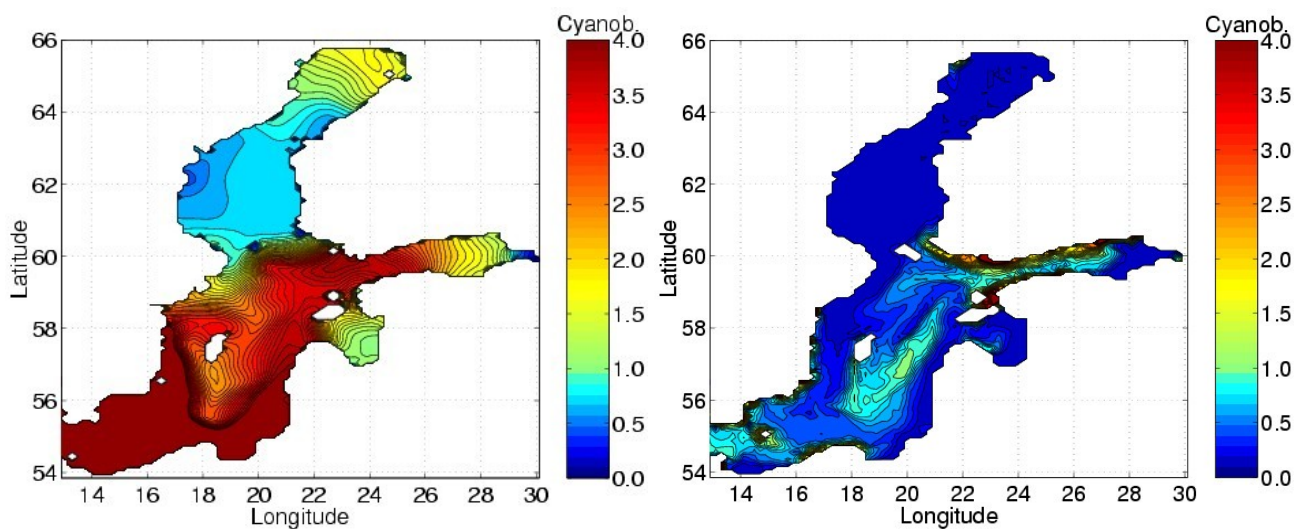




The year 2005

An environmental status report of the Baltic Sea



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Key messages

Two numerical ecosystem models are used to analyse the ecosystem health of the Baltic Sea in the year 2005 in relation to the target and reference levels in the planned Baltic Sea Action Plan of HELCOM.

The results of models run at Finnish Institute of Marine Research (FIMR) and Swedish Meteorological and Hydrological Institute (SMHI) show that in all Baltic Sea regions there are locations which can be considered as eutrophication problem areas based on HELCOM (2006) classification. The same conclusion can be drawn also according to a comparison with Alg@line results from sea areas as Arkona Basin, Bornholm Basin, Eastern Gotland Basin, Northern Gotland Basin and Gulf of Finland.

The winter concentrations of dissolved inorganic phosphorus (DIP) were high in all Baltic Sea regions except Bothnian Bay (and Bothnian Sea according to the SMHI model). In the Arkona Basin and the Bornholm Basin the DIP concentrations were exceptionally high according to Alg@line measurements.

According to the models, the algae blooming was remarkable approximately on 30 % of summer days in the Arkona Basin, eastern regions of Eastern Gotland Basin (including Lithuanian open waters and Gdansk Deep), Gulf of Finland and northern Bothnian Bay.

The chlorophyll a concentration of 2 mg m^{-3} (exceeding the HELCOM acceptable deviation levels) the concentration of 3 mg m^{-3} (indicating remarkable algal bloom) was exceeded for more than 60% and 30% of summer days, respectively, in the Arkona Basin, eastern regions of Eastern Gotland Basin (including Lithuanian open waters and Gdansk Deep), Gulf of Finland and northern Bothnian Bay according to both models. Alg@line 2005 chlorophyll a concentrations were lower than the Alg@line-references in the Arkona and Bornholm Basin, but higher than on Alg@line-references in other regions.

The oxygen concentration in the bottom layers was under the critical limit (of 2 mg/l) for living organisms most of the year in northern parts of the Eastern and Western Gotland Basins and in the Northern Gotland basin.

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1 Introduction

The Baltic Sea Protection Commission (HELCOM) is preparing a new approach to the management of the Baltic Sea. As a part of that process, indicators are needed to illuminate the state of the Baltic in relation to the defined objectives. The defined objectives (reference conditions and tolerable disturbances from them) are discussed in HELCOM (2006) as:

“Reference conditions are the starting point for any assessment. Consequently, their definition is an important step for the assessment of the eutrophication status of a given water body or basin. According to the Water Framework Directive, the reference condition for a given indicator is a description of the chemical and biological quality elements that exist, or would exist, at high status according to the EU Water Framework Directive, that is, with no or only very minor disturbance from human activities.”

“There is an urgent need for further coordination and harmonization in terms of indicators and time periods that the assessment should cover (seasonally and/or single year, multiple year (mean, running mean)).”

Nutrients and their ratios form the preconditions for harmful algal blooms as well as the overall eutrophication. The standard HELCOM COMBINE program monitors the Baltic Sea several times a year. As low-frequency COMBINE sampling cannot adequately cover short-term changes in the state of the Baltic Sea brought about by seasonal processes, other relevant mapping methods are needed. The combination of [Alg@line](#) monitoring and ecosystem models used in the current project reveals the short-term fluctuations in the Baltic environment.

The observed and modelled nutrient and phytoplankton conditions need to be related to their respective reference and target levels when interpreting the state of the marine environment. The comparison with averages of the years 1993-2004 (Alg@line-reference) represents deviation of this year from the present state of the Baltic Sea. The comparison with the reference levels and acceptable deviation values by HELCOM (2006) reveals the deviation from the goals specified by HELCOM and the state of the Baltic Sea before 1950s.

The Baltic Sea is strongly affected by seasonality: during the winter the water is rich in nutrients, but as long as the surface water stratification remains weak and the availability of light is limited, the phytoplankton biomass remains low. As a consequence of initiation of thermal stratification in the surface water and increasing day length in spring, the biomass of phytoplankton increases massively during a short period. When the dissolved nitrogen is depleted from the surface water the algal biomass decreases significantly. As the spring algal production maximum is typically terminated by exhaustion of nitrogenous nutrients from surface water, the amount of phosphate left over varies between the years depending on the prevailing ratio of these major nutrients in water. When the seawater warms up during the summer, the blue-green algae become more common utilizing the surplus phosphate. The occasional upwelling events of deeper, nutrient rich water can stimulate the algal growth.

The amount of nutrients together with temperature variation and the amount of light form the basis for phytoplankton succession of phytoplankton production. Nutrient concentrations as such indicate the level of eutrophication in a sea basin. Chlorophyll *a* concentration can be used as a relative measure (proxy) of

phytoplankton biomass in the water. Since high nutrient concentrations increase the intensity and frequency of phytoplankton blooms, chlorophyll *a* can be used as an indicator of the eutrophication level in sea basin.

This is the second year joint status report for the Baltic Sea area carried out by FIMR and SMHI as a part of the project BANSAL, supported by the Nordic Council of Ministers' Sea and Air Group. The aim of the project is to integrate marine observations and ecological model simulations in an annual assessment of the Baltic and the North seas.

2 Material and Methods

2.1 Modeling approach

The state of the Baltic Sea was analyzed with two state-of-the-art ecosystem models: one calculating daily forecasts at FIMR and another that is coupled to the climate model of SMHI Rossby Centre.

2.1.1 FIMR

The model is based on the MIT GCM (Marshall et al., 1997). The model is realized for the Baltic Sea on a spherical polar grid using the bathymetric data of Seifert & Kayser (1995) (cf. Fig. 1). The spatial discretization is made with a minimum filter for bottom topography at 6 nautical mile intervals, with 21 layers in the vertical. The southwestern corner of the grid is located at 53.85° N, 8.7° E, with 120 grid cells in the latitudinal and 108 grid cells in the longitudinal direction.

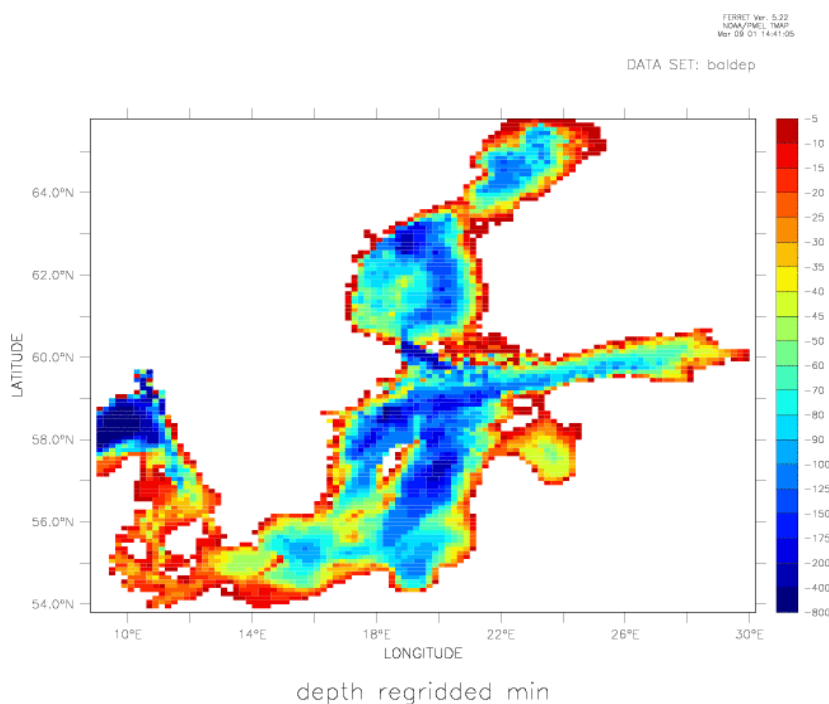


Figure 1.: Bathymetry and model area used in the BalEco model

The vertical resolution is concentrated to the euphotic zone. The topmost layer thickness is 3 meters, but is reduced to 2 meters in the minimum for cells hugging the coast. Four subsequent layers in the vertical have a thickness of 2 meters, with an increase through 3.3 meters (3 layers) to 6 meters (10 layers).

Several numerical algorithms within the MIT GCM model could be applied to the study of the Baltic; here, a linearized, implicit free surface is used in the model integrations and checked for volume conservation. We opt for a non-linear flux-limited advection scheme for all tracers to retain the positive definiteness of the ecological variables, which are also calculated within the model. The sub-grid scale turbulence is represented in the model with the non-local KPP closure Large et al (1994) in the vertical. Due to non-linear stability constraints, a horizontal harmonic as well as biharmonic diffusivity is applied ($k_2 = 50 \text{ m}^2 \text{ s}^{-1}$, $k_4 = 10^{11} \text{ m}^4 \text{ s}^{-1}$). The horizontal turbulent Prandtl number is set to 4 to ensure numerical stability.

Initial conditions

Both physical and chemical initial conditions for the model integrations were obtained from the continuous state estimates calculated by the model, and augmented with winter monitoring data obtained by FIMR within the HELCOM COMBINE program in January-February 2005. The observed values were interpolated in three dimensions with a robust nearest neighbor interpolation. These observed initial fields for the Baltic Sea were supplemented by climatological values for the North Sea from the World Ocean Atlas¹.

However, the monitoring data was not available immediately after the observations. Therefore the assimilation of new information to the model was delayed, and updated fields were included in the model only at the end of spring 2005.

Boundary conditions

The physical atmospheric forcing is taken from the ECMWF operational forecasts. Atmospheric fluxes calculated from the air temperature, humidity and wind by the bulk formulae in the model as well as radiation fluxes calculated by the ECMWF atmospheric model are used as driving forces. Climatological means of the freshwater flux from 18 rivers in the Baltic catchment area is used as a representation of the coastal runoff.

The increase in mean sea surface height in the model domain due to river runoff and precipitation was validated. An open boundary with a sponge layer in the North Sea was investigated, but was not properly validated. Therefore, for the present purposes no open boundary is used, but the initial conditions and their development in the North Sea provided the required boundary conditions for the Baltic Sea through the Danish Straits.

The surface average of 0-6m from the model results is used in this analysis. The BalEco model results in the beginning of the year 2005 are affected by an error in assimilation of observations. The results will be re-produced and figures presented here must be considered as drafts.

¹ <http://www.nodc.noaa.gov>

2.1.2 SMHI

A high-resolution 3D coupled biogeochemical-physical ocean model has been developed to investigate the Baltic Sea response to climate variations and anthropogenic activities on time scales of 100 years (Eilola and Meier, 2006). The model system is based on the Swedish Coastal and Ocean Biogeochemical model (SCOBI) (Marmefelt et al., 1999; 2000; 2004; Eilola et al., 2006; Eilola and Sahlberg, 2006) (Fig.1) and the Rossby Centre ice-ocean circulation model (RCO) (Meier et al., 2003; Meier and Kauker, 2003).

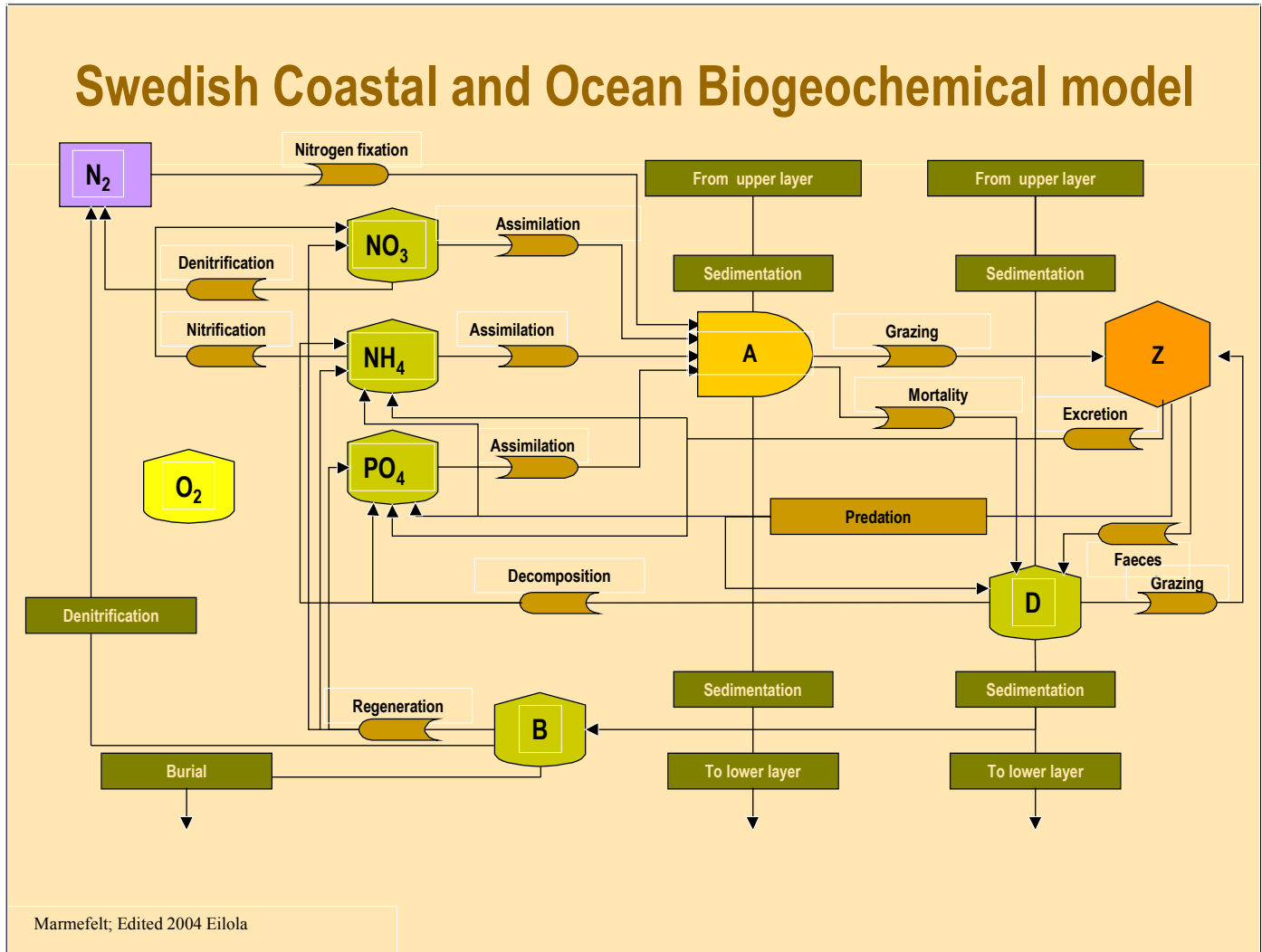


Figure 2: The SCOBI model contains nitrate (NO_3), ammonium (NH_4), phosphate (PO_4), autotrophs (A1, A2, A3), zooplankton (ZOO), detritus (DET), and oxygen (O_2). Hydrogen sulfate (H_2S) is included as negative oxygen. The sediment (B) contains nutrients in the form of benthic nitrogen (NBT) and phosphorus (PBT). The sediment module includes sediment re-suspension and aggregated process descriptions for oxygen dependent nutrient regeneration, denitrification and adsorption of ammonium to sediment particles as well as permanent burial of organic matter.

The surface layer of 3-6m is used in this analysis.

2.1.3 Classification method

The modeled concentrations of nutrients and chlorophyll were scaled with the reference conditions and the target values. The resulting indicator p_i was defined for concentration C_i as

$$p_i = (C_i - R_i) / (T_i - R_i)$$

where R_i is the HELCOM (2006) reference and T_i is the acceptable deviation level. Values < 1 are within the acceptable deviation, whereas > 1 are higher than acceptable deviation. Values between 0-1 are between reference conditions and acceptable deviation and values under 0 are under reference conditions.

HELCOM (2006) classification of the state of the Baltic sea marine environment is based on the “one out, all out” principle, which means that if one of the examined variables excess the acceptable deviation then the sea area is classified as an eutrophication problem area. To be a non-eutrophication problem area all variables examined should be under the acceptable deviation, which means that the value of calculations above should be < 1 .

The values from classification calculations above are presented in chapter 4.1. Recognising the maturing state of the reference condition definition, the “one out, all out” principle was not applied to the graphs. Rather, it is left for the viewer to analyse how representative the result would be.

2.2 Indicators, reference conditions and acceptable deviation

The indicators used in this report to evaluate the state of the sea environment can be grouped for three different categories. 1) *The causative factors* as nutrient concentrations and -ratios on the surface layer of the sea, 2) *the direct effect indicators* as chlorophyll *a* (Chl *a*) and cyanobacterial concentrations on the surface layer of the sea and 3) *the indirect effect indicator* as oxygen concentration in bottom layer of the water body are analysed in this report. The used nutrient concentration and ratio indicators are winter concentrations of dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP), DIN:DIP -ratio and DIN:silicate (SiO_4) -ratio.

In this report the classification of the state of the Baltic Sea is based on reference conditions and recommendations defined by HELCOM proceeding of “Development of tools for assessment of eutrophication in the Baltic Sea” (HELCOM, 2006) and additionally on comparison of the Alg@line measurement time series. The Alg@line measurements carried out year 2005 are compared to the corresponding 12year averages of Alg@line measurements.

The *reference conditions* and *acceptable deviation* from HELCOM (2006) are presented in Table 1. Nutrient values are winter averages and Chl *a* -values are summer averages. The reference levels present the state of the open Baltic Sea at times of no, or only very minor, anthropogenic influence. The upper limit, acceptable deviation, has been defined as +50% of the corresponding reference conditions. The deviation shall be justified, but not exceed 50%. Defining reference conditions and acceptable deviation is an ongoing process, and in great importance for developing appropriate reference and target values for the each sea area separately. Reference conditions used here are tentative values, but the best available information. The reference conditions are developed by using historical data, modeling and expert judgment (HELCOM, 2006).

BANSAI: Baltic Sea environmental status report year 2005

Table 1: Used reference conditions and acceptable deviation values in open sea regions

Basin number	Basin name	DIN		DIP		Chla		DIN/DIP	DIN/SiO4
		Ref.	Ad.	Ref.	Ad.	Ref.	Ad.	Ref.	Ref.
1	Bothnian Bay	3,500	5,25	0,10	0,15	1,00	1,50	16	1
2	Bothnian Sea	2,000	3,00	0,20	0,30	1,00	1,50	16	1
3	Gulf of Finland	2,500	3,75	0,30	0,45	1,20	1,80	16	1
4	Northern Gotland Basin	2,000	3,00	0,25	0,38	1,00	1,50	16	1
5	Gulf of Riga	4,000	6,00	0,13	0,20	1,10	1,65	16	
6	Western Gotland Basin	2,000	3,00	0,25	0,38	1,00	1,50	16	
7	Eastern Gotland Basin	2,290	3,44	0,35	0,53	1,40	2,10		
7b	Lithuanian open waters	5,000	7,50	0,30	0,45	3,00	4,50	16	
7c	South East Gotland Basin	2,500	3,75	0,25	0,38	1,40	2,10		
7d	Gdansk Deep	4,250	6,38	0,25	0,38	1,40	2,10		
8	Bornholm Basin	1,700	2,55	0,34	0,51	1,40	2,10		
9	Arkona Basin	2,440	3,66	0,29	0,44	1,40	2,10		

Reference values (Ref.) and acceptable deviation (Ad.) are from:

	Helcom, 2006. Baltic Sea Environ. Proc. No. 104
	Calculated 150% of reference value
	Value from neighbouring basin

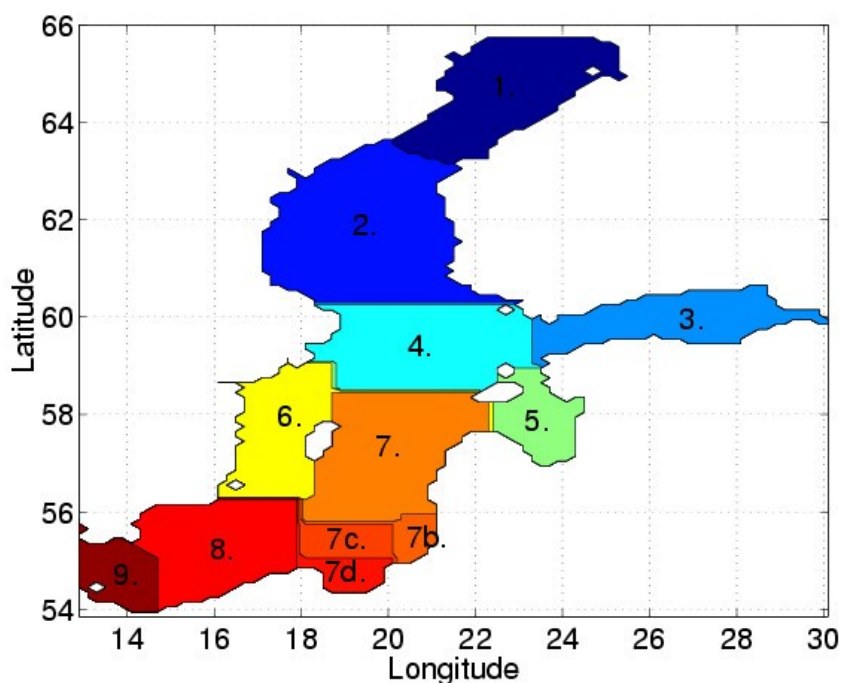


Figure 3: Baltic Sea regions presented in Table 1.

2.3 Observations used

The observations used to validate model results in this report are Alg@line ship-off-opportunity measurements from year 2005 (later: Alg@line 2005). The corresponding 12 years averages from years 1993-2004 Alg@line observations are used as an additional reference conditions (later: Alg@line reference). Both Alg@line 2005 and Alg@line reference –measurements were carried out each year at the same locations.

Alg@line is a research program led by the Finnish Institute of Marine Research (FIMR) that monitors extensively fluctuations in the Baltic Sea ecosystem both in space and time. The main emphasis of Alg@line is to adequate monitoring of the phytoplankton, especially harmful algae blooms (Rantajärvi, 2003). The measurements are based on automatically collected water samples from the 24 stationary locations (Fig. 17) for biological and chemical purposes. The sampling is carried out at least once a week on spring-, summer- and autumn, but about once a month in winter (from October to March). The depth of measurements was at the water intake in the ship hull at about 5 meters depth. Since the ship hull mixes the water to substantial degree, the measurements represent the conditions of the surface layer of the sea.

3 Model results

3.1 Baltic Sea region -seasonal averages

3.1.1 Nutrients

Seasonal averages of indicators were derived from the model results. According the validation calculations presented later in this report the RCO-Scobi overestimates the DIP values in the Gulf of Finland, but otherwise both models underestimate DIP and DIN values. Bothnian Sea and Basin are not presented in validation calculations.

Dissolved inorganic phosphorus

The average of wintertime surface layer nutrient concentration presented in Fig 4 (DIP) and 5 (DIN) varies between the two models. The DIP mean winter value varies between 0.01 and 1 μM for the most of the Baltic Sea in both model results. On the RCO-Scobi model the highest values are found in the Gulf of Finland, Gulf of Riga and on the south coastline of the Bornholm and Arkona Basins. Also in the Eastern Gotland Basin and whole Bornholm Basin the values rises above 0.7 μM . The lowest values are in the Bothnian Sea and Bothnian Bay. On the BalEco values past 0.7 μM only in the Bornholm and Western Gotland basin and in the Gulf of Finland and the lowest values are in Bothnian Bay.

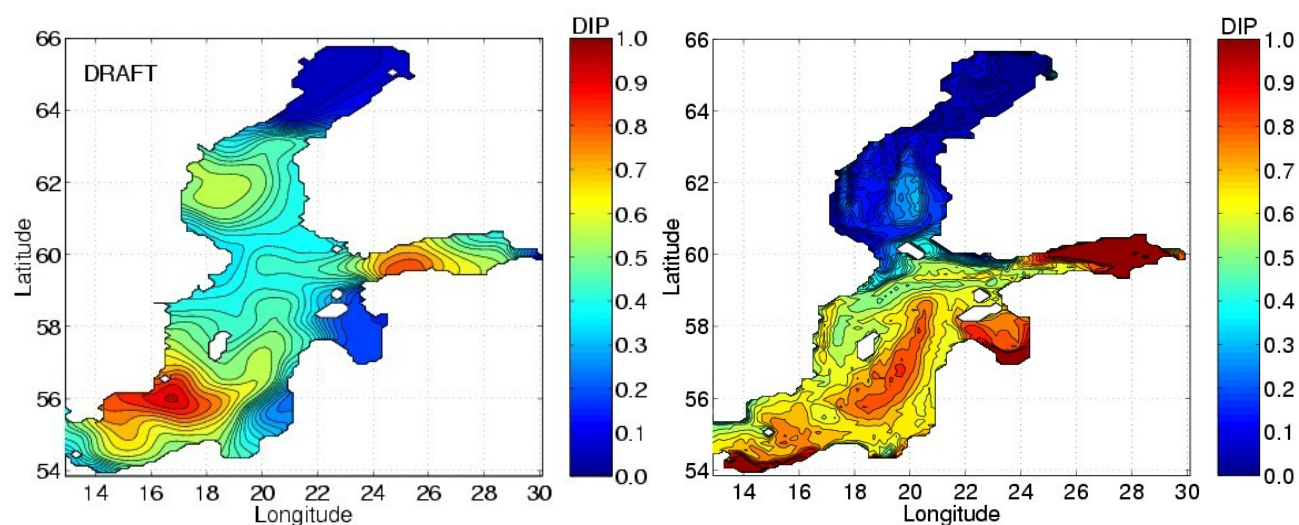


Figure 4: The surface water winter mean of dissolved inorganic phosphate ($PO_4 \mu\text{mol l}^{-1}$) on the Baltic Sea, BalEco left, RCO-Scobi right.

Dissolved inorganic nitrogen

The average of wintertime surface layer DIN varies between $0.1 \mu\text{M}$ and $8 \mu\text{M}$ for the most of the area. In the RCO-Scobi results the DIN concentrations exceeds $8 \mu\text{M}$ only in the Eastern Gulf of Finland, Gulf of Riga and Eastern coast near regions. The lowest values are found in the Bothnian sea.

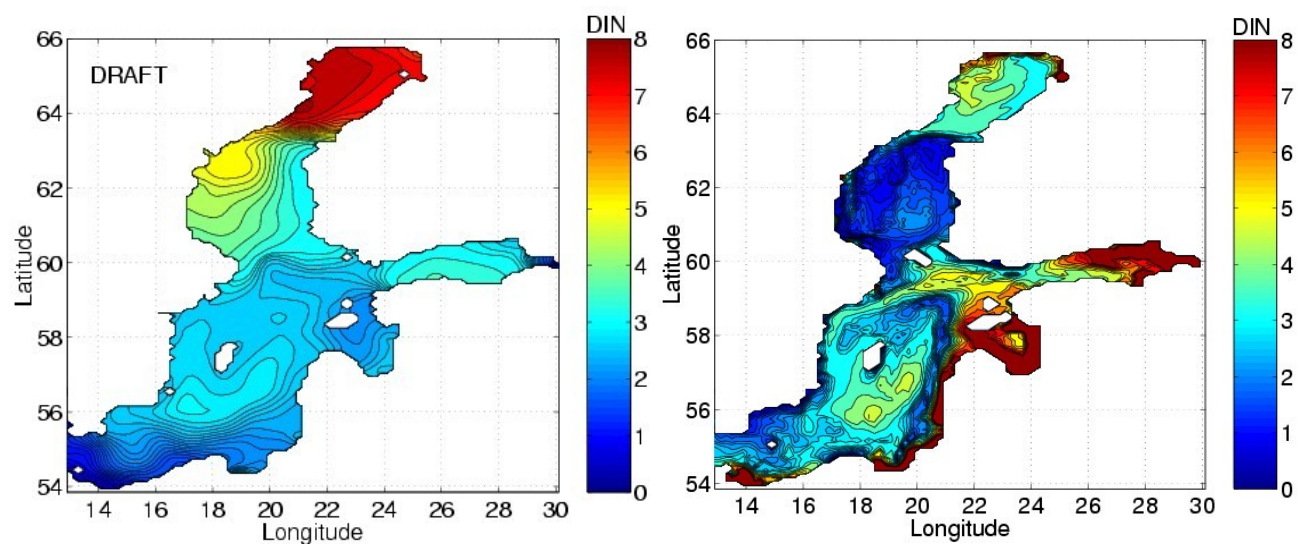


Figure 5: Idem, but dissolved inorganic nitrogen ($NO_3+NO_2 +NH_4 \mu\text{mol l}^{-1}$), BalEco left, RCO-Scobi right.

Nitrogen to phosphorus ratio

The average of wintertime surface layer DIN/DIP ratio presented in Fig. 6 exceeds the Redfield-ratio (16) only in the Bothnian Bay and some very coastal regions. It is mostly under 8 μM .

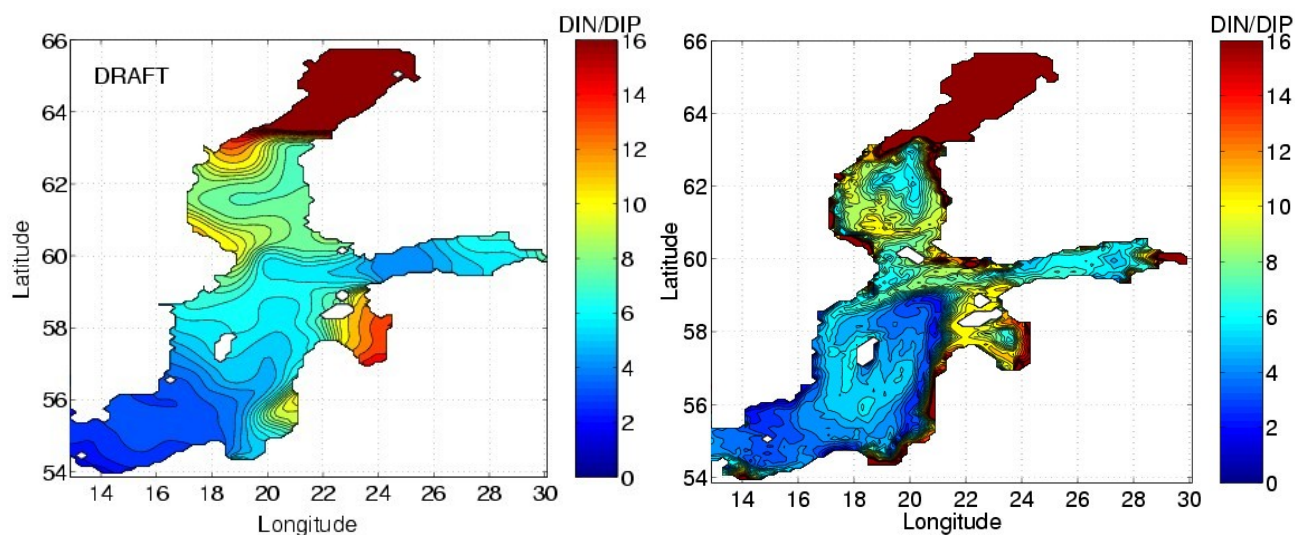


Figure 6: *Idem*, but ratio of dissolved inorganic nitrogen and -phosphate ($(\text{NO}_3 + \text{NO}_2 + \text{NH}_4)/\text{PO}_4 \mu\text{mol l}^{-1}$), BalEco left, RCO-Scobi right.

Nitrogen to silicate ratio

The winter mean DIN/SiO_4 -ratio exceeds 1 only in the eastern Gulf of Finland and in the Gulf of Riga (Fig. 5).

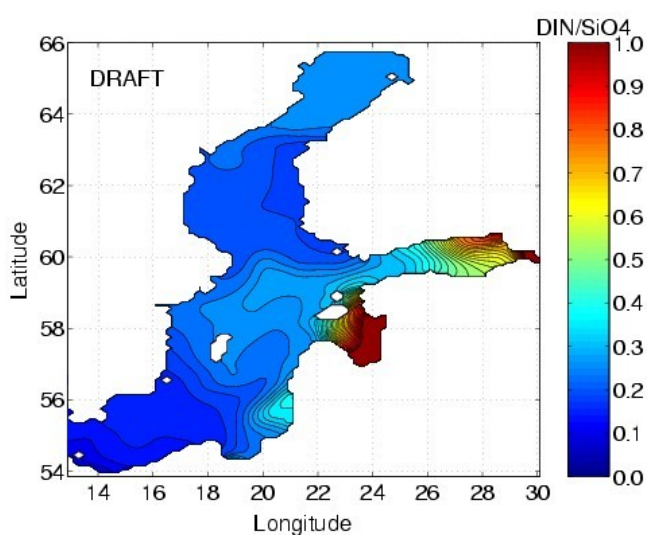


Figure 7: *Idem*, but ratio of dissolved inorganic nitrogen and silicate ($(\text{NO}_3 + \text{NO}_2 + \text{NH}_4)/\text{SiO}_4 \mu\text{mol l}^{-1}$). BalEco.

3.1.2 Chlorophyll *a*

Chlorophyll *a* summertime (June-September) surface water average is presented in Fig. 6. The RCO-Scobi's values are higher than those of BalEco and exceeds 4 mg m^{-3} in gulfs and coastal regions especially in south and east. The BalEco's results do not exceed 4 mg m^{-3} in any regions. The value 2.5 mg m^{-3} is exceeded in Bothnian Bay, Gulf of Riga and southern Baltic Sea. There is some uncertainty in model Chl *a* results due the simplified calculations of the Chl *a* – N – C relations in the algae bloom cell.

The days of the summer period (June-September) when the Chlorophyll *a* concentration exceeds 2 or 3 mg m^{-3} are presented in Fig. 7. The concentration of 2 mg m^{-3} was exceeded for more than 60% of summer days and the concentration of 3 mg m^{-3} was exceeded for more than 30% of summer days in regions as the Arkona Basin, eastern regions of Eastern Gotland Basin (including Lithuanian open waters and Gdansk Deep), Gulf of Finland and northern Bothnian Bay according to both models.

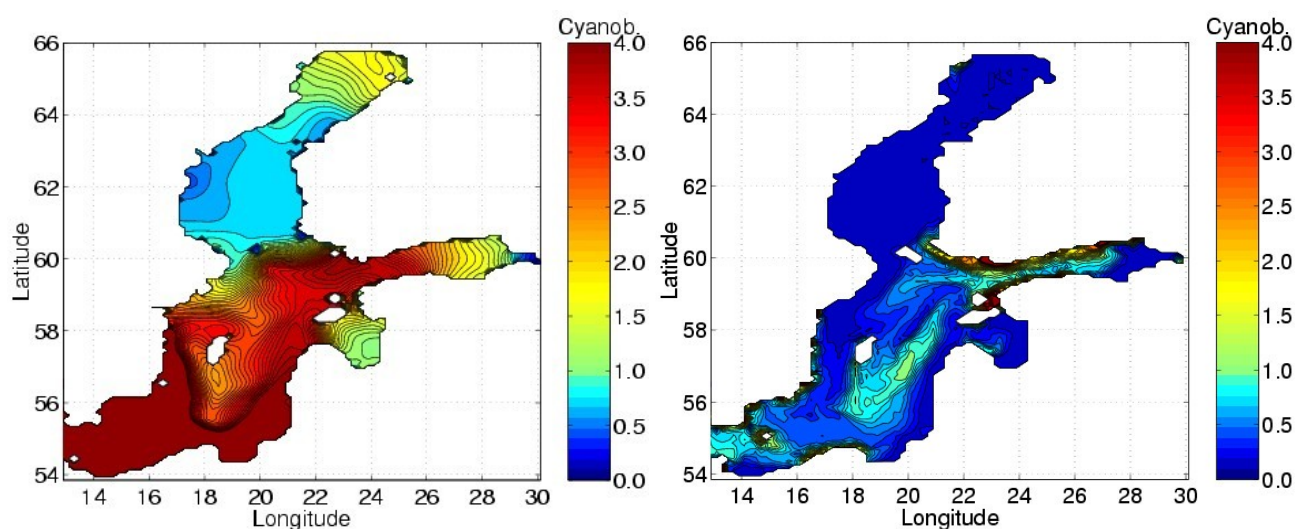


Figure 8: The surface water summer (June-September) mean of chlorophyll *a* ($\mu\text{g/l}$) on the Baltic Sea, BalEco left up, RCO-Scobi right up. And the surface water July-August mean of cyanobacteria, BalEco left down, RCO-Scobi right down.

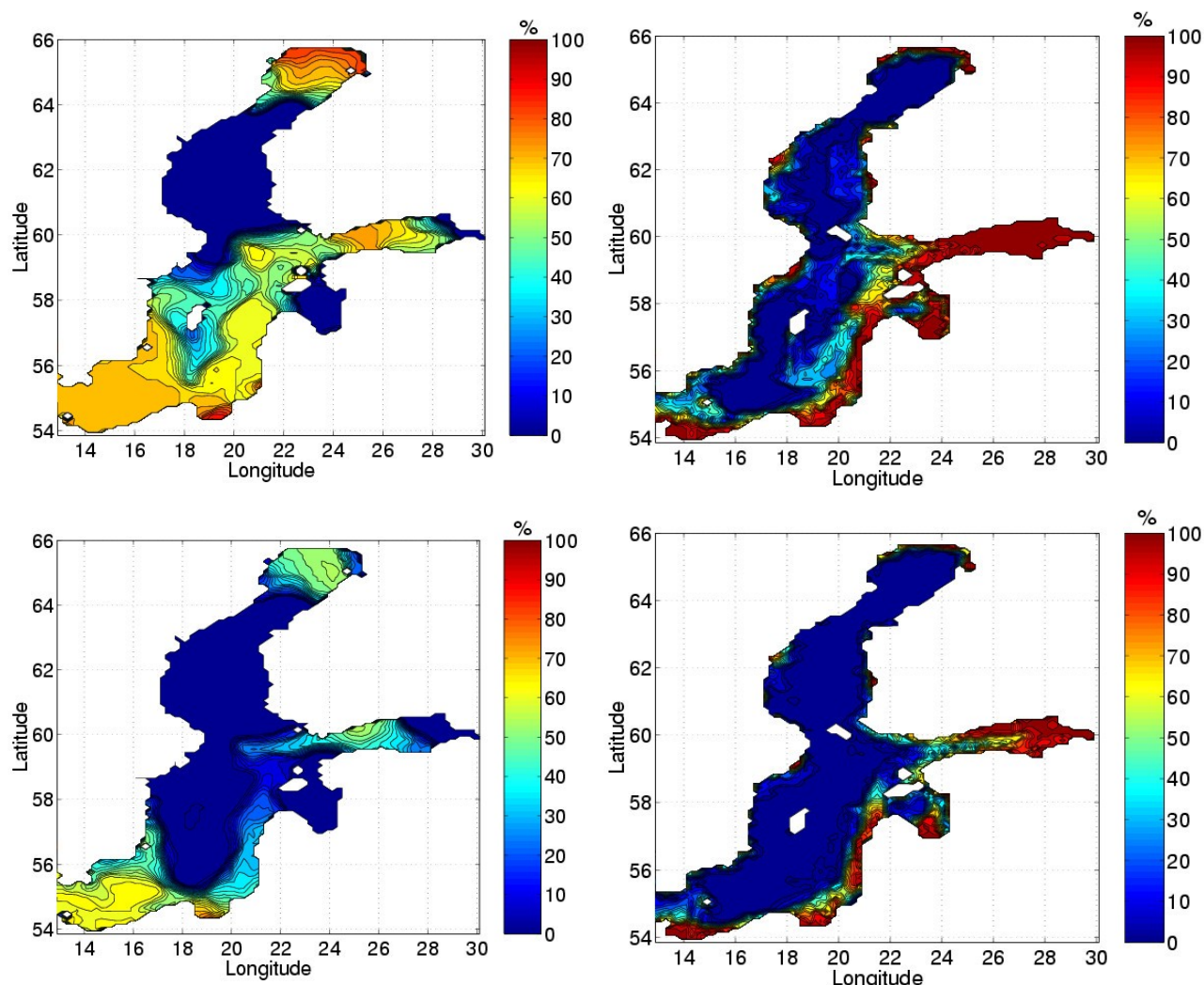


Figure 9: The proportion of summer days when the surface water chlorophyll a (mg m^{-3}) concentration was above 2 (up) and was above 3 (down) in the Baltic Sea. BalEco left, RCO-Scobi right.

3.1.3 Oxygen

The oxygen minimum of the year 2005 (Fig. 8 left) is near 0 ml/l in the Gotland Basins and Bornholm Basin according to RCO-Scobi. The Fig. 8 right side shows the percentage amount of days when the oxygen level in bottom layer was under 2 ml/l, which is a critical value for most of the living organisms (HELCOM, 2006). In the northern parts of the Eastern and Western Gotland Basins and in the Northern Gotland Basin the situation of the year 2005 was critical. The oxygen concentration in these regions was under the critical value of 2 ml/l for the most of the year.

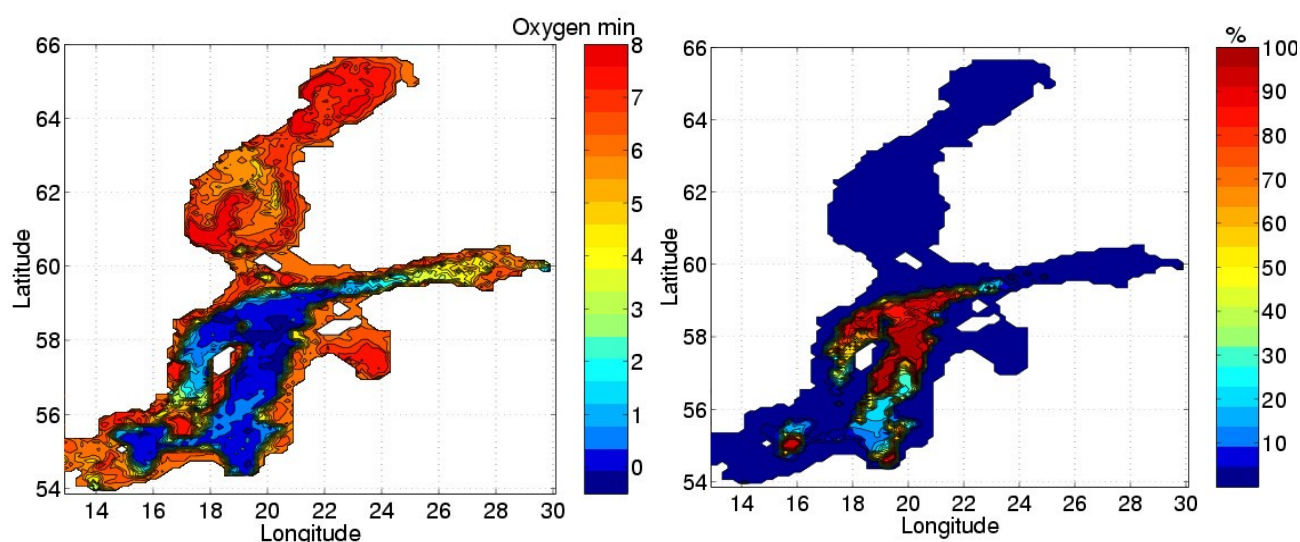


Figure 10: The minimum oxygen value in the Baltic Sea bottom (left) and the per cent of days of the year 2005, when the oxygen concentration decreased under 2 ml/l. RCO-Scobi.

4 Ecological status classifications

4.1 Scaled model results – seasonal averages

The Figures 11, 12 and 13 represent the scaled deviation of the variable concentrations (DIP, DIN and Chl *a*) from HELCOM reference levels and acceptable deviation levels in Table 1. From the scaled figures 11 (DIP), 12 (DIN) and 13 (Chl *a*) the deviation of the variable concentrations from HELCOM reference levels and acceptable deviation levels are presented. When the scaled value is below zero the model result is lower than the reference value, when the scaled value is between 0 and 1 the model result is between the reference and the acceptable deviation, and when the scaled value is above 1 the model result has exceeded the acceptable deviation.

HELCOM (2006) classification of the state of marine environment is based on the “one out, all out” principle, which means that if one of the examined variables excess the acceptable deviation the sea area is classified as an eutrophication problem area. To be a non-eutrophication problem area all variables examined should be within the limits of the acceptable deviation.

At least one of the variables DIN, DIP or Chl *a* exceeded the acceptable deviation values in all sea regions in 2005. That defines that all regions of the Baltic Sea were eutrophication problem areas. However, if winter nutrient values of BalEco are excluded, the open sea areas of the Bothnian Sea can be regarded as non-eutrophication problem area.

The average of wintertime surface layer DIN/DIP ratio presented in Fig. 6 exceeds the HELCOM reference level (Redfield-ratio) only in the Bothnian Bay and some very coastal regions. The winters mean DIN/SiO₄ –ratio exceeds HELCOM reference level (1) only in the eastern Gulf of Finland and in the Gulf of Riga (Fig. 7).

4.1.1 Nutrients

Dissolved inorganic phosphorus

In RCO-Scobi results the winter DIP exceeded the acceptable deviation levels in all other regions except in the Bothnian Sea and Bay. In BalEco results the winter DIP exceeded the acceptable deviation in the Bothnian Sea, Gulf of Finland, middle of Northern Gotland Basin, Western Gotland Basin, part of Eastern Gotland Basin (including South East Gotland Basin and Lithuanian open waters), Bornholm Basin and in some parts of the Arkona Basin.

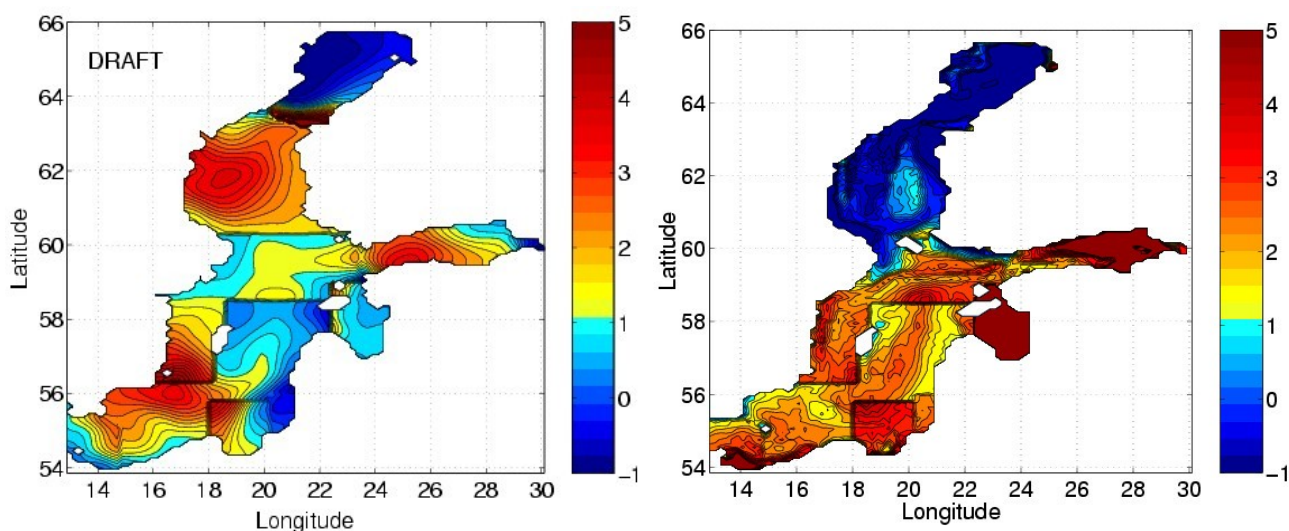


Figure 11: The surface water winter DIP, scaled with the formula given in Section 2.3 with *Ri ja Ti*-values. BalEco left, RCO-Scobi right.

Dissolved inorganic nitrogen

The BalEco DIN values exceeded the acceptable deviation only in the Bothnian Bay and Sea and in the northeast parts of the Gotland Basin, and in RCO-Scobi the winter DIN exceeded the acceptable deviation more locally and in smaller regions, but also in same sea basins.

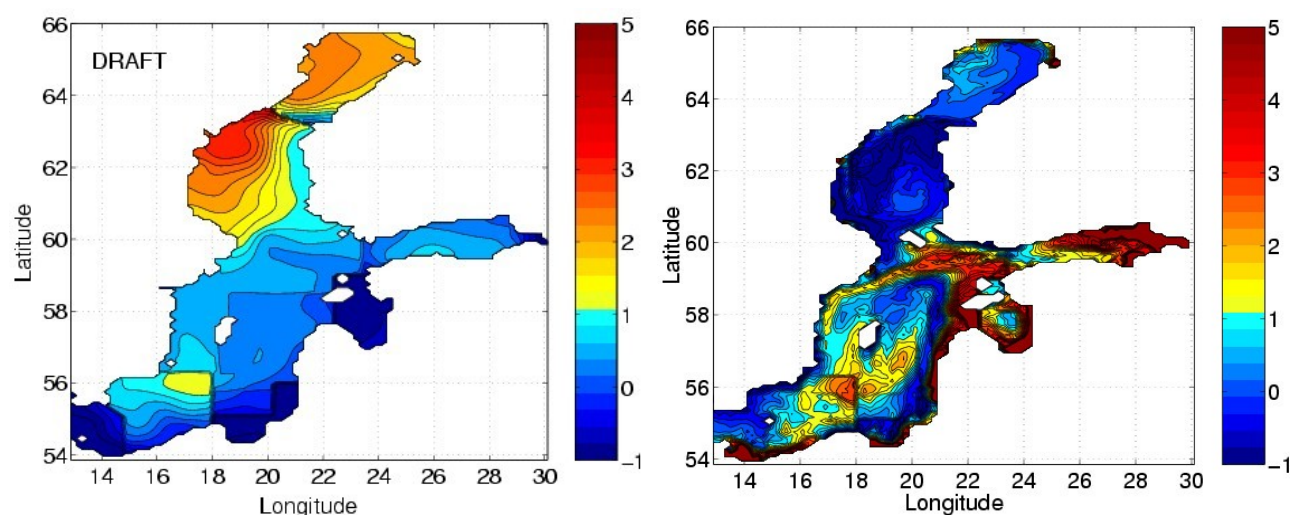


Figure 12: *Idem*, but DIN. BalEco left, RCO-Scobi right.

4.1.2 Chlorophyll a

The BalEco results of the Chl_a summer average exceeded the acceptable deviation value in all other regions except Bothnian Sea, Eastern Gotland Basin (including Lithuanian open waters) and Gulf of Riga. The RCO-Scobi results exceeded acceptable deviation values in all regions, mostly in the Gulf of Finland and Gulf of Riga.

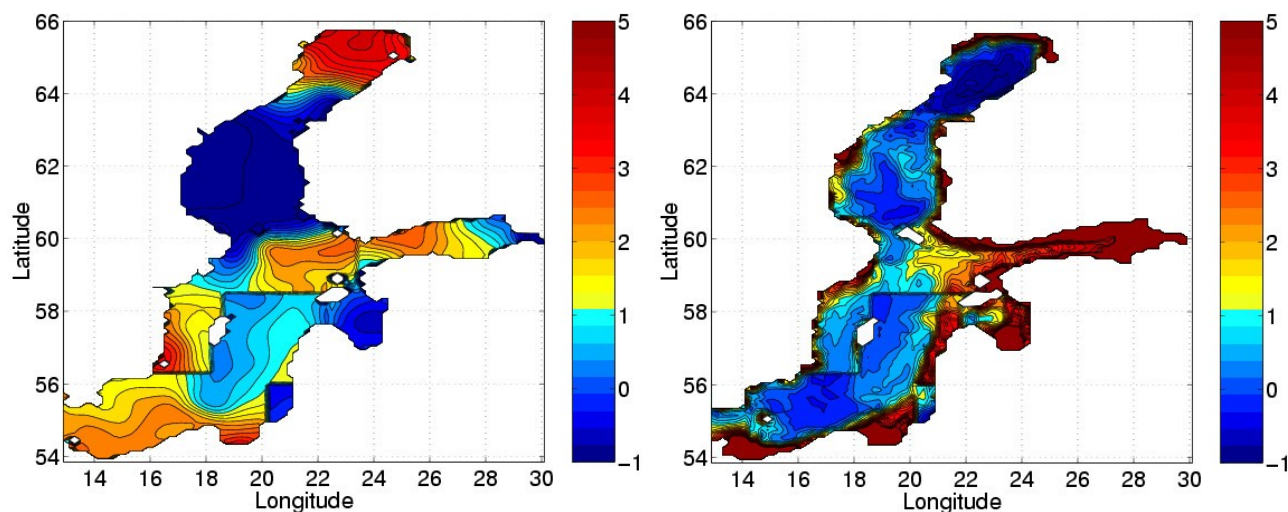


Figure 13: *Idem*, but scaled surface water summer mean chlorophyll a. BalEco left, RCO-Scobi right.

5 Alg@line comparison –annual variability

The annual variability of examined variables on Alg@line water sample locations (Fig. 17) are presented by Alg@line results from year 2005, Alg@line reference conditions (average between years 1993-2004) and by both models in Fig. 12 (DIP), 13 (DIN), 14 (DIN/DIP-ratio), 15 (DIN/SiO₄-ratio) and 16 (Chla). The comparison of Alg@line 2005 observations and reference conditions is discussed in following sections as well as the agreement of model results and Alg@line 2005 observations. More detailed calculations of model validation are included in the Annex.

5.1 Nutrients

Dissolved inorganic phosphorus

On the years 2005 Alg@line observations the highest surface water DIP concentrations were found in the Bornholm Basin and in the Gulf of Finland. In the Arkona Basin and the Bornholm Basin the concentrations were exceptionally high during the whole year. The difference between Alg@line concentrations of the year 2005 and the Alg@line-reference concentrations was significant. The measured DIP concentration was above the Alg@line-reference in all regions.

Both models underestimate winter DIP concentrations at the whole study area except RCO-Scobi overestimates DIP concentrations in the Gulf of Finland. The BalEco is more close to the observations on the Bornholm Basin, but RCO-Scobi model on other regions.

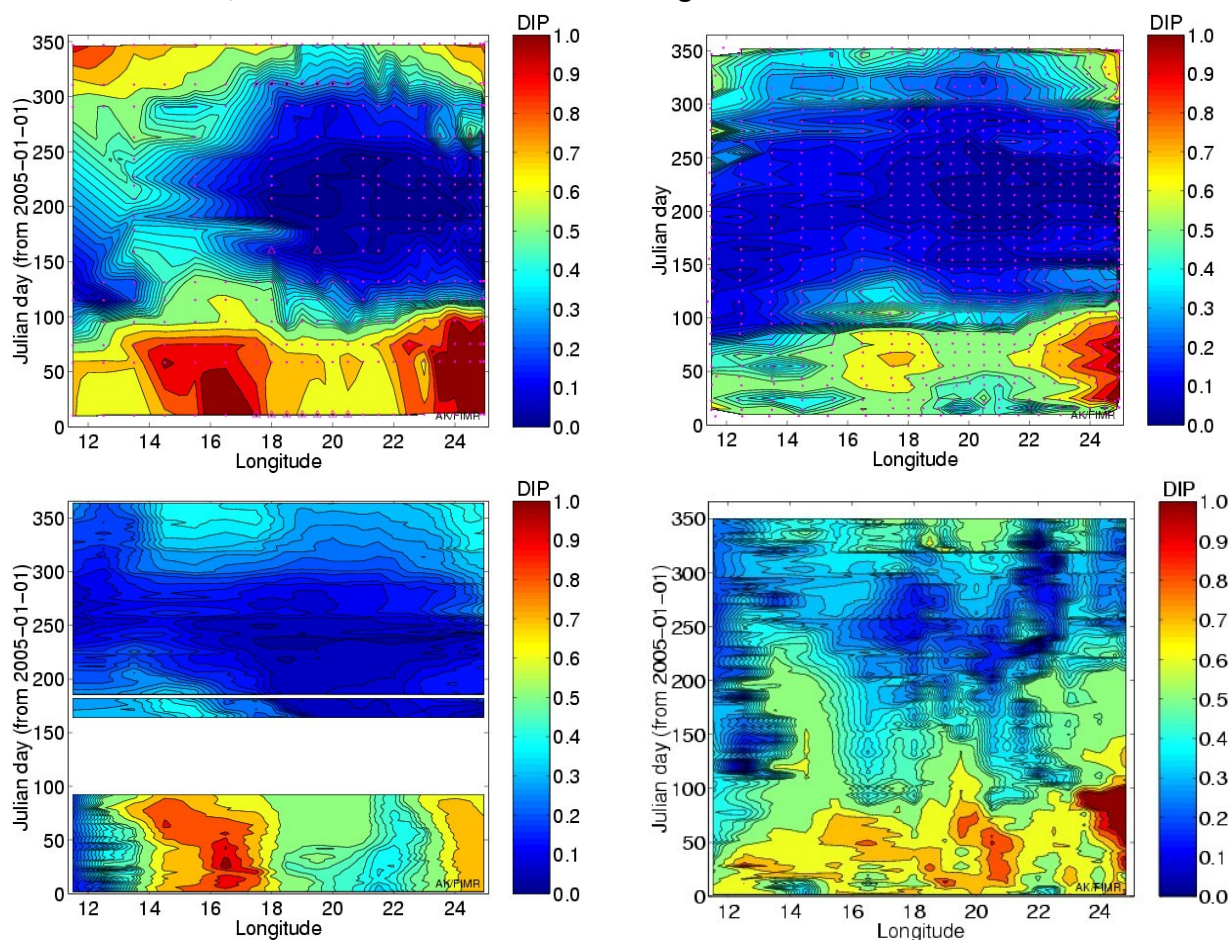


Figure 14: Surface DIP on Alg@line route. Left up are Alg@line measurements of the year 2005. The figure is based on red dots, which represents the measurements place and time. Right up is 1993-2004 average of Alg@line measurements. Left down is BalEco model results on the year 2005 and right down is RCO-Scobi model results of the year 2005.

Dissolved inorganic nitrogen

On the year 2005 Alg@line observations the highest early spring levels of DIN surface water concentrations were found in the Arkona Basin and at the entrance to and within the Gulf of Finland. The decrease of the spring values in Alg@line 2005 concentrations and Alg@line-reference occurred at the same time, but in Alg@line 2005 observations the autumn DIN concentrations started to rise earlier in the Gulf of Finland, but later in other regions.

Both models underestimate winter DIN concentrations.

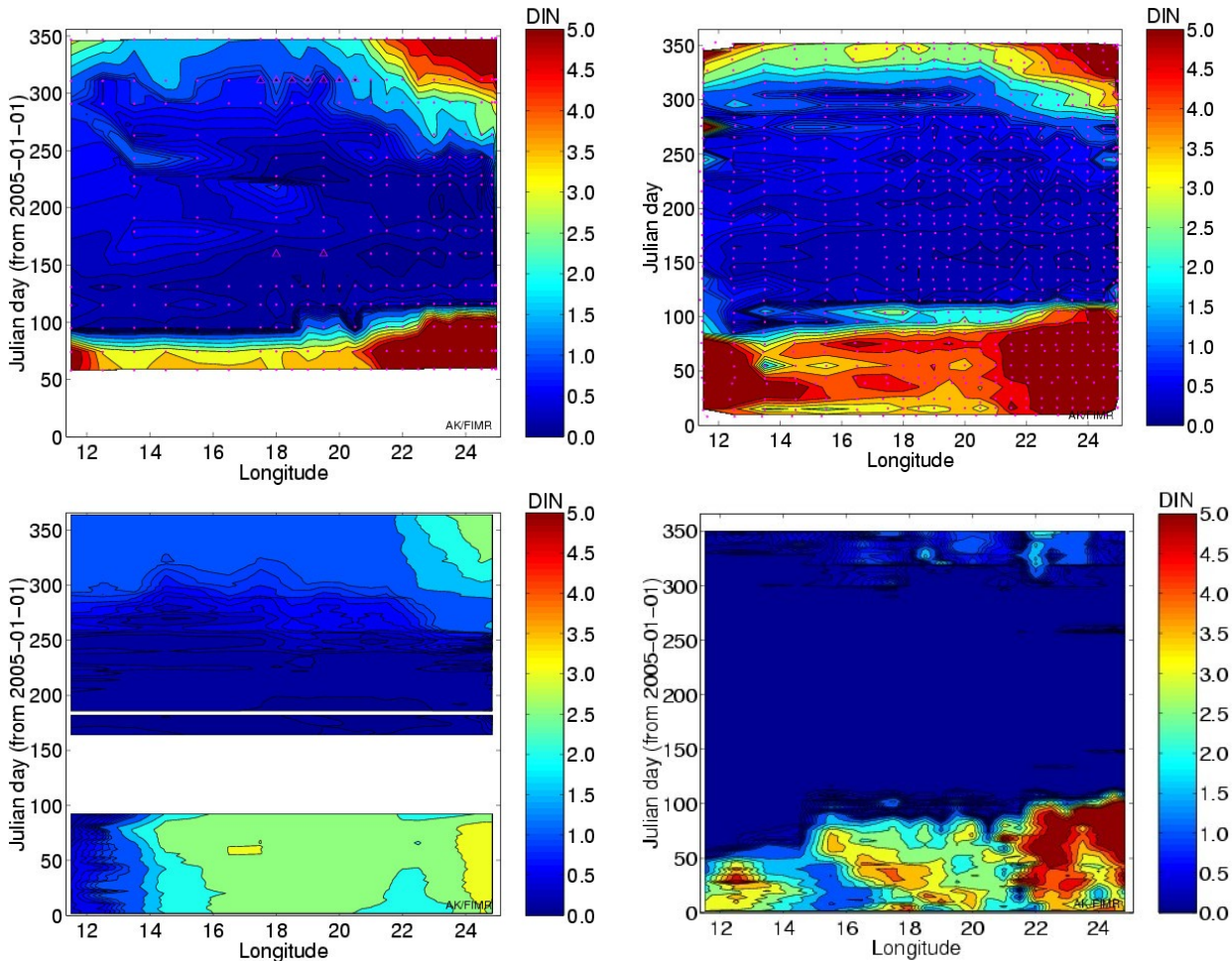


Figure 15: *Idem*, but DIN. Left up Alg@line results from the year 2005, right up Alg@line average 1993-2004, left down BalEco model 2005, right down RCO-Scobi model 2005.

Nitrogen to phosphorus ratio

The results received from the Alg@line 2005 show that the DIN:DIP ratio exceeded the HELCOM (2006) reference value ($16 \mu\text{mol l}^{-1}$) only once: In the Northern Gotland Basin in the beginning of September. In the Arkona and Bornholm Basin the Alg@line 2005 DIN:DIP ratio was lower than the Alg@line-reference.

The BalEco overestimates and RCO-Scobi model underestimates the DIN:DIP-ratio.

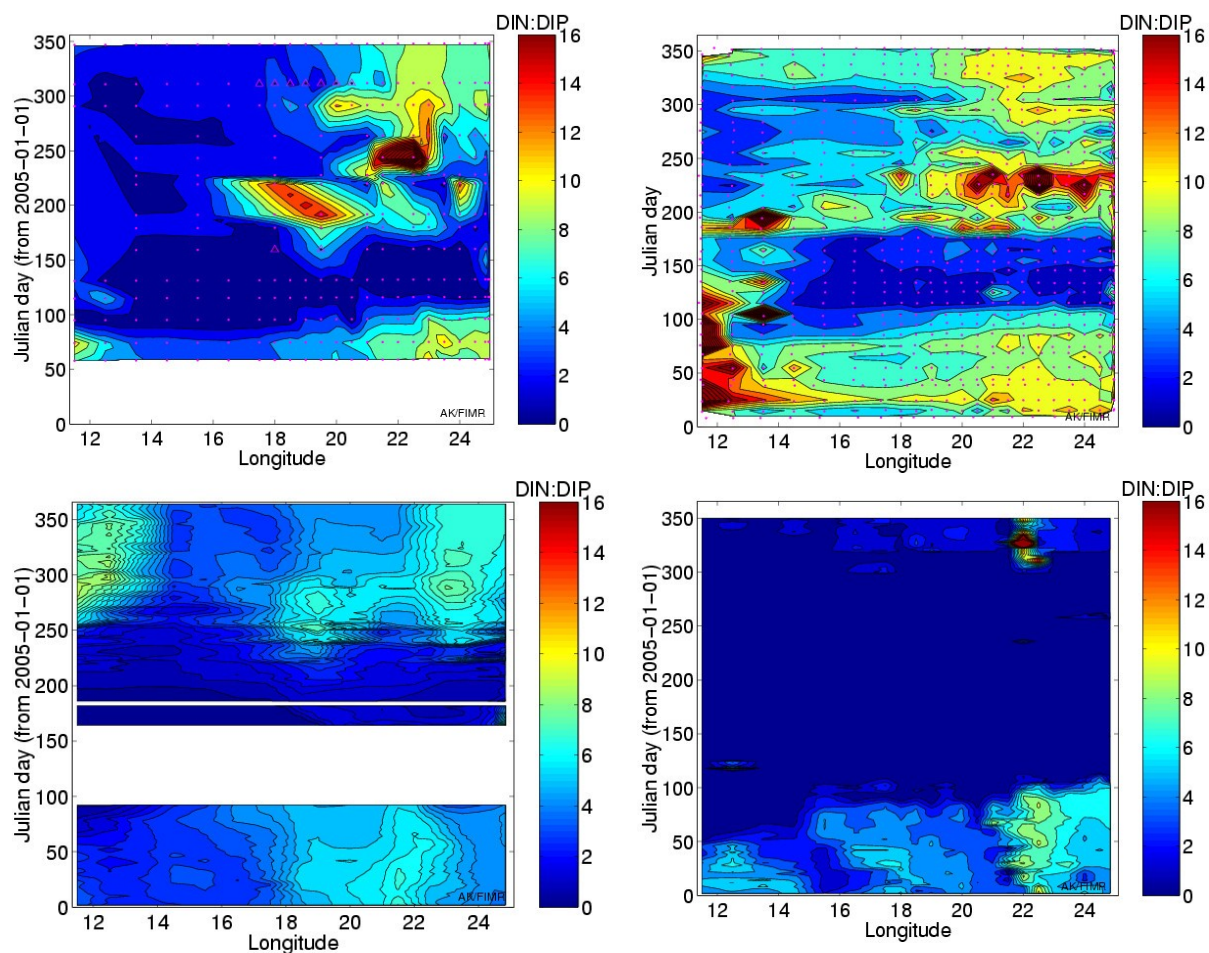


Figure 16: *Idem*, but DIN/DIP-ratio. Left up Alg@line results from the year 2005, right up Alg@line average 1993-2004, left down BalEco model 2005, right down RCO-Scobi model 2005.

Nitrogen to silicate ratio

In the Alg@line 2005 observations the DIN:SiO₄ ratio did not exceed the HELCOM (2006) reference value (1 µM) during the whole year, but it was higher than Alg@line-reference in the spring in the Gulf of Finland.

The DIN:SiO₄ ratio is well presented by BalEco model.

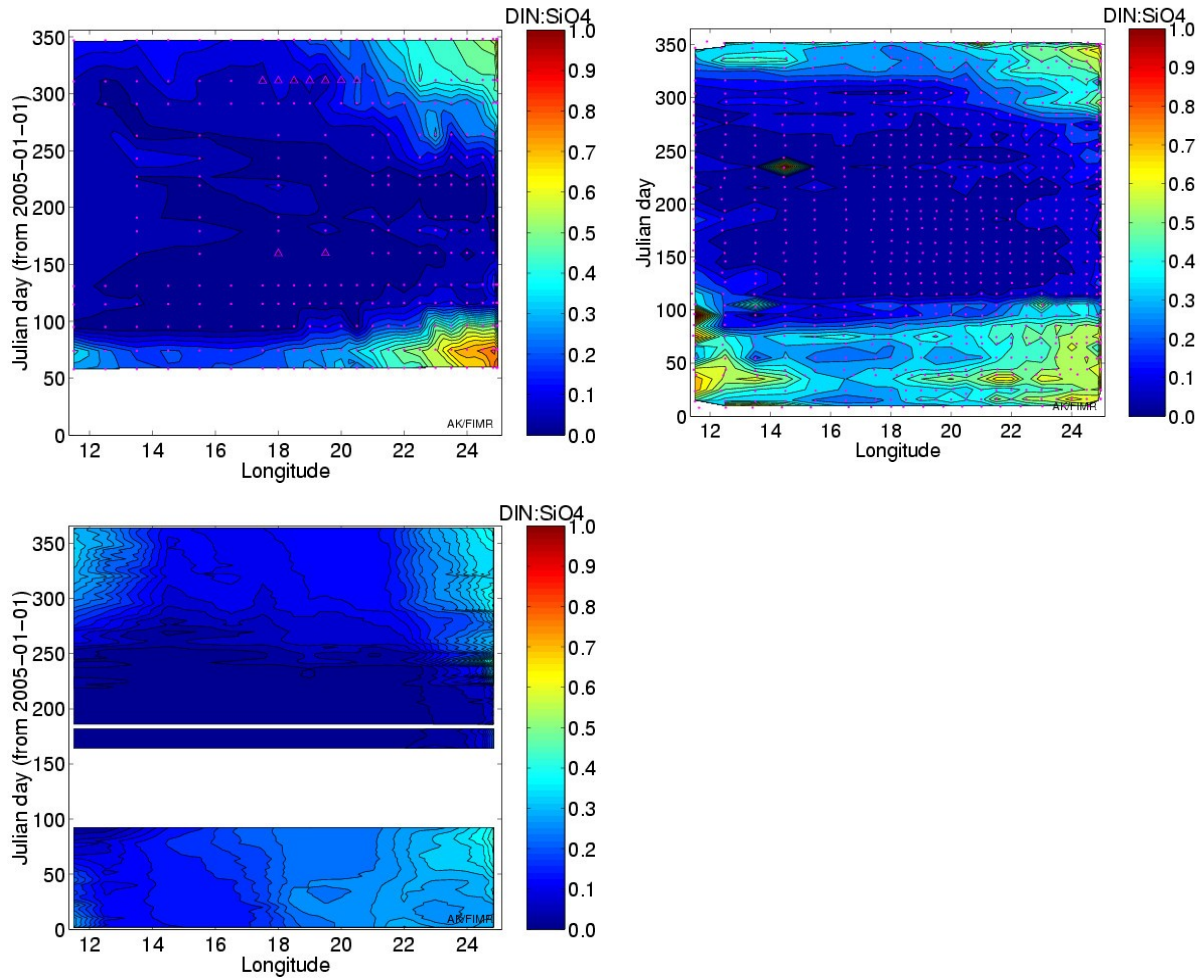


Figure 17: Idem, but DIN/SiO₄-ratio. Left up Alg@line results from the year 2005, right up Alg@line average 1993-2004, BalEco model 2005 left down.

5.2 Chlorophyll a

At the Alg@line 2005 observations the spring bloom started exceptionally almost at the same time in all regions, being strongest and lasting longest at the entrance and within the Gulf of Finland and weakest in the Arkona Basin. In the Eastern and Northern Gotland Basin the second increase in July was exceptionally high. The third increase started already in the middle of August in the Gulf of Finland and occurred from the middle to the end of October in the Gotland and Arkona Basin. Alg@line 2005 chlorophyll *a* concentrations were lower than the Alg@line-reference concentrations in the Arkona and Bornholm Basin, but higher in other regions.

Both models underestimate the Chl *a* concentrations. This probably results from an inaccurate method used to calculate the Chl *a* concentration from model results, and this problem will be addressed in future.

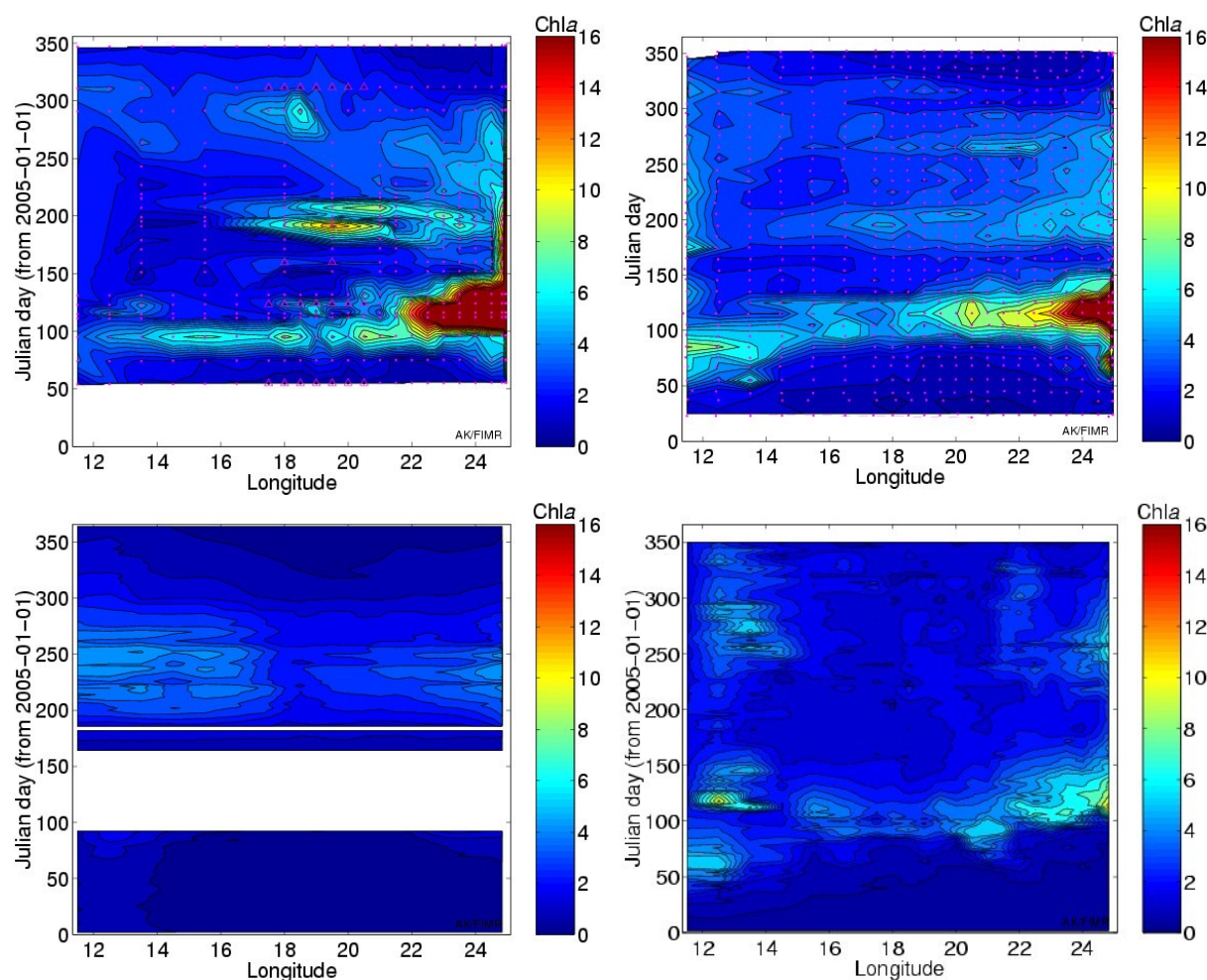


Figure 18: Idem, but Chl_a. Left up Alg@line results from the year 2005, right up Alg@line average 1993-2004, left down BalEco model 2005, right down RCO-Scobi model 2005.

6 Discussion and Conclusions

The model results from year 2005 show that in all Baltic Sea regions there are locations which can be identified as eutrophication problem areas based on HELCOM (2006) classification. Because models rather underestimate than overestimate both winter nutrient concentrations and summer Chl *a* concentrations on the surface water, we conclude that identified eutrophication problem areas correspond the actual situation with high certainty.

In the Arkona Basin and the Bornholm Basin the dissolved inorganic phosphorus concentrations were exceptionally high during the whole year compared to the [Alg@line-reference](#).

According to both models, the Chl *a* concentration of 2 mg m⁻³ and 3 mg m⁻³ were exceeded for more than 30% and 60 % of summer days, respectively, in the Arkona Basin, eastern regions of Eastern Gotland Basin (including Lithuanian open waters and Gdansk Deep), in the Gulf of Finland and in northern Bothnian Bay.

In the northern parts of the Eastern and Western Gotland Basins and on the Northern Gotland Basin the oxygen concentration were under the critical value of 2 ml/l for the most of the year 2005.

Comparison with Alg@line results indicates eutrophication problems being found in Arkona Basin, Bornholm Basin, Eastern Gotland Basin, Northern Gotland Basin and Gulf of Finland.

7 Acknowledgements

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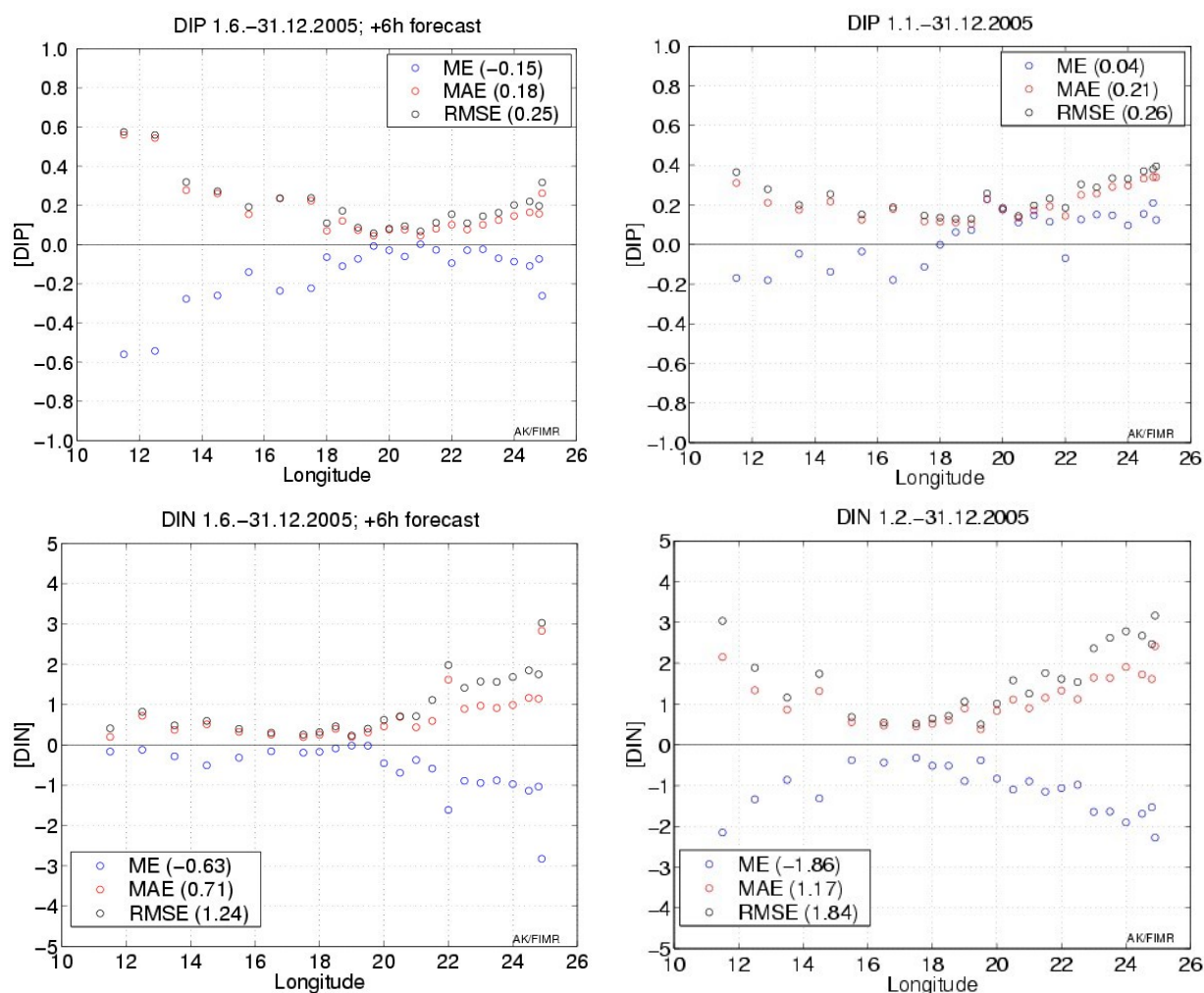
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8 Annexes

1Quality information

1.1Model validation

The accuracy of the models, compared against the [Alg@line](#) observations in 2005, are illustrated in Figure 17. The statistical indicators as mean error (ME), mean absolute error (MAE) and root mean square error (RMSE) were calculated for every Alg@line water sample location along the route of the M/S Finnpartner. In the figure boxes there are average values of ME, MAE and RMSE to the whole area.



BANSAl: Baltic Sea environmental status report year 2005

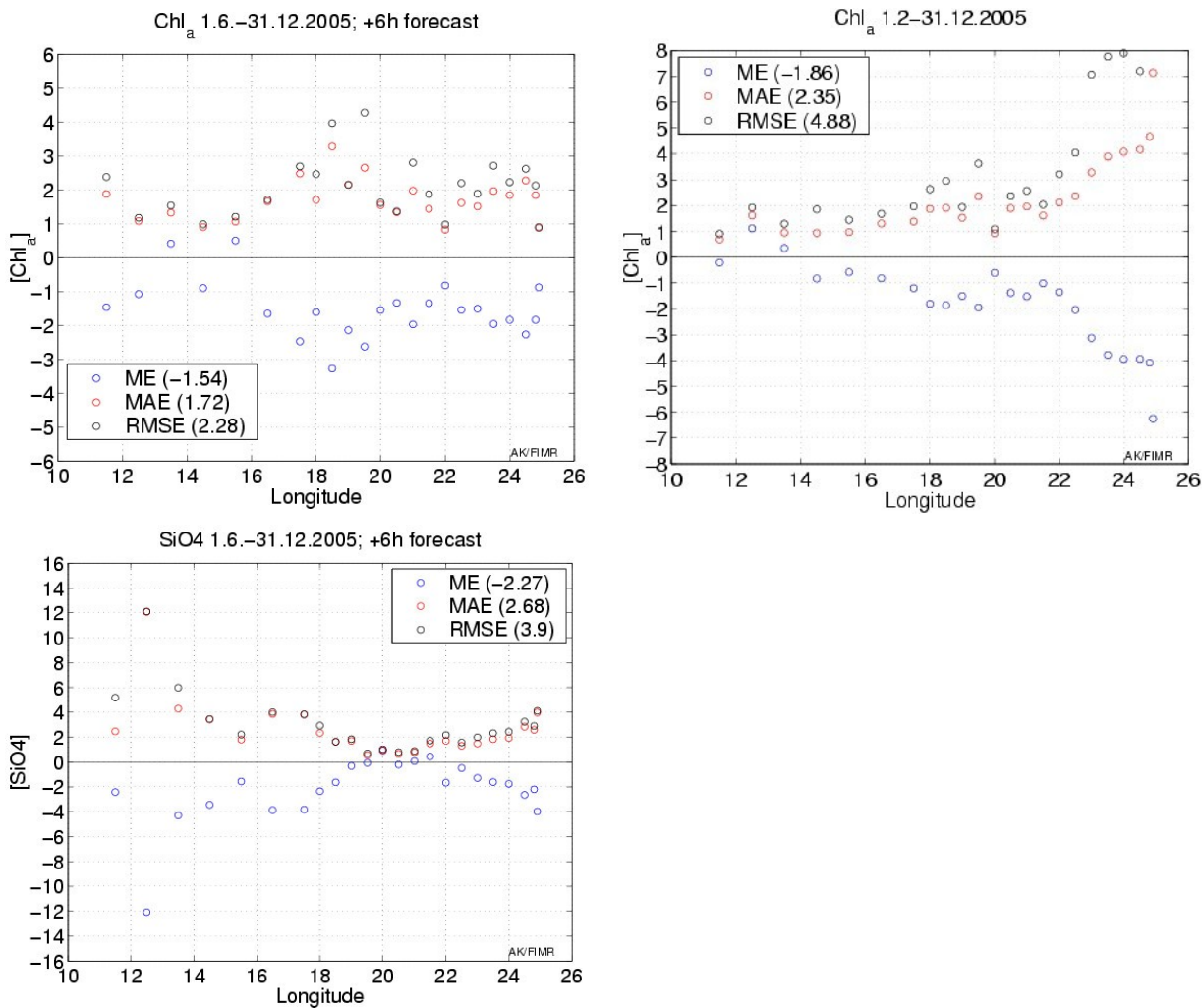


Figure 17. Validation results for BalEco left (half of the year), RCO-Scobi right (whole year). (The measurement intensity can be seen from Alg@line Hovmöller-figures).

1.2 Measurements

1. Source: Finnish Institute of Marine Research, contact persons Anniina Kiiltomäki and Tapani Stipa.

2. Description of data:

Original unit of measure: nutrients, silicate $\mu\text{mol l}^{-1}$

Original unit of measure: Chl *a* mg m^{-3}

Original purpose of the data: Phytoplankton monitoring of FIMR, Alg@line project

4. Temporal coverage: Alg@line-reference: 1993-2004, Analysis: 2005

5. Methodology and frequency of data collection: Automated flow-through sampling system on merchant ships, sampling depth ca. 5 m, Weekly biweekly monthly sampling during the period January- December.

6. Methodology of data manipulation: None.

Quality information

8. a) Reliability, accuracy, precision, robustness (at data level) of Alg@line:

Measurement uncertainty: Chl a: 0.5 mg m⁻³ if the concentration < 5.0 mg m⁻³, 1.0 mg m⁻³ if the concentration > 5.0 mg m⁻³.

Measurement uncertainty: Phosphate 20-30%, Nitrate 14-20% and Nitrite 12-45%, Ammonium 20-60%, Silicate 15-50%

9. Geographical coverage:

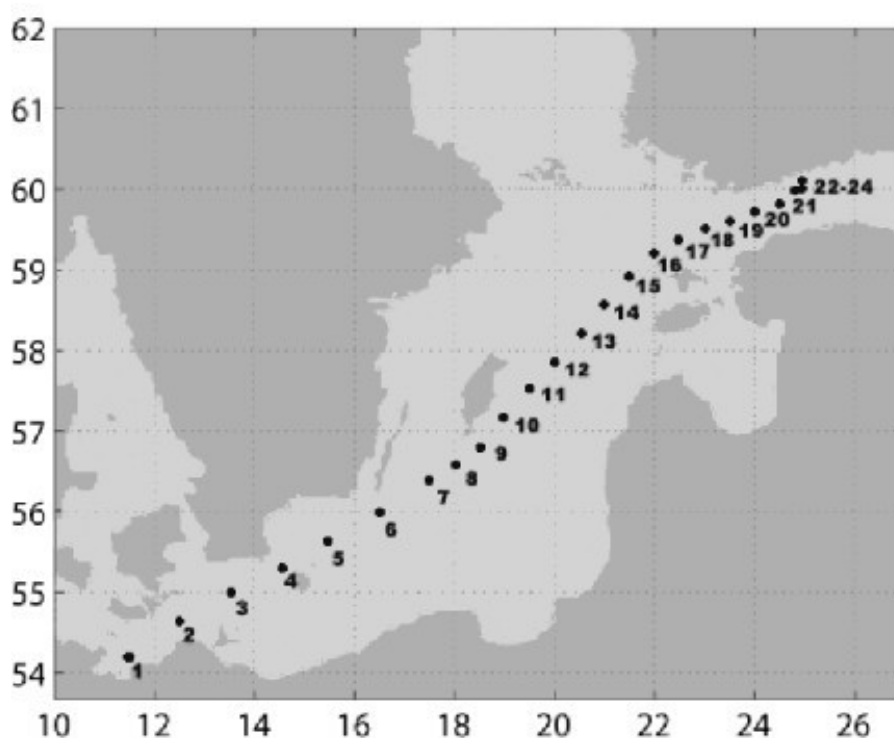


Figure 19: The Alg@line sampling locations on the route of M/S Finnpartner between Travemünde- Helsinki and the model transect in the Bothnian Sea. The Alg@line sampling locations are on following regions of the Baltic Sea: 1-2; Arkona Basin, 3-5 Bornholm Basin, 6-12; Eastern Gotland Basin, 13-18; Northern Gotland Basin and 19-24; Gulf of Finland.