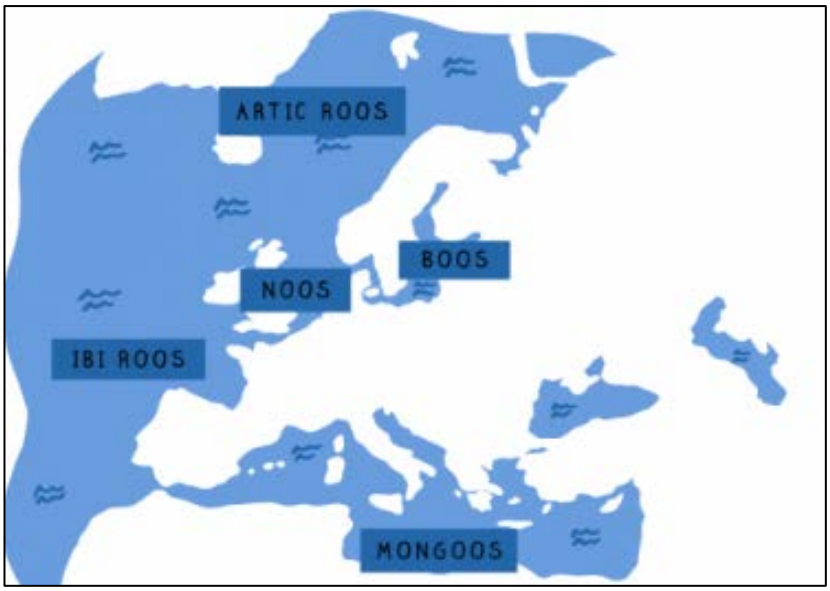

Figure 2. *Schematic overview of the five regional operational oceanographic systems in EuroGOOS.*

Graphical Interface Design – The BONUS INTEGRAL Map: After the implementation of the data mining of GHG and carbon system data in task 2.1 (Deliverable 2.1), the aim was to create a map which allows easy accessible information about where and when the GHG and carbon system data in the Baltic Sea region was gathered.

The metadata is manually collected in a excel file. A python script reads the metadata and generates a html-map. The python script is well commented, written, and run in the Jupyter interface, which enhances its capability to be used by less programming-experienced users. Theoretically, the script can be set up to run once a day/week to update the metadata map or manually when metadata is updated. The platforms used within WP3 of this project have been added to the database, and **the site will be continuously updated over the course of the project.**

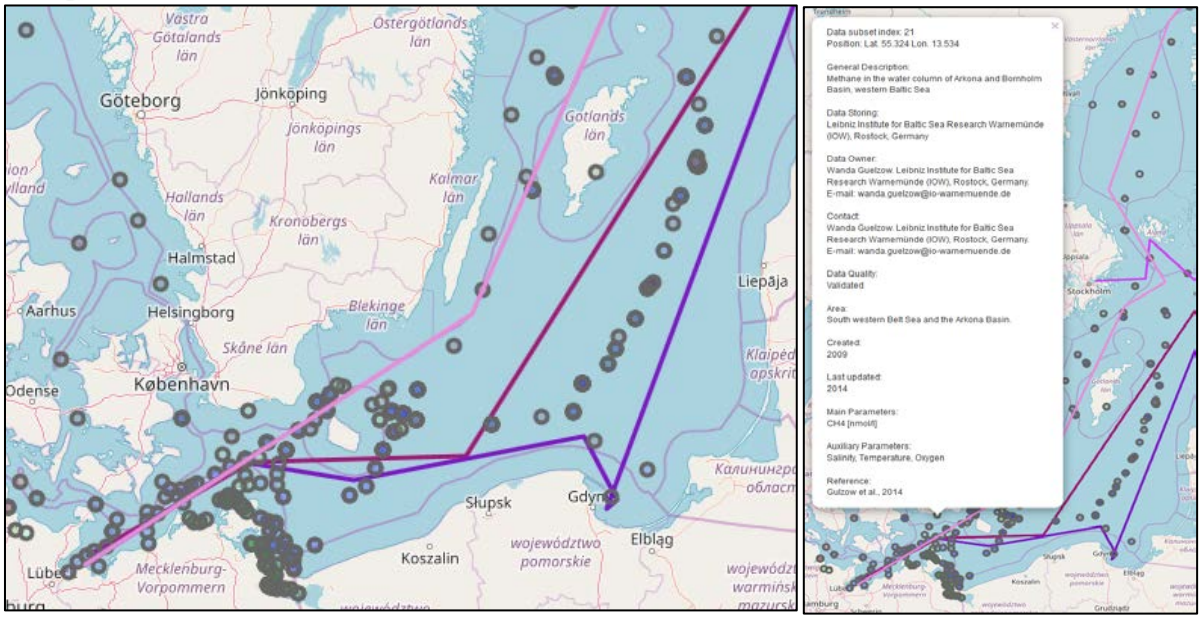

***Figure 3**. Example of the metadata map for GHG and carbon measurements on the left and metadata information from one of the measuring cites on the right.*

In the interactive map (Figure 3), the small circles are coloured differently on the interior depending on which gas measurement has been conducted; CH_4, CO_2 or N_2O. By clicking on a circle a metadata box appears, as shown above.

In order to make this information available to the research community, the aim is to add the map to the BOOS portal. Since BOOS is reconstructing its web page at the moment, the metadata information was put on both the BONUS Integral home page (https://www.io-warnemuende.de/integral-home.html) and the SMHI web page for the time being (https://www.smhi.se/en/theme/marine-environment-2-885). Direct link to the map:

https://www.smhi.se/k-data/oceanografi/The_BONUS_INTEGRAL_meta_data_map.html

As soon as the new BOOS webpage is finalized, the website will be moved. This is anticipated for the end of 2018.

Work towards Deliverable 2.3: Report on the historical data quality

Quality of the historical data will be evaluated for both data completeness and applied methodology. The scale that will be used for the quality assessment will be structured similarly to those previously used in other European projects, like e.g. in Jerico Next.

Until now, the data identified within deliverable 2.1 have been only roughly evaluated for quality. The full assessment will be done until the end of M18 and submitted in form of the report to the BONUS EPSS. The metadata will be updated accordingly.

D.) WORK PACKAGE 3 (Lead: IOW)

In order to get vital additional information on surface greenhouse gas concentrations and fluxes as well as carbon system data to support WPs 4-6, INTEGRAL will: provide several amendments to existing infrastructure, use its close relation/involvement in the HELCOM monitoring to effectively gain carbon system and trace gas data from selected monitoring stations, seek to execute two field campaigns on research vessels, and install a basic underway pCO_2 system on a coastal-near ferry line traversing the plume of the river Vistula.

The "base case" year for this additional efforts will be the 2nd year of the project, though installations for continuous measurements on the VOS-lines and permanent stations are foreseen to be operational until the end of the project and in most cases beyond. For individual platforms and locations, please refer to Figure 4.

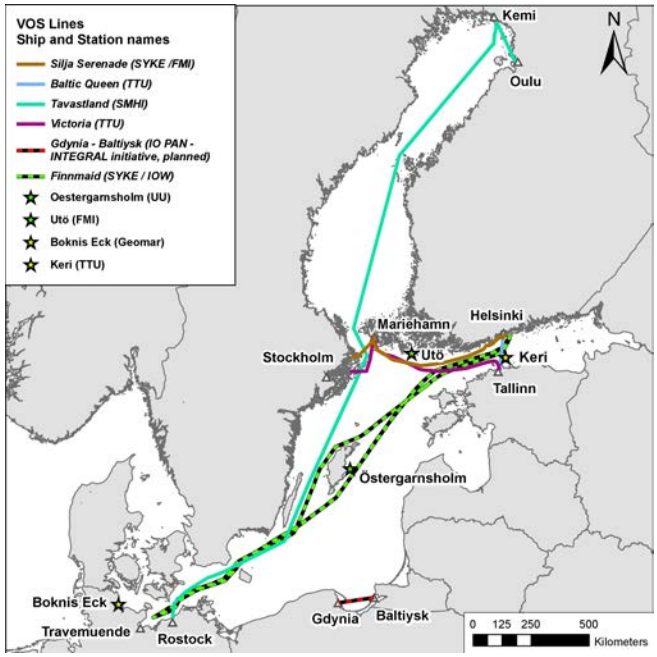

Figure 4: *Map of locations of infrastructure used within BONUS INTEGRAL. The stations Östergarnsholm, Utö, and VOS Finnmaid are part of ICOS. The line Gdynia Baltiysk (VOS Agat) is projected within BONUS INTEGRAL. All other infrastructure is established by other initiatives, but will be partially amended.*

Work towards Deliverable 3.1: Installation / operation of infrastructure amendments

VOS Finnmaid

The VOS Finnmaid has been operational and taking pCO_2 measurements since 2003, and pCH_4 measurements since 2010. The scientific effort is a joined effort between the Finnish Environmental Institute (SYKE) and IOW. Unfortunately, the system stopped its GHG measurements in the time frame from October 2017 to April 2018, because of a severe blocking of the seawater inlet by biofouling, which had to be removed through a diver operation; a task that was impossible to complete before spring. A current complete rebuild of the instrumentation with amendments to the measurement of pN_2O and $\delta^{13}C\text{-}CO_2$ is close to being finalized and expected to be installed in the 3rd/4th quarter of 2018. All the pCO_2 data since 2003 have been evaluated in order to characterize underlying biogeochemical processes. This work started before the project and was finalized as a contribution to the project, and published in a scientific monograph (Schneider and Müller 2018, see Chapter 7). The compiled data set is displayed in Figure 5. The assessment of the data is an important contribution to the dataset available for the goals of WP 4 and 5. Moreover, it clearly points to our current knowledge – and knowledge gaps – in connection to the controls on productivity, carbon uptake, and gas exchange, all of which is relevant for a state-of-the-art implementation of the carbon system in the biogeochemical model (WP6). Similarly, the eight years of pCH_4 data are currently compiled and interpreted for spatiotemporal variability and underlying controlling parameters as part of the Ph.D. thesis of BONUS INTEGRAL scientist Erik Jacobs.

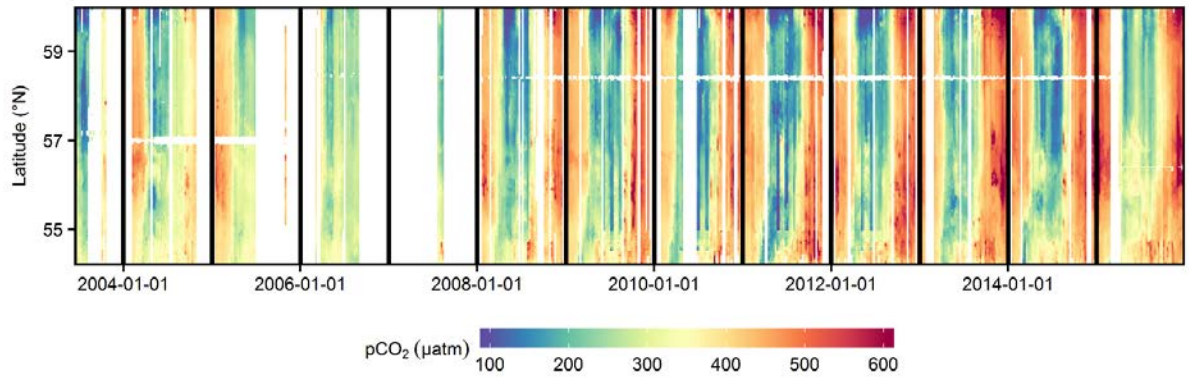

Figure 5: *Compiled pCO_2 data between 2003 and 2016 between Lübeck (lowest part of panel) and Helsinki (uppermost part of panel) gathered on VOS Finnmaid. For cruise track information, refer to Figure 4 (VOS Finnmaid). Plot from Schneider and Müller, 2018.*

VOS Tavastland

SMHI and the Finnish Environmental Institute, SYKE, installed a ferrybox on M/S Tavastland in 2009. The ferrybox measures salinity, temperature, oxygen, turbidity, chlorophyll fluorescence, phycocyanin fluorescence, and CDOM-fluorescence. There are two automated water samplers that can be used to collect reference samples. In 2010, a pCO_2 system from General Oceanic based on IR-absorption spectroscopy was purchased and installed next to the ferrybox. After years of problems with the system and sporadic data collection, it was finally fully operational in the fall of 2017 due to supportive efforts by the BONUS INTEGRAL project, and has been measuring continuously since.

Figure 6. *The cargo vessel Tavastland travelling between Umea and Lübeck.*

Time and position, and all parameters from the ferrybox system are part of the complete data set. The data from the ferrybox is transmitted to SMHI by satellite using the ftp-protocol every hour. The pCO_2 data is not yet transferred in near real time but work is ongoing to make this possible in the near future. So far, the pCO_2 data cannot be checked remotely, and are gathered during system maintenances approximately every 6 weeks, and the data is stored at the Swedish Oceanographic Data Centre at SMHI. The raw data is recalculated to pCO_2 with the in situ values for salinity and temperature from the ferrybox.

IOW and GEOMAR provide two off-axis ICOS CH_4/CO_2 and N_2O/CO sensors (Los Gatos Research, San Jose, CA) for the installation onboard VOS Tavastland to expand the existing measurement setup by continuous high-frequency measurements of methane and nitrous

oxide. For those parameters, the database in the Northern Basins is particularly scarce. The instruments are currently undergoing final laboratory tests at GEOMAR and will be ready for the installation onboard Tavastland in the 3rd quarter of 2018.

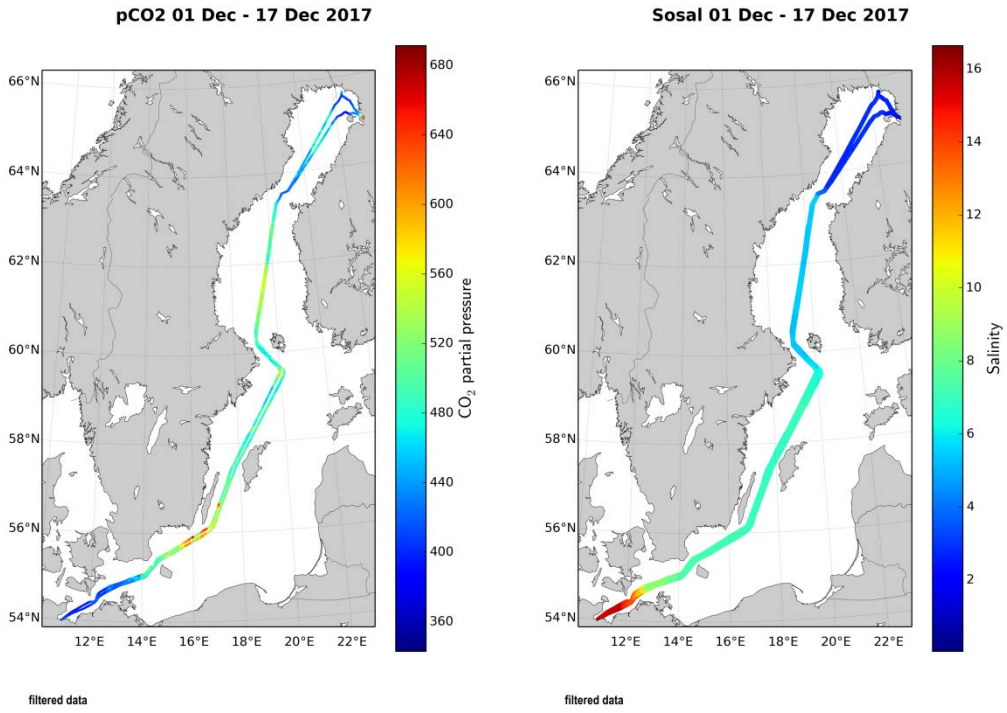

Figure 7. *Exemplary pCO2 (µatm) and salinity measurements from Tavastland during December 2017.*

VOS Silya Serenade

FMI set up the pCO_2 observation on M/S Silja Serenade in November 2017. The observations were stopped for the ice season and started again in March 2018. Since that they have operated continuously, with some breaks due to several instrument failures. In addition to setting up the measurements, FMI together with Finnish Environment Institute (SYKE) set up a www-page (http://swell.fmi.fi/Algaline/) for data visualization. The web page is currently under development and the aim is to add pCO_2 and pH observations with basic QC in August/September 2018.

VOS Silja Europa & Baltic Queen

Observations along the ferry lines Tallinn-Helsinki (Silja Europa) and Tallinn-Stockholm (Baltic Queen) have been carried out as planned. The Tallinn-Helsinki ferrybox records horizontal profiles of temperature, salinity and chlorophyll a fluorescence twice a day. Bi-weekly sampling for chlorophyll a, phytoplankton, and nutrient analyses are conducted. The system is ready to connect additional sensors (including pCO_2, pH, etc.). pCO_2 data are available only from spring 2010. MS Baltic Queen is equipped with a ferrybox measuring temperature, salinity, turbidity, and pCO_2 daily between Tallinn and Stockholm (pCO_2 measurements running since spring 2017). Altogether, 195 successful pCO_2 transects are available for 2017.

Fixed Station Utö

Observations at Utö continued during the entire funding period until 21st May 2018, when they were stopped due to several instrument failures. All observations started again 3 July 2018 after a scheduled maintenance visit. The main amendment during the first year of BONUS INTEGRAL was the installation of a cabled profiling observatory at Utö in April 2018. The new

system provides vertical information on biological and physical variables relevant to the biological carbon sink (Laakso et al., 2018).

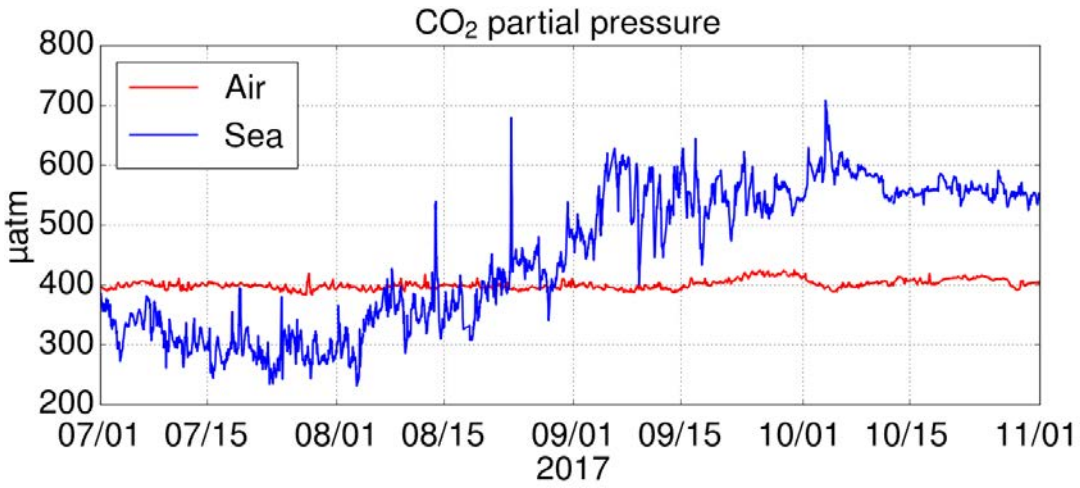

Figure 8: *Atmospheric and sea water carbon dioxide partial pressures at Utö during the period of 1 July – 1 November 2017 (Honkanen et al., 2018). During the summer period, the sea water pCO_2-concentration is lower than the atmospheric concentration due to the biological carbon sink. Atmospheric CO_2-observations at Utö are part of ICOS.*

Fixed Station Östergarnsholm

The station is situated east of the Island of Gotland and thus in the central parts of the Baltic Sea. It is a marine micrometeorological field station with continuous direct air-sea flux measurements of CO_2 exchange accompanied by other atmospheric parameters (heat flux, turbulence, radiation, precipitation). In the water the station features continuous measurements of pCO_2, O_2, temperature profile, and salinity. The station is funded by Swedish Research Council (VR) and Uppsala University and is presently the only Swedish marine contribution to ICOS. For the BONUS INTEGRAL project, direct flux measurements of methane was added in November 2017 and is running continuously.

For the field campaigns within INTEGRAL, we will complement the other systems, high-frequency water samples to measure the variability in time and space of methane and CO_2 concentration in the water near the station was performed during June 24th to June 26th, 2018.

Boknis Eck Time Series Station

Discrete water column sampling (6 depths, 1 - 25m) for N_2O, CH_4 and DIC/Alkalinity is conducted on a monthly basis. All samples taken until March 2018 have been analyzed and are currently post-processed by PhD student Xiao Ma.

Additional surface and water column samples for N_2O and CH_4 were collected during a measurement campaign (R/V Alkor expedition 510) in June 2018 at Boknis Eck and in the surrounding waters.

The underwater node at Boknis Eck has been operative from July to October 2017 and from April 2018, conducting continuous CH_4 and pCO_2 measurements at 14m.

Fixed Station Keri

Vertical profiles of temperature, salinity, dissolved oxygen, chlorophyll a, and turbidity are recorded and delivered 8 times a day from 3 to 100 m at the Keri station in the Gulf of Finland. No additional sensors for carbon system observations have been installed yet. Keri site is also sampled during the national monitoring cruises where BONUS INTEGRAL additional measurements (including pCO_2, CH_4, N_2O, etc.) are conducted. The station is part of the Estonian Environmental Observatory (a Research Infrastructure facility) which contains

atmospheric, terrestrial and marine stations and has applied for funding to join the ICOS network.

Work towards Deliverable 3.2: Additional parameters from HELCOM monitoring

IOW has been performing sampling for methane and nitrous oxide on some of the monitoring stations during all five campaigns of the German HELCOM monitoring performed by IOW. Starting from January 2019, additional sampling for carbon system parameters has been incorporated in the ship's working schedule at five stations (one Arkona Basin, two Bornholm Basin, two Gotland Basin)

Estonian marine monitoring cruises, which are arranged six times a year, have been chosen to conduct additional carbon system and trace gas measurements both using the vessel flow-through system and additional sampling at the selected monitoring stations. An agreement of in-kind use of the research vessel for BONUS INTEGRAL studies has been signed between the ship operator (Tallinn University of Technology, Estonia) and BONUS Secretariat. These monitoring cruises cover the Gulf of Finland, the Gulf of Riga and the northern Baltic Proper (Figure 9). Hydrographic conditions, oxygen, nutrients, and plankton communities are monitored. The flow-through system records temperature, salinity, dissolved oxygen, chlorophyll a, fluorescence, and turbidity along the ship track with a time resolution of 1 minute (see the ship track with temperature recordings in Fig. 10). Additional on route BONUS INTEGRAL measurements for pCO_2 and pCH_4 have been performed during all cruises (only pCO_2 in January).

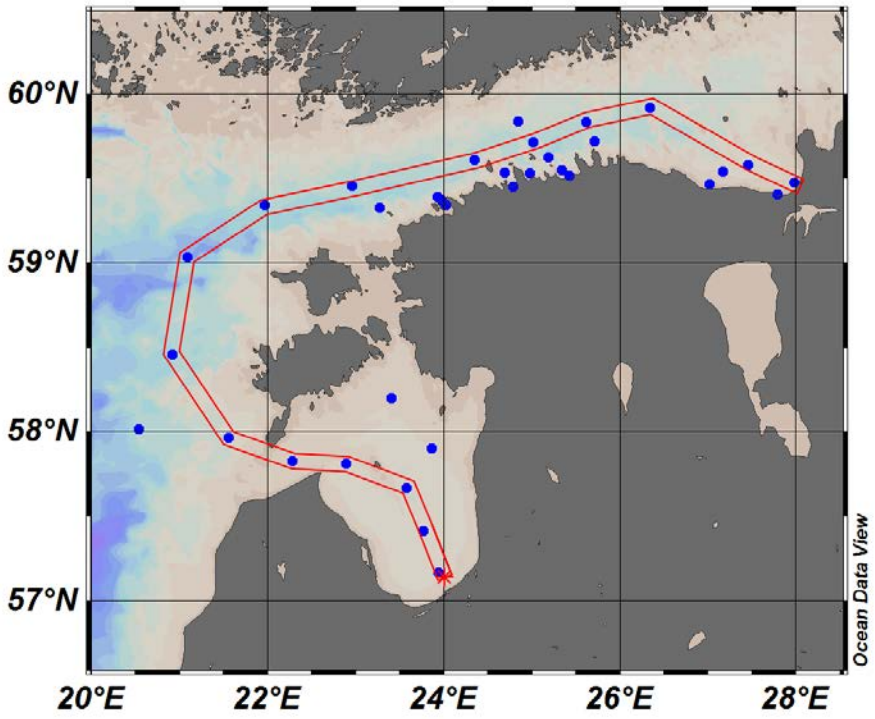

Figure 9: *Monitoring stations during the monitoring / BONUS INTEGRAL cruise on May 28 – June 2, 2018. Red line indicates a line usually used for hydrographic section work.*

In addition to the routine monitoring parameters, water sampling for trace gas analyses is performed along the transect from the northern Baltic Proper to the Gulf of Finland, and at seven stations in the Gulf of Riga (two of them in the Latvian waters in the southern gulf). The measured parameters will allow a first assessment of the trace gas and carbon system

dynamics in this region. For a better biogeochemical assessment, water samples for additional nutrient analyses are also collected. In the first half of 2018, three monitoring cruises were completed – from January 8th - 12th , April 16th -20th, and May 28th – June 2nd. The next three cruises are planned in July, August, and October 2018.

The study is a joint effort between TTU and IOW, and beside its clear scientific merit, because it is to our knowledge the first seasonal trace gas study in the Gulf of Riga, this one year long endeavour demonstrates a seamless integration of standard HELCOM monitoring and the amendments pursued within BONUS INTEGRAL.

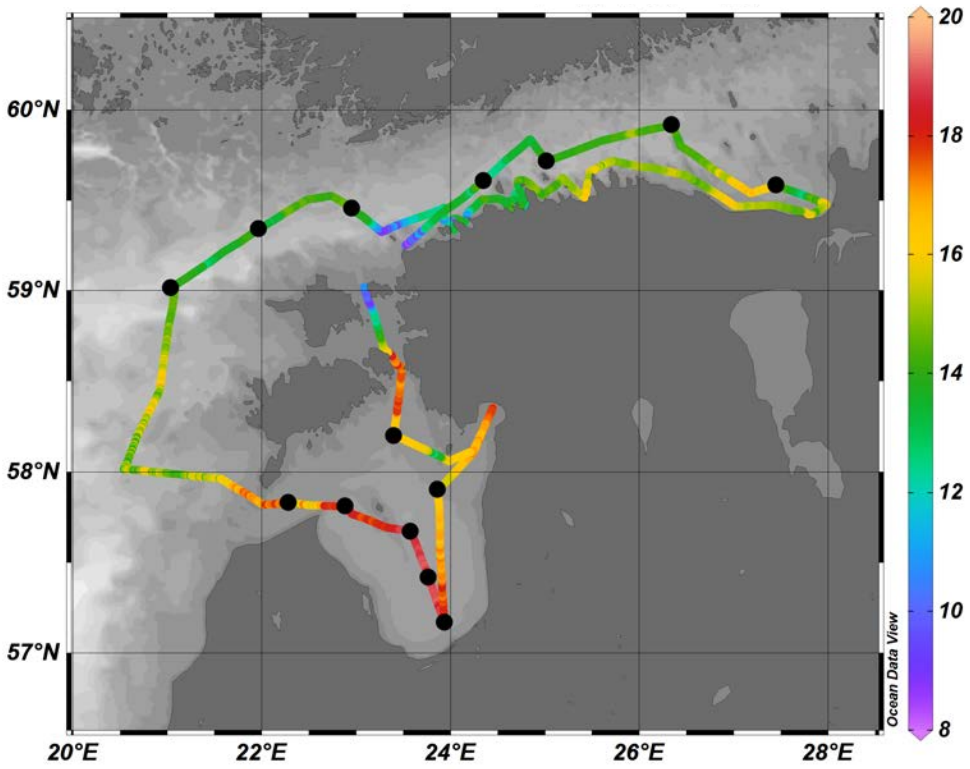

Figure 10: *RV SALME track during the monitoring / BONUS INTEGRAL cruise on May 28 – June 2, 2018. Colour scale shows surface water temperature (in degC, water intake at 2 m depth) recorded by the flow-through system. Black dots indicate monitoring stations where additional water sampling for BONUS INTEGRAL analyses is conducted.*

SMHI has, for many years, performed monthly monitoring cruises around Skagerrak, Kattegat, the Baltic Proper, and once a year the Gulf of Bothnia. In the last years, SMHI used the Finnish research vessel Aranda for this work. The monitoring expeditions visit the same fixed positions every month including some extended cruises for mapping nutrient loads and oxygen concentration, when the numbers of stations are doubled. The monitoring data is quality controlled and hosted in the database SHARK (SwedishSeaArchive), and can be downloaded at:

https://www.smhi.se/klimatdata/oceanografi/havsmiljodata/marina-miljoovervakningsdata.

The Swedish monitoring data is open data and freely accessible after the monitoring cruise. During the monitoring cruises there is potential for additional sampling of parameters interesting for the partners in BONUS INTEGRAL. The suggested parameters are alkalinity, and spectrophotometric pH. The alkalinity samples will be taken during regular monitoring

cruises and later analysed at the SMHI Oceanographic Laboratory in Gothenburg. The spectrophotometric pH can be measured in collaboration with the IOW, who coordinated the BONUS Innovation project BONUS PINBAL, during which a system for spectrophotometric pH measurement for brackish water applications was developed by Kongsberg Maritime Contros. BONUS INTEGRAL serves as an alpha test project for the instrument. One of the systems is foreseen to be set up on Aranda after initial testing, and the measurements can then be carried out during the cruises. This action is planned for 2019.

IOW procured 3 spectrophotometric pH instruments from Kongsberg Maritime Contros (CONTROS HxdroFia pH), which were delivered during the last days of the reporting period. The system was developed within the project BONUS PINBAL, coordinated by IOW (PI Rehder). During this project, also some fundamental gaps in the description of the method for brackish water conditions were filled (Müller et al., 2018, Müller and Rehder 2018, see Chapter 7). Another earlier prototype of the system is already in use by IO PAN on VOS Agat (see work towards deliverable 3.4). IO PAN has been another partner in BONUS PINBAL. Two of the other instruments will be used on VOS Finnmaid and VOS Tavastland (see above) after some further testing at IOW. A benchmark test will be performed during a joined effort for testing several carbon system sensors in the framework of a Transnational Access (TNA) activity within the European Jericho Next project. The TNA is organized by Lauri Laakso from FMI and will take place in November 2018 in Oslo.

Work towards Deliverable 3.3: Expeditions on RVs dedicated to BONUS INTEGRAL

Deliverable 3.3, as the Milestones M2 and M3, were dependent on the timely and successful application for ship time through the respective Finnish and German authorities.

Ship time for 12 working days on RV Aranda in late winter 2018/2019 was successfully applied for by FMI. During the annual meeting in Helsingör in June 2018, the cruise leaders for the winter cruise (Heidi Pettersson/FMI) and cruise leaders for the summer cruise (Gregor Rehder / IOW and Herman Bange / GEOMAR) discussed and agreed on the ship cruise routes and instrumentation used on the cruises. For the winter cruise, the exact cruise route will depend on ice conditions in the Northern Baltic Sea, the planned route will cover Gulf of Finland, Archipelago Sea, and the Bothnian Sea. In the case of a mild winter, the cruise will continue to the Gulf of Bothnia.

For early summer (May-June) 2019, 17 working days on RV Elisabeth Mann Borgese have been applied for by IOW. The ship time has been granted, but the cruise plan is not finalized yet. The successful application for ship time, and resulting provision of in-kind infrastructure to the project, is a great success for the project.

The cruise track of RV EMB for summer 2019 is expected to cover all major basins, with the aim to explore the areal representativeness of the data gathered on the VOS lines and fixed stations, and to retrieve surface data which might assist in finding smart extrapolation schemes (see Figure 11).

Both cruises are exclusively designed to serve the research questions of BONUS INTEGRAL. One priority will be the biogeochemical assessment with special emphasis on GHG in the Gulf of Bothnia, where data coverage is particularly sparse, and primary production is not well constrained. Moreover, there are only very limited number of CH_4 and N_2O measurements from the Gulf of Bothnia, even less from the winter period, and to our knowledge, no observations taken under the sea ice.

It was agreed on the first annual meeting that the detailed cruise planning, including type of - and responsibility for - individual parameters, will be harmonized and finalized by October 2019. At this time, we also expect the cruise plans for both research vessels with the exact time and duration of the cruises to be finalized by the ship-coordinating agencies.

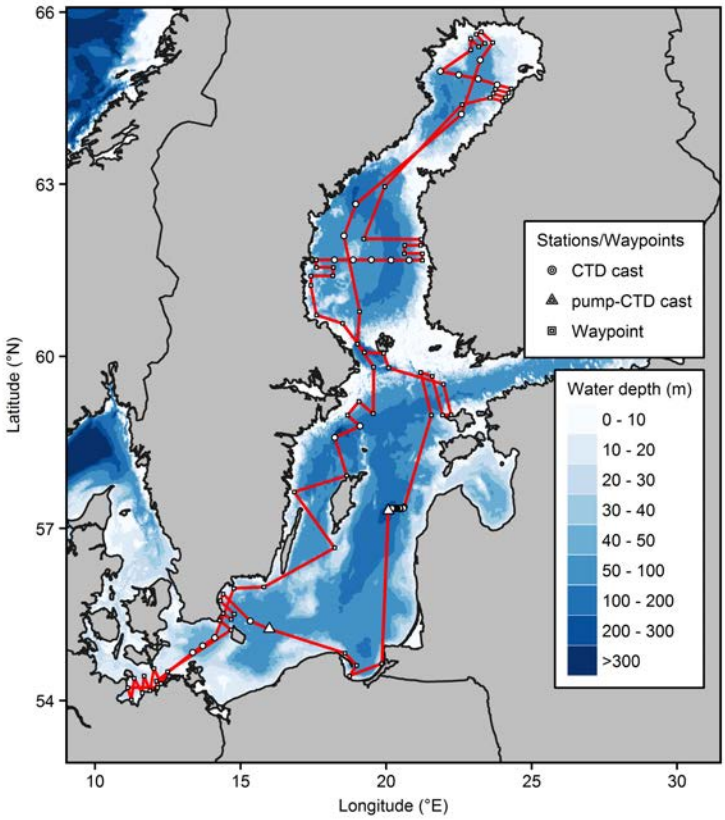

Figure 11: *Tentative Cruise Track for the BONUS INTEGRAL summer cruise (from the granted ship's application).*

Additional activity related to Deliverables 3.2 and 3.3: The BloomSail project

Within the INTEGRAL subproject BloomSail, we are investigating the occurrence of cyanobacteria blooms off the east coast of Gotland and compare in situ observations by measurements from a sailboat to recordings of the INTEGRAL infrastructure (VOS Finnmaid, flux tower Östergarnsholm) and remote sensing products. With this ambition, we are trying to integrate observations from existing infrastructure and work on a better interpretation of autonomous observations, mainly by adding depth-resolved data with high temporal resolution during a mid-summer plankton bloom period (June – August 2018). The project is partially funded by BONUS INTEGRAL, IOW and the National Geographic Society, and coordinated by BONUS INTEGRAL Post Doc Jens Müller. More information is available at:

https://www.io-warnemuende.de/Tina-V-home-en.html

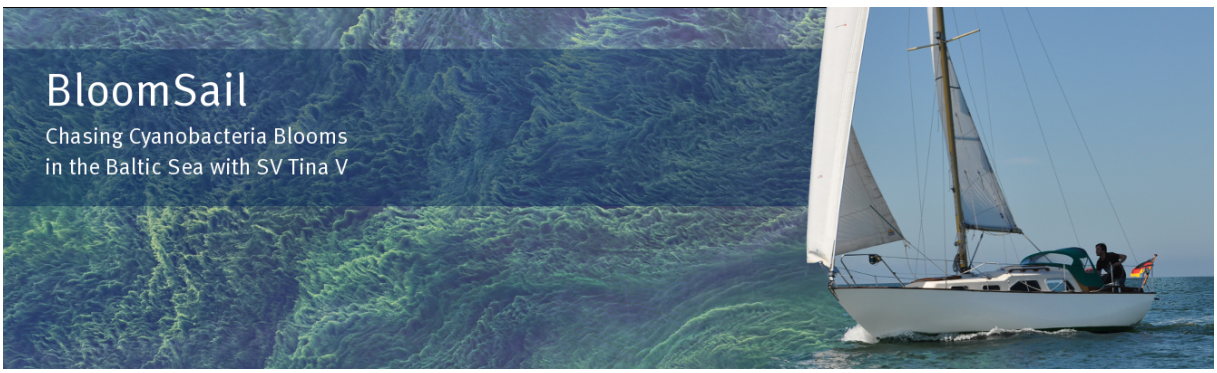

Figure 12: *Dissemination example in connection to the BloomSail expedition.*

Work towards Deliverable 3.4: Installation/Operation/Results of small VOS line package in the Gulf of Gdansk

Much attention has been directed towards the CO_2 system functioning in the Gulf of Gdansk. This region is highly influenced by the Vistula River, which is the second largest river entering the Baltic Sea. Similar to other rivers draining the continental part of the Baltic Sea catchment, Vistula is characterized by a very high A_T, nutrient and organic matter loads, and high productivity in its estuary. Nevertheless, the Gulf of Gdansk is still highly undersampled in terms of its CO_2 system. This is especially important, as the transformations and transport paths of the CO_2 system constituents between the river mouth and the open Baltic Sea remain unknown.

Figure 13: *upper and lower left - m/s AGAT (source: www.naszbaltyk.com), right - ferrybox installed in the engine room of m/s AGAT.*

The ferrybox system, exclusively funded by the BONUS INTEGRAL project, was installed in December 2017 on m/s AGAT – a small passenger ferry operating regularly in the Gulf of Gdansk on the routes Gdynia-Hel and Gdynia-Baltijsk (Figure 13). In the open tender the instrumentation offered by 4H Jena Engineering GmbH has been selected and purchased. The system contains thermosalinograph (Seabird) and pCO_2 detector (Kongsberg Maritime Contros GmbH). Additionally, the system has been equipped with a spectrophotometric system for pH measurements, HydroFIA pH, developed within the BONUS PINBAL project.

In the first half of 2018, the ferrybox system was extensively tested for both its long-term mechanical stability as well as data quality. Now, the small shortcomings were removed, and the system fully adjust to the conditions on the ship. The quality of the pCO_2 measurements have been verified by cross-comparison of measured pCO_2 values with those calculated from DIC and pH. The experiment was conducted in May 2018. Along with continuous measurements by the ferrybox system, discrete samples for DIC and pH were collected and measured later in the IO PAN laboratories. Then DIC and pH results have been used to

calculate pCO_2. The performed comparison of pCO_2 showed in most cases a consistency within 10 µatm (Figure 14).

It is envisioned that from July 2018, i.e. from the beginning of the 2nd year of the BONUS INTEGRAL project, the system will be fully operational. Still, it will be regularly tested and obtained data will be verified by cross-check experiments, as well as by comparison to the parallel measurements performed occasionally from aboard r/v Oceania.

Apart from the valuable data on the CO_2 system variability in the vicinity of the Vistula river mouth, this initiative also contains an important aspect related to the transfer of the know-how from countries, where ICOS is well implemented, to Poland, which is still in the process of developing its strategy towards ICOS. Importantly, m/s AGAT with the instrumentation installed within the BONUS INTEGRAL project is the first Polish VOS line measuring pCO_2 regularly in the seawater.

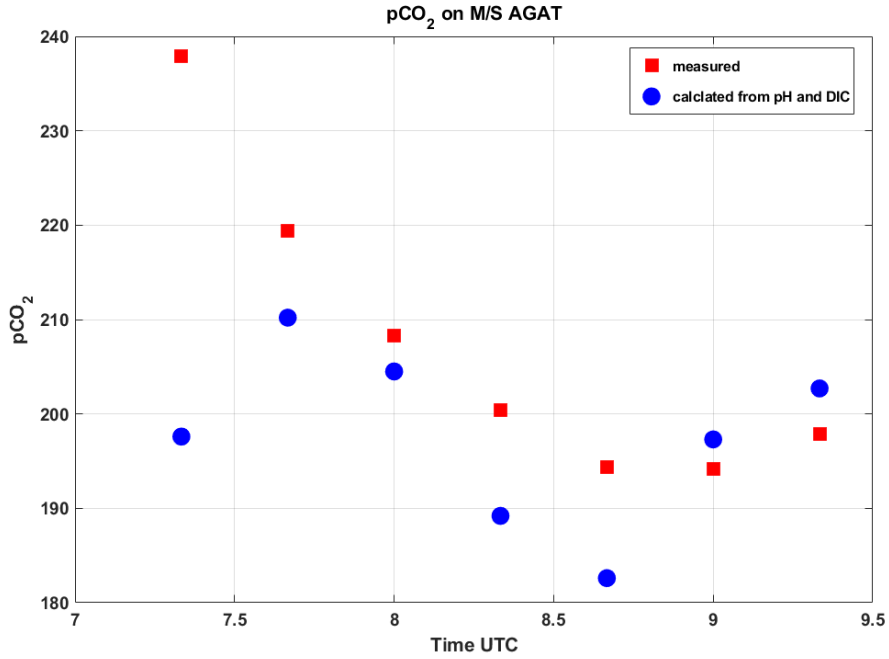

Figure 14: *Results of the crosscheck experiment performed on m/s AGAT in May 2018. Comparison of the pCO_2 measured (red dots) and calculated from DIC and pH (blue dots).*

E.) WORK PACKAGE 4 (Lead: GEOMAR)

The overall objective of WP4 is to provide GHG (CO_2, N_2O and CH_4) concentration fields for the Baltic Sea and make them available to WP5, other scientists, and the public/stakeholders.

Specific objectives are: i) to merge historical data provided by WP2 as well as actual data from the Baltic Sea GHG monitoring network under BONUS INTEGRAL; ii) to perform quality check and harmonize the data; iii) to compute GHG concentrations fields; and iv) to publish the Baltic Sea GHG concentration fields.

Work towards Deliverable 4.1 and 4.2: GHG data integration and computation of GHG concentration fields.

Based on the metadata list of existing N_2O, CH_4 and pCO_2 data (WP 2), a compilation of Baltic Sea greenhouse gas data has started at GEOMAR: from the 33 metadata files compiled within WP 2, 16 files are already included in the MEMENTO and SOCAT databases. Additional data sets from the metadata list are added either by accessing the data through other databases (e.g. PANGAEA) or by contacting the authors of the related publications.

In addition to the existing data, an inventory list of the infrastructure amendments within BONUS INTEGRAL (WP 3) is currently established by GEOMAR to enable a smooth data flow of these data into the greenhouse gas compilation and thus to make these data rapidly available for the calculation of greenhouse gas concentration maps.

FMI PhD-student Martti Honkanen submitted his first paper to Atmospheric Measurement Techniques in spring 2018 and is currently working with the minor review comments given by the reviewers. Part of the work of the paper was to do quality assurance for carbonate system observations at Utö, with the aim to be able to provide input data for WP 4. In addition to this paper, FMI is currently analysing and cleaning the data both from Utö and VOS line MS Silja Serenade for the period 2017/04- 2018/04. The aim is to create a data set that is compatible with ICOS-OTC and SOCAT database requirements, and for this reason the QC procedures have been discussed with representatives of ICOS-OTS and SOCAT.

IOW has compiled the pCO_2 data gathered on VOS Finnmaid until 2016 and published the data overview and some derived biogeochemical processes in a recent scientific monograph, which was finalized within the project (Schneider and Müller, 2018). Data for 2017 have been post processed, validated, and reported to the SOCAT database. The surface methane data have been post processed, and validated since the beginning of the record (2010) until fall 2017. These data will be further interpreted by BONUS INTEGRAL PhD-student Erik Jacobs, and will be provided for the surface mapping provided in WP4. Data from two cruises on research vessels in 2010 and 2012 are currently reprocessed to follow the exact same procedures.

GEOMAR has post-processed all CH_4 and N_2O depth profile data from the Boknis Eck Time Series from 2005 (N_2O) / 2006 (CH_4) until June 2015 and added these data to the MEMENTO database. In addition, data from three sampling campaigns in 2013, 2014, and 2015 have been processed and added to the MEMENTO database.

UU plans to extend earlier work, applying the SOMLO (self-organizing multiple linear output) methodology, which combines self-organizing maps and multiple linear regression by using remotely sensed SST, chlorophyll, CDOM and high quality GHG in situ measurements. The work of introducing additional remote sensing-based information, as well as taking the vertical temperature profile (skin effect to SST) into account, is being planned, and an improved methodology for deriving remote sensing extrapolated GHG concentration fields will be developed within BONUS INTEGRAL, with additional support from other funding sources.

F.) WORK PACKAGE 5 (FMI)

Within WP5, Baltic Sea sea-atmosphere gas fluxes will be calculated using new, state-of-the art methods and the concentration fields provided by WP4. The work comprises a new Baltic-specific, air-sea parameterization based on turbulence, wave, and air-sea flux data. The parameterization will be introduced into an operational wave model, and implemented in the Flux Engine toolbox to allow a comparison of different air-sea exchange models for the Baltic Sea flux estimates.

Work towards Deliverable 5.1: Report presenting the new turbulence-based gas exchange coefficients

During the first year of Bonus Integral, Heidi Pettersson (FMI) and PhD-student Jan-Victor Björkqvist (FMI) have worked with the pre-existing data set collected on board RV Aranda and at Östergarnsholm measurement station operated by the University of Uppsala. The quality assurance for this data set is a precondition for the new parameterization.

Data from the Östergarnsholm measurement station in Sweden is being analysed by UU scientists for the continued development of new parametrizations and determination of the

processes controlling the gas transfer coefficient.

Work towards Deliverable 5.2: Calculation of spatially and temporally compartmentalized fluxes for the Baltic Sea based on the new parameterization implemented in WAM model

PhD-student Jan-Victor Björkqvist (FMI) has modified the WAM model to output the wave dissipation. This is a necessary step to calculate wave dissipation based flux parameterizations, and for creating the wave dissipation gridded data that can then be used as a forcing field for calculations made inside of the FluxEngine. The gas fluxes over the Baltic Sea will be calculated using different formulations for the gas transfer velocity.

Work towards Deliverable 5.3: FluxEngine runs with different ASE parameterizations

The FluxEngine toolbox has been overhauled to allow simple installation on Apple Mac, Linux, and Windows computers along with verification tools and data to allow the user to easily confirm that the software has installed correctly (the toolbox can now be easily used at the project training workshop). This has included altering the internal structure of the toolbox, so that it is now easier to add and extend the toolbox to include new functions, such as additional ice-specific air-sea gas parameterisations. We are now in a good position to start extending the FluxEngine toolbox to include Baltic specific data sets and methods.

The improved version of FluxEngine is set up at UU (with support of UNEXE) and ASE parameterisations particularly for the Baltic Sea are being developed.

G.) WORK PACKAGE 6 (Lead: IOW)

WP 6 aims to improve carbon cycle models by using the improved process understanding from measurements compiled in WP 2 and 3, and implement carbon as central variable for the assessment of the Baltic Sea eutrophication. We will calculate the carbon budget and its changes in time for the entire Baltic Sea, for the coastal zone, and the Baltic Sea sub-basins separately, using a high-resolution carbon system model and BONUS INTEGRAL observations. The model will also be used to develop strategies for optimized carbon monitoring with as little as possible sampling effort into account, taking temporal and spatial variability of the system

Deliverable 6.1: Report on model performance with focus on the carbonate system

For the assessment of model performance, the simulated pCO_2 have been compared against observational data measured on a regular basis on VOS Finnmaid and therefore provide a high temporal and spatial resolution. We mainly conclude that the simulated carbon fixation, based on a Redfield stoichiometry model, highly underestimates observations. That is, for a realistic model of the carbon cycle, a non-Redfield approach is needed, or additional supply of N and P would be required. In a first step, state variables for non-Redfieldish DOC and POC have been introduced in the ecosystem model. The impact on the simulated pCO_2 is shown in Figure 15.

The non-Redfield model improves the performance of the simulation concerning the surface pCO_2 considerably. Therefore, in order to model further exercises, the non-Redfield approach will be used. However, if new process understanding explaining the observed low pCO_2 values emerges from field observations, these processes will be tested with the model. More detailed information on the model evaluation and first steps towards improvement are given in Deliverable Report 6.1.

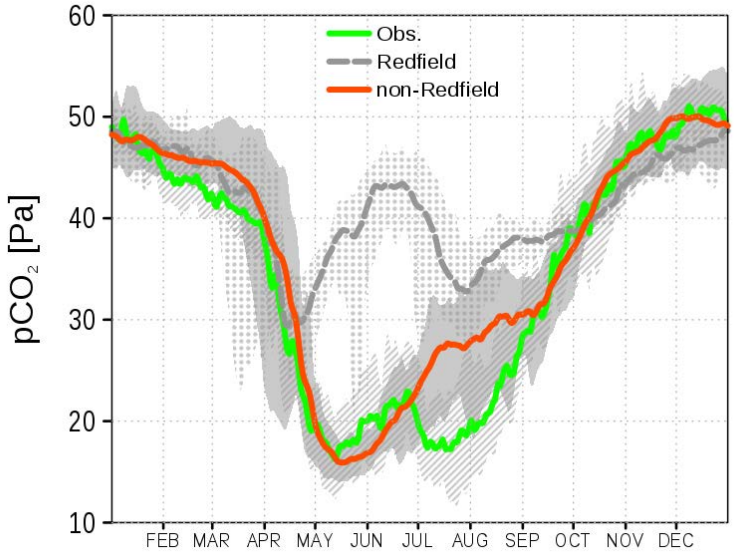

Figure 15: *Observed and simulated pCO_2 climatology (2003-2015) in the surface water at station BY15 (Eastern Gotland Sea). Shaded areas show the 80% range of data.*

Work towards Deliverable 6.2 and 6.3: Model-derived carbon budget and trends, and optimized monitoring strategies.

Long-term simulations have been started already. They are necessary to adjust and fine tune parametrizations used for the DOC and POC dynamics. These simulations are the basis for deliverable 6.2.

G.) WORK PACKAGE 7 (Lead: UU)

Dissemination of knowledge from INTEGRAL at various levels is an essential part of the project's concept. This includes knowledge transfer within the group and among countries, training about modern carbon and greenhouse gas analytics, flux assessment and modelling for the next generation of enthusiastic scientists in the framework of a summer school and training workshops, the promotion of the use of VOS lines and carbon data for a cost effective monitoring of the Baltic Sea via workshops and a stakeholder conference, and a Report/White Paper and brochure demonstrating and road-mapping a better integration of VOS-based sampling strategies and ICOS-related infrastructure for the ecosystem monitoring of the Baltic Sea.

Work towards Deliverable 7.1: Knowledge transfer measures during installation / operation of infrastructure amendments

The transfer of knowledge was (and still is) especially important for countries that just began regular monitoring of pCO_2. In case of Poland, the small VOS line in the Gulf of Gdansk established within BONUS INTEGRAL is the first VOS line running, not only by the IO PAN, but also in Poland in general. This initiative required repeated transfer of know-how about pCO_2 measurements: before the installation, during the installation, and afterwards while performing the first tests on the instruments. Thus, the first plans for this installation were developed in a close collaboration between Karol Kuliński (PI from IO PAN) and Bernd Schneider from IOW, who has great experience in this field, being the initiator of regular pCO_2 monitoring in the Baltic Sea on the VOS Finnpartner, later replaced by VOS Finnmaid.

Transfer of knowledge about trace gas and carbon system analysis will take place through the joined work between Germany and Estonia in connection to the Estonian Monitoring in the Gulf of Riga and Gulf of Finnland (see also WP3-Work towards Del. 3.2). PI Urmas Lips (TTU) is a member of the thesis committee of PhD-student Erik Jacobs (IOW).

Over the last years, the IOW became one of the leading institutes for pH-measurements in brackish waters, strongly reinforced by the coordination of the Innovation Project BONUS PINBAL, with three papers published on the brackish-water-specific aspects of the method. BONUS INTEGRAL is alpha user of the instrument that was developed during the project. In total, four of these instruments are available within the BONUS INTEGRAL consortium and will be used on different platforms. This will be combined with a transfer of technology and scientific expertise.

Work towards Deliverable 7.2: Workshop on ICOS implementation in Poland and Estonia

Over the first year of the project, it became clear that some of the partners would benefit from transfer of knowledge about the various instruments, data handling and quality control procedures, as well as strategies on the implementation of ICOS; therefore a workshop was proposed. Using our network and established link to the IOCCP (see also work towards Deliverable 7.3), the opportunity opened up to bridge some of these knowledge gaps by joining a planned IOCCP workshop on data quality control (primary and secondary, QC1, QC2) for underway instruments and sensors, automated data submission system and automated metadata submission system in the pCO_2 monitoring. The workshop will take place in Sopot, Poland, on November 7-9, 2018. During the first, theoretical part, the invited experts from international community, including SOCAT, will present state-of-the-art quality control for pCO_2 measurements. The second part of the workshop will be dedicate to more practical aspects, and the participants will have the chance to apply quality control to their data.

The coordinator of BONUS INTEGRAL is also in contact with the leader of WP2 of the EU project RINGO (Readiness for ICOS). RINGO WP2 (Geographical Readiness) aims to foster the development of ICOS networks in countries not yet contributing, and therefore is a strong partner to pursue this deliverable.

Work towards Deliverable 7.3: BONUS INTEGRAL summer school

The basic concept of the BONUS INTEGRAL summer school was developed during the first months of the meeting. After discussions with international contacts like the ones in ICOS OTC meetings, the annual meetings, and internal communication of the EU project RINGO, it was revealed that related activities were already in preparation by ICOS/RINGO and by the IOCCP. During the AGU/ASLO Ocean Science meeting in February 2018 in Portland, USA, the potential of merging the BONUS INTEGRAL effort with the planned 2nd IOCCP summer school on ocean sensors was discussed.

IOCCP had hosted a very successful summer school in June/July 2015 in Kristineberg, Sweden, which was also the designated location for the planned BONUS INTEGRAL summer school. The 2015 summer school attracted very bright students from all over the world, who had to go through a rigorous application process and were selected based on both motivation and performance. Amongst the tutors were leading scientists in the field, such as Andrew Dickson and Todd Martz (Scripps), Craig Neill (CSIRO), Ken Johnson (MBARI), Eric Achterberg and Arne Körtzinger (GEOMAR), and Doug Conelly (NOC). Information can be found at

http://www.ioccp.org/index.php/technical-training-workshops/14-trainingcourse/72-sensors-summer-course-2015

A renewal of this workshop was originally planned for 2018, but had to be postponed due to a

lack of co-funding sources.

The coordinator of BONUS INTEGRAL had several discussions with M. Telszewski, Director of IOCCP, and we came to the conclusion that a joined IOCCP / BONUS INTEGRAL summer school would be an ideal solution and a true win-win situation for both sides. It would lead to an outstanding summer school, increase the international visibility of BONUS INTEGRAL and BONUS as a whole, and would ideally be suited to train the next generation of bright students in the use of technology and data handling for autonomous high resolution environmental observation, which is exactly the strategy pursued by BONUS INTEGRAL.

Therefore, the request to use the funds allocated for the BONUS INTEGRAL summer school was made to the relevant German funding agency and BONUS EEIG and accepted by both sides. It was also formally agreed to follow this approach at the BONUS INTEGRAL first annual meeting in June 2018.

Two weeks have been reserved at the Sven Lovén Centre in Kristineberg for June, 2019.

Work towards Deliverable 7.5, or more specifically, Task 7.3: Stakeholder dialogue

With major input from BONUS INTEGRAL, HELCOM was addressed concerning the use of carbon system parameters as an indicator for marine acidification (see Chapter 3). The concept of using ICOS infrastructure as instrumentation to assess the ecosystem state of the Baltic Sea was presented at both national and international ICOS communities (see Chapter 4).

Based on a discussion with the Board of ICOS Sweden, a letter was written to the ICOS Board by the coordinator of BONUS INTEGRAL in February 2018, supporting the consideration of VOS Tavastland (run by BONUS INTEGRAL partner SMHI) as a potential ocean component site of ICOS Sweden. This was further discussed with Maj-Lena Linderson, coordinating director of ICOS Sweden, at the RINGO 1st annual meeting in Antwerp.

Karol Kuliński joined the ICOS-Poland consortium as the only representatives of the Ocean Thematic Centre. The consortium coordinated by Janusz Olejnik is negotiating with the Polish Ministry of Science and Higher Education as well as with the Ministry of Development the foundations for establishing the funding mechanism for ICOS-Poland.

TTU as part of the Estonian Environmental Observatory consortium submitted a proposal to the Estonian Research Council for joining the ICOS network by Estonia. The Observatory contains atmospheric, terrestrial, and marine components and the Keri station is a possible future marine station in ICOS.

3 Promoting an effective science-policy interface to ensure optimal take up of research results (corresponding with the reported performance statistics 1-4)

The Members of BONUS INTEGRAL are actively promoting the overarching goals of BONUS INTEGRAL to stakeholders and related science organizations. This is facilitated by the active role several PIs play in the key organizations (HELCOM, IPCC, SOLAS, ICOS, National Authorities). The activities according to the Performance Statistics 1-4 are listed below.

IOW

PS1: Gregor Rehder, together with Jacob Carstensen (Aarhus University) and Bo Gustaffson (University of Stockholm), proposed carbon system parameters as a candidate indicator for marine acidification at the HELCOM State and Conservation meetings in October 2017 (7/2017, presented by Jacob Carstensen) and May 2018 (8/2018 presented by Gregor Rehder who acted as guest at the meeting, PS3). Discussions about the parameters as indicators took place between these dates, at IN Eutrophication (Meeting 10-2018), and also in teleconferences with official German representatives. As a result, carbon system parameters

were adopted as a candidate indicator, with Germany and Sweden taking co-lead in this initiative.

PS1: Gregor Rehder has discussed the need and potential for state-of-the-art monitoring of pH as a measure for acidification with the Bundesamt für Schifffahrt und Hydrographie (BSH), who is responsible for the HELCOM monitoring in the German EEZ. A proposal for a demonstration/implementation project is currently under review. This effort is driven by an acknowledgment from BSH that currently there is a problem in the fulfilment of the obligations defined in the MSFD concerning marine acidification.

PS3: Markus Meier has been asked by HELCOM to assist in the organisation of an Expert's Network on Climate Change.

PS3: Gregor Rehder, observer and invited expert at the HELCOM S&C meeting, May 2018

PS4: Markus Meier was Chair of the Organization committee of the 2nd Baltic Earth conference on “The Baltic Sea Region in Transition”, Helsingør, Denmark, June 11th – 15th,2018; Gregor Rehder, Karol Kulinski, and Anna Rutgersson were members of the Scientific Committee.

UU

Towards PS2: Anna Rutgersson (being in the SOLAS SSC and in the WCRP, WDAC committee on surface fluxes) is (together with the SurFlux WDAC committee) developing a white paper stressing the need for ocean surface fluxes and the development of new methods for estimating surface fluxes. This is particularly important for regions with high variability (coastal regions and inland seas like the Baltic Sea).

PS3: Anna Rutgersson: Co-chair of Baltic Earth; SSC International SOLAS; Insynsråd, SMH

FMI:

PS3: Lauri Laakso, SOLAS (The International Surface Ocean - Lower Atmosphere Study SOLAS), National reporting for Finland; Finnish National Scientific Committee on Oceanic Research, February 2nd, 2018; Baltic Earth Science Steering Group June 6th, 2018; Finnish Marine Research Infrastructure FINMARI September 27th ,2017; Finnish Marine Research Infrastructure FINMARI January 22nd, 2018; Finnish Marine Research Infrastructure FINMARI February 26th, 2018

PS3: Heidi Pettersson, Finnish National Scientific Committee on Oceanic Research, February 2nd, 2018; Finnish National Scientific Committee on Oceanic Research, May 3rd, 2018

PS4:Lauri Laakso, five members of Finnish parliament visiting Utö Atmospheric and Marine Research Station for two days (September 4th – 5th, 2017) discussions on science policies, marine research and climate change observations.

PS4: Lauri Laakso, Finnish Meteorological Institute stakeholder day, March 23rd, 2017. Representing the audience (politicians, government representatives, diplomats and security organizations) Utö Atmospheric and Marine Research Station.

TTU

PS3: Urmas Lips acts as the co-chair of the HELCOM STATE&CONSERVATION Working Group where, among other topics, new methods for eutrophication- and ocean acidification-related monitoring are discussed. He co-chaired the WG meetings on October 23rd – 27th. 2017, Sopot, Poland and on May 14th – 18th, 2018, Klaipeda, Lithuania. Urmas Lips is also a member of the Scientific Advisory Board of FINMARI (Finnish marine research infrastructure) and he participated at the SAB meeting on February 26th to 28th, 2018 in Tvärminne, Finland. As a member of the EuroGOOS Executive Directors Board, Urmas Lips has discussed methods of automated high-frequency monitoring developments (including ferryboxes, profilers, etc.) in Europe at the board meetings on September19th – 20th, 2017, January 31st –

February 1st, 2018, and May 22nd – 25th, 2018 as well as Annual Meeting of EuroGOOS AISBL. Urmas Lips moderated a workshop at the 9th Annual Forum EU Strategy for the Baltic Sea Region on June 4th to 5th, 2018, Tallinn, Estonia where the questions of future actions regarding eutrophication and climate change issues were discussed.

SMHI

PS3: Kristin Andreasson participated in the ICES working group for Marine Chemistry (MCWG), March 5th -9th, 2018, in Galway, Ireland. The purpose of the group is to discuss and harmonize the chemical methods used within European environmental monitoring and provide technical advice in support of the EU Water Framework Directive and EU Marine Strategy Framework Directive. ICES MCWG works closely with Quaismeme, who arranged laboratory performance studies for laboratories analysing environmental monitoring parameters like salinity, nutrients and chlorophyll a.

UNEXE

PS3: Jamie Shutler Expert Reviewer for the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC); International Space Science Institute (ISSI) Working Group Leader (http://www.issibern.ch/workinggroups/atmosgasexchange); Member of the European Space Agency Mission Advisory Group for EE9 candidate SKIM.

4 Collaboration with relevant research programmes and the science communities in the other European sea basins and on international level (corresponding with the reported performance statistic 5)

The activities listed below fall into both categories 5 or 13 under performance statistics; we feel that category 13 is strongly related to category 5.

IOW:

March 8th to 10th, 2017: 8th Meeting of the Baltic Earth Science Steering Group, Warnemünde, Germany. Introduction of BONUS INTEGRAL. **The project was accepted as an official Baltic Earth project in the case of funding.**

May 3rd to 4th, 2017: BONUS 10 years celebration 'For the Baltic Sea and beyond' 3-4 May 2017, Helsinki, Finland. Gregor Rehder: An Introduction to the BONUS INTEGRAL project.

March 6th, 2018: WWF and Coalition Clean Baltic (CCB) side event at the HELCOM Ministerial Meeting in Brussels on "The uncomfortable truth of the BSAP – 10 years down the line towards saving the Baltic Sea", Brussels. H.E.M. Meier: What will the BSAP need to address to meet the challenges of climate change?

March 14th to 16th, 2018: MedCORDEX-Baltic Earth-COST Workshop on "Regional Climate System Modelling for the European Sea RegionsPalma de Mallorca, Spain. H.E.M. Meier: Baltic Earth and Integrated Earth System Modeling for the Baltic Sea Region.

May 6th to 11th, 2018: 8th GEWEX Open Science Conference: Extremes and Water on the Edge. Canmore, Canada. H.E.M. Meier: Integrated Earth System Modeling for the Baltic Sea Region.

June 11th to 15th, 2018: 2nd Baltic Earth Conference - The Baltic Sea in Transition. H.E.M. Meier, G. Väli, M. Naumann, K. Eilola, and C. Frauen: Recently accelerated oxygen consumption rates amplify deoxygenation in the Baltic Sea – observations and model results.

June 11th to 15th, 2018: 2nd Baltic Earth Conference - The Baltic Sea in Transition. Gregor Rehder, A. Rutgersson, L. Laakso, K. Kuliński, U. Lips, H. W. Bange, K. Andreasson, J. Shutler, and the BONUS INTEGRAL science party: BONUS INTEGRAL: Improved Biogeochemical Monitoring and Greenhouse Gas Flux assessment for the Baltic Sea through high resolution trace gas data acquisition (oral presentation)

June 11th to 15th, 2018: 2nd Baltic Earth Conference - The Baltic Sea in Transition. Anja Eggert, B. Schneider, T. Neumann, G. Rehder: High resolution nutrient data to unravel the post-spring bloom elemental cycling in the central Baltic Sea (oral presentation)

June 11th to 15th, 2018: 2nd Baltic Earth Conference - The Baltic Sea in Transition. Bernd Schneider: Organic matter mineralization in Baltic Sea deep waters: Rates and Stoichiometry (oral presentation)

June 11th to 15th, 2018: 2nd Baltic Earth Conference - The Baltic Sea in Transition. Thomas Neumann, A. Eggert: A Baltic Sea Ecosystem Model with non-Redfield Stoichiometry for Carbon Fixation (poster)

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June 11th to 15th, 2018: 2nd Baltic Earth Conference - The Baltic Sea in Transition. Anna Rutgersson, H. Pettersson, E. Nilsson, H. Bergström, M. B. Wallin, E. D.Nilsson, E. Sahlée, L. Wu, E. M. Mårtensson: Using land-based sites for air-sea interaction studies (oral presentation)

June 11th to 15th, 2018: 2nd Baltic Earth Conference - The Baltic Sea in Transition. Lucia Gutiérrez-Loza, A. Rutgersson, M. B. Wallin, E. Sahlée: Air-sea Methane fluxes in the Baltic Sea using eddy covariance (poster)

FMI

Four week visit (May 14th – June 8th, 2018) to IFREMER, France to discuss on co-operation between different projects, e.g. H2020 Jerico-Next and plans for carbonate system metronomy laboratory at IFREMER. Coordinating the carbonate system QC protocols with ICOS-OTC, SOCAT and JERICO-NEXT community.

June 12th – 16th, 2017: Martti Honkanen, Juha-Pekka Tuovinen, Timo Mäkelä, Sami Kielosto, Jukka Seppälä, Timo Tamminen, Pasi Ylöstalo, and Lauri Laakso: Sea-air exchange of CO_2 at the island of Utö in the Archipelago Sea. The 11th Baltic Sea Science Congress, Warnemünde, Germany 2017.

June 11th to 15th, 2018: 2nd Baltic Earth Conference - The Baltic Sea in Transition. Martti Honkanen, Juha-Pekka Tuovinen, Tuomas Laurila, Timo Mäkelä, Juha Hatakka, Sami Kielosto and Lauri Laakso: Measuring turbulent sea-air CO_2 fluxes with a closed-path gas analyzer.

June 7th, 2018: One hundred years of atmospheric and marine observations on Utö Island, the Baltic Sea, presentation given at European Institute for Marine Studies, Brest, France.

Lauri Laakso / FMI coordinates a joint research activity project on carbonate systems in H2020-project Jerico-Next. The aim of the JRAP is to develop marine carbon system observations throughout European coastal sea. Part of the activity is related to developing data QC methods, which are in-line with ICOS-OTC and SOCAT standard. The methodology partly developed in Jerico-Next is also used in Bonus-Integral. Jerico-Next is also organizing an instrument calibration exercise in Oslo in November 2018, where some of the partners from BONUS INTEGRAL will participate.

Lauri Laakso visited IFREMER, Brest, France in May and June 2018. During that period, he discussed with the IFREMER metrology laboratory representatives Florence Salvetat and Laurent Delauney on setting up a carbonate system metrology facility at IFREMER, which would locally support the ICOS-OTC especially on studies of marine carbonate system on biologically active coastal seas. This work and the plans are also coordinated with the Bonus-Integral partners, especially related to alkalinity and pH observations at low salinity and high CDOM environments.

IO PAN:

June 11th to 15th, 2018: 2nd Baltic Earth Conference - The Baltic Sea in Transition. Beata Szymczycha, Ż. Kłostowska, K. Kuliński, A. Winogradow, J. Jakacki, Z. Klusek, M. Grabowski, A. Brodecka-Goluch, B. Graca, M. Stokowski, K. Koziorowska, D. Rak: Deep submarine groundwater discharge indicated by pore water chloride anomalies in the Gulf of Gdańsk, southern Baltic Sea (oral presentation, solicited)

June 11th to 15th, 2018: 2nd Baltic Earth Conference - The Baltic Sea in Transition. Karol Kuliński, M. Stokowski, B. Szymczycha, K. Hammer, K. Koziorowska, A. Winogradow, M. Lengier, Ż. Kłostowska, B. Schneider: The acid-base system of the Baltic Sea (oral presentation)

June 11th to 15th, 2018: 2nd Baltic Earth Conference - The Baltic Sea in Transition. Marcin Stokowski, K. Kuliński, B. Schneider, G. Rehder, J. Müller: Transformations of the carbonate system in the Odra estuary (poster)

GEOMAR

June 26th, 2018: Invited introduction about Boknis Eck given by Hermann Bange at LLUR (Landesamt für Landwirschaft, Umwelt und ländliche Räume), Flintbek, Germany (oral presentation)

June 11th to 15th, 2018: 2nd Baltic Earth Conference - The Baltic Sea in Transition. Hermann Bange: The Eckernförde Bay (SW Baltic Sea) through the ages: Time-series measurements at the Boknis Eck time-series station (poster)

SMHI

October 17-19th, 2017: Anna Willstrand Wranne participated in the 8th Ferrybox work shop on Color Fantasy, hosted by NIVA, and presented both BONUS INTEGRAL and the ferrybox work done by SMHI. The work shop is every second year and gathers researchers and technicians working with ferrybox across Europe.

October 18th, 2017: During the ferrybox work shop, Anna Willstrand Wranne also participated in a Jerico Next meeting concerning work package 2; Harmonization of technologies and methodologies - technical strategy.

UNEXE

UNEXE has shared software with the EU Ringo project by making all FluxEngine software updates and development available on GitHub through this link: https://github.com/oceanflux-ghg/FluxEngine

5 Progress in comparison with the original research and financial plan, and the schedule of deliverables

Several deliverables were submitted with a slight delay for various reasons, but all deliverables due in the reporting period were met and the project is proceeding according to the DoW. The Deliverable 1.7 Communication plan was not in the original work plan, and fulfilled when it appeared most reasonable (month 13).

As a contribution to WP3 and WP4, the research through sailing expedition “BloomSail” will give valuable information on the temporal evolution of the summer bloom, representativeness of the VOS line Finnmaid, and in particular the vertical extent of the productivity signal. The project is embedded in BONUS INTEGRAL and only possible through the effort and enthusiasm of BONUS INTEGRAL PostDoc Jens Müller, who is fully in charge of the mission.

Additional funding to UU by the Swedish National Space Board will support extended work related to the GHG maps to be developed using remote sensing data. The additional funding will allow for improved use of the new Sentinnel satellites and the development of improved chlorophyll based products to be used in the SOMLO methodology.

For IOW, underspending during the first reporting period led to a budget change request. This was due mainly because the procurement of the spectrophotometric pH-measurement systems had to be delayed because the manufacturer was not yet able to meet the specifications. By the time of the finalization of this report, these problems have been overcome and the instruments have been purchased. As the upgrade of the instruments involved several quality control and test runs at the manufacturers side and at IOW, a lot of them in the original work plan, this did not lead to any delay in the work plan.

For UU there is a shift in the budget. Due to coordination with other projects (in particular the project funded by Swedish National Space Board) and some delays in the recruitment of the PhD student there is a delay in the spending of resources. However, we have been able to start the project as planned, with mainly the in-kind contributions. We expect the continuation of the project to follow the plan and deliverables to be ready in time, with no impact of the content or schedule.

Partner GEOMAR will soon have to request a budget change (consumables and personnel) because

1) the set up of the N_2O/CO analyzer on the VOS (Tavastland) line is delayed by several months due to the unforeseen shift of the VOS line to the North Sea and
2) Dr. Annette Kock, postdoc funded by BONUS INTEGRAL, was on maternity and parental leave from 10 September 2017 to 16 May 2018. Since she came back to work she works part-time with a reduced working time of 30 h/week (instead of 39.5 h/week). Xiao Ma (PhD student) was employed as replacement for Dr Kock from 1 October 2017 to 31 March 2018 with 29.6h/week.

Despite the requested budget change, the overvall objectives as well as the dates of both milestones and deliverables of WP4 do not need to be modified.

Partner SMHI requested a budget change for 1) partly redistribution of personnel costs over time due to lack of resources initially 2) partly redistribution between personnel and other direct costs for increased travels due to unexpected events in the route of the ferrybox vessel Tavastland. No impact on the work plan.

6 Amendments to the description of work and schedule of deliverables

None

7 Other information

Publications arising from the project

Peer reviewed publications:

Kuliński, K., Szymczycha, B., Koziorowska, K., Hammer, K., Schneider, B., (2018). Anomaly of total boron concentration in the brackish waters of the Baltic Sea and its consequence for the CO_2 system calculations. Marine Chemistry 204, 11-19.

Laakso, L., Mikkonen, S., Drebs, A., Karjalainen, A., Pirinen, P., and Alenius, P., (2018). 100 years of atmospheric and marine observations at the Finnish Utö Island in the Baltic Sea, Ocean Sci., 14, 617-632, https://doi.org/10.5194/os-14-617-2018.

Müller, J. D., Bastkowski, F., Sander, B., Seitz, S., Turner, D. R., Dickson, A. G., & Rehder, G., (2018). Metrology for pH Measurements in Brackish Waters—Part 1: Extending Electrochemical pHT Measurements of TRIS Buffers to Salinities 5–20. Frontiers in Marine Science, 5(July), 1–12. https://doi.org/10.3389/fmars.2018.00176

Müller, J. D., & Rehder, G., (2018). Metrology of pH Measurements in Brackish Waters—Part 2: Experimental Characterization of Purified meta-Cresol Purple for Spectrophotometric pHT Measurements. Frontiers in Marine Science, 5(July), 1–9. https://doi.org/10.3389/fmars.2018.00177.

Nilsson, E., H. Bergström, A. Rutgersson, E. Podgrajsek, M.B. Wallin, G. Bergström, E. Dellwik, S. Landwehr, and B. Ward, (2018). Evaluating Humidity and Sea Salt Disturbances on CO_2 Flux Measurements. J. Atmos. Oceanic Technol., 35, 859–875, https://doi.org/10.1175/JTECH-D-17-0072.1

Scientific monographs:

Schneider, B. and Müller, J.D., (2018). Biogeochemical Transformations in the Baltic Sea - Observations Through Carbon Dioxide Glasses. Springer Oceanographie. Springer Scientific, Berlin (116 pp).

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