CRUISE REPORT

R/V Aranda

Cruise 06/2015

CFLUX14/CTD calibration

4 May - 15 May 2015

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This report is based on preliminary data and is subject to changes.

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CFLUX

4 May – 15 May 2015

Chief Scientist: Kristian Spilling

1. General description of the cruise

The cruise was shared between Finnish Environment Institute (SYKE) and Finnish Meteorological Institute (FMI). The SYKE team concentrated on the plankton community during and following the spring bloom. FMI had two teams onboard; the first objective was studying the spatial variability in pCO_2 and flux of CO_2 through the water air interface; the second objective was deployments of various buoys and CTD calibration work.

1.1. SYKE objective and work

The spring bloom in the Baltic Sea has the highest annual productivity of phytoplankton, and this event have been much studied over the last decades. In the Gulf of Finland and Baltic Proper, the algae generally stop to grow once their source of nitrogen has been depleted, i.e. N limited system. Further north in the Gulf of Bothnia the phytoplankton community is generally P limited.

The objective with the cruise was to document the phytoplankton spring bloom community in different parts of the Baltic Sea and to characterize basic chemical and biological parameters such as inorganic nutrients, chlorophyll *a* (Chl *a*) and plankton community composition. We also measured particular organic nutrients (carbon, nitrogen and phosphorus), size fractionated primary production, bacterial production (both leucine and thymidine incorporation), dissolved organic carbon and nitrogen, community respiration and grazing rates of bacteria and picoplankton.

One of the questions we wanted to address was how Bothnian Sea and Bothnian Bay differ from the Baltic Proper and Gulf of Finland in terms of spring bloom development (e.g. nutrient limitation). We were specifically interested in the Bothnian Sea, as this has been reported to have become increasingly N-limited over the past decades. Additionally, we investigated to what extent the phytoplankton community composition affects the release of dissolved organic matter (DOM) and to what extent this is channeled up the food web through the microbial loop.

1.2. FMI objective and work

Partial pressure of carbon dioxide and the exchange of CO_2 at the air-sea interface

During the spring bloom season, the difference of the partial pressures of carbon dioxide CO_2 in the sea surface water and in the atmosphere is expected to be large due to photosynthesis. This difference is the driving force of the CO_2 exchange across the sea surface, but the mechanism of the exchange is not yet well understood. The aim of the cruise was to study the factors affecting the partial pressure of CO_2 in the seawater, its spatial variation and the exchange processes at the sea-air interface.

The measurements included the concentration and the flux of atmospheric CO_2 and the fluxes of momentum, heat and humidity. A set of flux sensors was mounted at a height of 10 metres on the horizontal boom projecting from the bow of the ship. The wind waves were simultaneously measured with a wave staff at the bow. The flux and wave measurements were made at 20 of the stations visited during the cruise. During the cruise the partial pressure of CO_2 in sea surface water (at a depth of four metres) was monitored continuously with two different sensors attached to a flow-through system of the ship. The atmospheric partial pressure of CO_2 was also measured continuously. The ship's weather station provided the standard meteorological measurements together with the sea surface temperature and salinity and the navigational information. Additional directional wave data were obtained from the FMI wave buoy in the Bothnian Sea.

Deployments and maintenance

A small wave buoy was moored near the Helsinki wave buoy for testing purposes on the 4th May. The Northern Baltic Proper wave buoy was recovered on the 5th May, serviced onboard Aranda and moored again on the next day.

A modified Metocean iSVP buoy with several SBE37 CT instruments measuring temperature and salinity at different depths along an inductive modem cable was moored about 2 km south of Utö island on the 5th May. Two CTs were equipped also with an oxygen sensor. The surface buoy transmits the data through satellite system ashore. This measurement system is part of Utö Atmospheric and Marine Research station situated at the southern edge of the Archipelago Sea.

Intercalibration of different CTD instruments and other sensors measuring temperature and conductivity was carried out at the station TPDEEP1 in the northern part of Baltic Proper on the 6th of May. The total water depth at TPDEEP1 was 218 m and the water below 150 m was quite homogeneous. The reference CTD used was Aranda's SeaBird SBE911 Plus. The instruments involved in the intercalibration were eight RBR XR-620 CTDs, two SBE19 CTDs, two DST CTDs, one Alec CT logger, one Hobo CT logger, one SBE56 and one Seastar Mini temperature logger. The instruments were kept in five homogenous layers for 20 minutes in each layer. Water samples were taken from the same depths for salinity analysis. All SBE CTDs and one RBR CTD instrument were equipped with an oxygen sensor and water samples for oxygen content analysis were taken in the upper layer. Titrated values were compared with oxygen content values measured by the CTD instruments. Data for the comparison of fluorometers of the three SBE CTDs were gathered also in the upper layer. The intercalibration of the instruments with operating range under 100 m, seven DST CTDs and three CastAway CTDs, was carried out at the station Vitharu in the Archipelago Sea.

Pathfinder surface drifter buoys were also tested. Three buoys were attached to a long rope (approximately 100 m), which was secured to the ship. The buoys were turned on and kept floating in the water for about 18 h, while their data transmission and GPS-position accuracy was monitored.

2. The observations

2.1. Sailing route and basic measurements

We started from Helsinki 4 May, 12.30, and made the first deployment at AALTO_HKI (Table 1) before continuing to LL7 in the open of Gulf of Finland (Fig. 1). We sailed through the night to AALTO_PI where we picked up a buoy for servicing and continued to Utö where we did additional deployments. The following day we continued southwards to the TPDEEP for intercalibration of CTDs. The route then continued to the Archipelago Sea where we spent one day. From there we continued to Uusikaupunki, Thursday 7.5, where there was a shift of crew, before continuing northwards into the Bothnian Sea and Bothnian Bay. We reached the northernmost point Saturday 9.5 and turned southwards again. We were back in the Åland Sea 12.5, and Gulf of Finland 14.5. We arrived our home port in Helsinki Friday 15.5.2015 at 14.40.

2.2. Inorganic nutrients

There was clear differences between the different sea areas. In Gulf of Finland, Archipelago Sea, Åland Sea and Bothnian Sea inorganic nitrogen was depleted, but phosphate was remaining at concentrations >0.1 µmol L^{-1} (Fig 1). In Bothnian Bay this was reversed with phosphate being depleted, but with nitrate concentrations being relatively high (>4µmol L^{-1}).

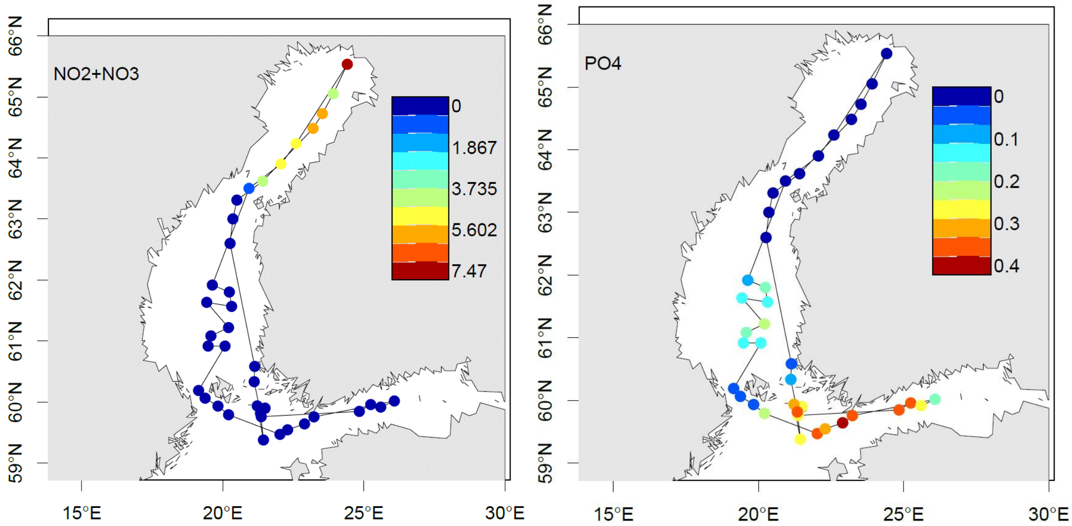

Fig. 1. Sum of nitrite (NO_2) and nitrate (NO_3) left, and phosphate (PO_4) right at the different sampling points. All values are in in µmol L^{-1} and samples were taken from 3 m depth.

2.3. Phytoplankton concentration and community composition

Chlorophyll *a* (Chl *a*) concentration was variable in the different sea areas. Highest Chl *a* concentration was found at some stations in Gulf of Finland and in the Bothnian Sea where it was approximately 10 µg Chl a L^{-1} (Fig 2).

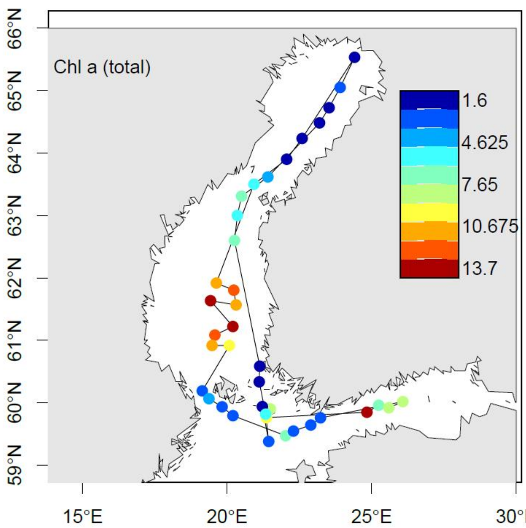

Fig 2. Chlorophyll *a* concentration in µg L^{-1} at the different sampling points. All samples were from 3 m depth.

Based on images taken with an microscopic image analyzer (FlowCam; Fluid Imaging), the phytoplankton community composition was in most southern stations dominated by dinoflagellates (*Biecheleria baltica*) and the ciliate *Mesodinium rubrum*

(Fig 3). North of Åland, diatoms were relatively more abundant with diatom chains of *Skeletonema marinoi*, *Chaetoceros* sp. and *Thalassiosira* sp..

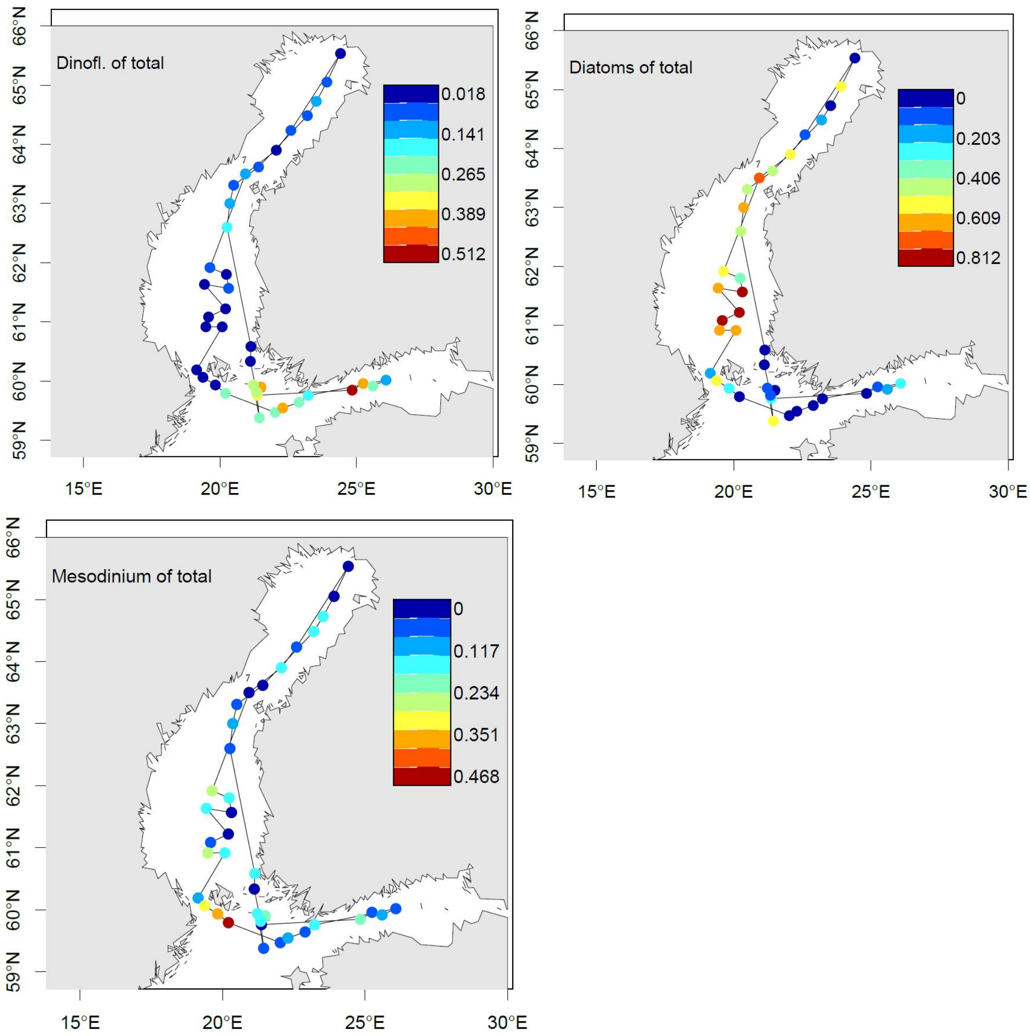

Fig 3. The fraction of dinoflagellates (upper left), diatoms (upper right) and *Mesodinium rubrum* (lower left) of total biomass as estimated with a FlowCam (Fluid Imaging).

2.4. Other parameters

The gross primary productivity was in most stations <1 µg C L^{-1} h^{-1}. Size fractionated incubations revealed that the smaller fraction was quite important (mostly >20% of the total production) to very important (>50%). During the spring bloom the primary production is generally dominated by large phytoplankton (>10 µm), and the finding suggest that the smaller size fractions become relatively more dominating once nitrate have been depleted.

In the Bothnian Sea the smaller size fraction contributed only 10-20% of the primary production suggesting actively growing large phytoplankton. The Chl *a* and inorganic nutrient concentrations suggested that we were sampling close to or at the spring bloom peak in the Bothnian Sea.

The bacterial production was relatively high suggesting that there were organic carbon suitable for bacterial growth. At present we do not yet have any data on the grazing rates of bacteria, but this will be available in the near future.

During the cruise, measurement were obtain from several different oceanographic and meteorological events, and the spatial variability of the partial pressure of CO_2 in the sea surface water was 150 - 600 ppm. The obtained data set will be further analysed in detail at FMI.

2.6. Concluding remarks

The cruise was clearly after the peak of spring bloom in the Gulf of Finland and Archipelago Sea where nitrate was deleted at most of the sampling points. There remaining phosphate was relatively high. In the Bothian Bay there were nitrate left but phosphate was in very low concentration. This reflects the different dynamics during spring in the different sub-basins of the Baltic Sea where the northernmost areas typically is P limited whereas areas more to the south are N limited. In Bothnian Sea the Chl *a* concentration suggested that we were sampling close to or at the peak of the spring bloom, and the very low inorganic NP ratio support the hypothesis that this sea basin is becoming increasingly N limited.

3. Participants

Chief scientist:	Kristian Spilling	SYKE
CTD chief:	Riikka Hietala	FMI
Chief chemist:	Ilkka Lastumäki	SYKE
	Kirsi Hyvärinen	SYKE
	Kimmo Kahma	FMI
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	Markku Jansson	FMI
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	Pekka Kosloff	FMI
	Tero Purokoski	FMI
	Eetu Savilahti	FMI
	Tobias Lipsewers	SYKE
	Jonna Piiparinen	SYKE
	Jan-Erik Bruun	SYKE
	Jouni Heiskanen	Univ. Helsinki
	Tobias Tamelander	Univ. Helsinki
	Riina Klais	Univ. Tartu
	Cristina Sobrino	Univ. Vigo

4. List of stations

Table 1. List of the stations. The observations are explained in chapter 2 and were CTD, nutrients from surface and bottom waters and plankton samples from 3 m depth. The positions indicate where the CTD casts were made.

Index	Station	Position (°N; °E)	Depth	Date and time (UTC)
0207	**AALTO_HKI_**	**N59.5738 E025.1478**	**58.00**	**20150504 1145**
0208	**LL7**	**N59.5079 E024.5027**	**104.00**	**20150504 1458**
0209	**LL7**	**N59.5079 E024.5027**	**104.00**	**20150504 1553**
0210	**AALTO_PI**	**N59.1498 E020.5982**	**98.00**	**20150505 0412**
0211	**UTO_S**	**N59.4550 E021.2200**	**76.00**	**20150505 0855**
0212	**VITHARU**	**N59.5402 E021.2991**	**58.00**	**20150506 0515**
0213	**VITHARU**	**N59.5402 E021.2991**	**58.00**	**20150506 0740**
0214	**IU6**	**N59.5621 E021.1326**	**119.00**	**20150506 1115**
0215	**TPDEEP1**	**N59.2270 E021.2647**	**218.00**	**20150506 1506**
0216	**TPDEEP1**	**N59.2270 E021.2647**	**218.00**	**20150506 1621**
0217	**AALTO_PI**	**N59.1498 E020.5980**	**99.00**	**20150506 2008**
0218	**TPDEEP1**	**N59.2270 E021.2647**	**218.00**	**20150506 2207**
0219	**IU7**	**N59.4891 E021.2020**	**93.00**	**20150507 0308**
0220	**IU3**	**N60.2000 E021.0680**	**50.00**	**20150507 0725**
0221	**IU2**	**N60.3501 E021.0781**	**47.00**	**20150507 1107**
0222	**BMP-C2**	**N62.3590 E020.1550**	**83.00**	**20150508 0505**
0223	**SSN4**	**N63.0001 E020.2148**	**57.00**	**20150508 0800**
0224	**MEK1**	**N63.1851 E020.2997**	**73.00**	**20150508 1115**
0225	**A2A**	**N63.3701 E021.2477**	**38.00**	**20150508 1430**
0226	**JAA7906**	**N64.2900 E023.1200**	**57.00**	**20150509 0500**
0227	**RR7A**	**N64.4352 E023.3177**	**78.00**	**20150509 0730**
0228	**EP2**	**N65.0302 E023.5477**	**30.00**	**20150509 1000**
0229	**A15**	**N65.3178 E024.2524**	**32.00**	**20150509 1815**
0230	**BO4**	**N64.1402 E022.3577**	**90.00**	**20150510 0500**
0231	**SM4**	**N63.5401 E022.0377**	**61.00**	**20150510 0800**
0232	**SPC3**	**N63.3001 E020.5577**	**27.00**	**20150510 1325**
0233	**MS7**	**N61.5501 E019.3781**	**75.00**	**20150511 0500**
0234	**AALTOSM**	**N61.4811 E020.1403**	**112.00**	**20150511 0740**
0235	**EROS13**	**N61.3401 E020.1879**	**124.00**	**20150511 1125**
0236	**JR34**	**N61.3800 E019.2580**	**69.00**	**20150511 1420**
0237	**JR57**	**N61.1320 E020.1219**	**123.00**	**20150512 0500**
0238	**SR5**	**N61.0500 E019.3478**	**125.00**	**20150512 0745**
0239	**NOL48**	**N60.5500 E019.2900**	**100.00**	**20150512 1045**
0240	**NOL45**	**N60.5500 E020.0479**	**82.00**	**20150512 1245**
0241	**F64**	**N60.1134 E019.0855**	**286.00**	**20150513 0455**
0242	**S4B**	**N60.0380 E019.2250**	**181.00**	**20150513 0730**
0243	**F67**	**N59.5600 E019.4980**	**210.00**	**20150513 1100**
0244	**NOL27**	**N59.4750 E020.1230**	**179.00**	**20150513 1400**
0245	**VIP6A**	**N59.2820 E022.0151**	**84.00**	**20150514 0500**
0246	**VIP7**	**N59.3270 E022.1781**	**53.00**	**20150514 0645**
0247	**LL12CN**	**N59.3851 E022.5381**	**50.00**	**20150514 0900**
0248	**LANGDEN**	**N59.4541 E023.1391**	**45.00**	**20150514 1250**
0249	**LL4A**	**N60.0101 E026.0481**	**58.00**	**20150515 0500**
0250	**LL5**	**N59.5501 E025.3582**	**69.00**	**20150515 0700**