Answers to the reviewer comments:

All the comments of the reviewer were exhausted in detail in corrected in the manuscript. We agree with reviewer suggestions and the paper was corrected.

The objective of this study was to simulate the contemporary seasonal dynamics of particulate organic carbon (POC) in the southern Baltic as well as its possible changes in the future. Unfortunately, the implemented means do not match this important goal: the chosen approach neglects important Baltic Sea features and validity of the model was not demonstrated. Consequently, presented numerical experiments could only be considered as a mere learning exercise, which publication would, perhaps, be appropriate two-three decades ago but not nowadays. Therefore, I cannot recommend this manuscript for publication, especially in the Special Issue of OS presenting results of "...Operational... forecasting systems"

The purpose of the study described in the manuscript was twofold
-recognize seasonal dynamics of POC in the Baltic proper
-investigate the influence selected physical (temperature, irradiation) and chemical (nutrients concentrations) factors exert on the dynamics
The study was perform using a POC model described in details, and validated with experimental results as described by Dzierzbicka at al. (2010)

General comments
1. Both model formulation and its setup totally disregard a well-described "vicious circle" determined by feedbacks in a coupled nitrogen and phosphorus cycles: primary production of sinking POC = > expanding hypoxia = > simultaneous decrease of DIN and increase of DIP = > increased cyanobacterial nitrogen fixation re-introducing nitrogen into biotic cycling. (In fact, neither cyanobacterial blooms nor nitrogen fixation were mentioned in this MS even once.) Consequently, future PP would be determined not just by future nutrient pools but also by their DIN:DIP ratio that cannot be predicted from linear interpolations of trends estimated at 1965-1998 time interval. In result, the quantitative reliability of obtained increases of PP and POC, which were predictably generated by some prescribed increases of temperature, light, and nutrients, cannot be evaluated.

Details of the POC model are presented by Dzierzbicka-Głowacka et al., (2010). The model incorporate a general nutrient loop that describes regeneration of nutrients due to organic matter mineralization. Release of dissolved inorganic phosphorus above the level established by organic matter mineralization is not included. This is due to specific situation on the study areas where anoxic condition prevail in the below the halocline water layer (HELCOM, 2007). Thus, a steady state between nutrients pools in deep water and nutrients pool available for primary production exists. The model aims at describing "an average" POC dynamics, thus the disequilibrium indicated by the referee was not incorporated. This includes also blue-green algae blooms caused by reduced DIN/DIP ratios in the surface water.
The aim of the work described in the present manuscript ("Numerical modelling of POC yearly dynamics in the southern Baltic under variable scenarios of nutrients, light and temperature") was purely answering to the question how will the system respond to alteration of selected physical (temperature, irradiation) and chemical (nutrients concentrations) conditions crucial for phytoplankton activity and thus conditioning the final POC

concentrations. References to increases of temperature and light within the past 30 years or so were used just to select a reliable ranges for the parameters changes.

2. Another important feature of the Baltic Sea eutrophication is long nutrient residence times ("system memory"), which requires long continuous (transient) computations, accounting for bottom-water interactions and advective transports, instead of annual slices, presented in MS.

Concentration of POC and dynamics of POC concentration in the system (Baltic Proper) respond to actual nutrients concentrations in a way conditioned by physical factors. These influence directly and indirectly POC concentrations that are modeled and the results are described in the presented manuscript. Neither origin nor history of nutrients is of importance for this model. We intend to answer the question: what is the dynamics of POC concentration under scenario of altered nutrients and light conditions?

3. MS contains neither model validation nor any justification of its applicability for chosen locations. Meanwhile, as could be deduced both from the manuscript and from Dzierzbicka-Glowacka et al. (2010) for the Gdansk Deep: a) deep-water nutrient pools are greatly overestimated, most likely because of ignoring oxygen dynamics and its effects on the nitrogen and phosphorus fluxes; b) annual nutrient cycles are not closed, which means misbalanced dynamics and would result in artificial long-term trends; c) maximum development of zooplankton in the reference conditions 1965-1998 occurs in June-July, i.e. one-two months earlier than in reality, which implausibly affects summer nutrient regeneration. Note also, that simulated nutrient dynamics were neither demonstrated, nor even mentioned in the manuscript. Were these simulated at all?

The model was verified based on actual POC, temperature, nutrients (P,N) measurements in the Gdansk Deep (see Dzierzbicka-Głowacka et al., (2010) "Particulate organic carbon in the southern Baltic Sea: numerical simulations and experimental data", Oceanologia 52(4), 621-648). Since processes affecting POC dynamics in the Bornholm Deep and the Gotland Deep are quantitatively similar to these in the Gdańsk Deep it was assumed that the model depicts POC dynamics there as well. Differences in POC concentrations in the three study areas are due to different concentrations of nutrients and intensity of physical factors.
a) Nutrient concentrations in the Gdansk Deep agree well with actual values regarding vertical distribution and time dependence in surface water layer (see Dzierzbicka-Głowacka et al., 2010; fig. 2, 3, 4). The modeled and observed nutrients concentrations in the deep water layer differ considerably (see Dzierzbicka-Głowacka et al., 2010; fig. 5) due to the assumed water depth. This has little if any influence on surface layer POC dynamics.

b) Annual nutrient cycles seem to be closed good enough for this kind of modelling. We see that in the absence of long term trend if we do not change other parameters in control runs (not shown). However we do add an artificial trend simulating changing advection from rivers and deposition according to Renk (2000) – see the reply Reviewer #1.

c) In this model, the zooplankton is considered by one state variable and defined as microzooplankton (heterotrophic planktonic) and mesozooplankton (herbivorous copepods). The maximum development of zooplankton in Gdansk Gulf occurs mainly in June-July or July-August in dependent on environment conditions (see Mudrak 2004). However the most probable period in the historical data we used was June-July.

Nutrients seasonal dynamics were simulated (see Dzierzbicka-Glowacka et al. 2010).
It was shown in Figures 4 & 5 in that paper.

4. The entire MS is loosely composed and poorly written, omitting many important details in presentation of the model formulations and set-up of numerical experiments, while excessively lengthy in a mere description of pictures.

It is pity the reviewer did not precise what exactly is wrong in the manuscript. It is difficult to make corrections basing on such a comment. However we will try to make it clearer in the corrected manuscript that the set-up of the 1D model has been described in Dzierzbicka-Glowacka et al. 2010 while the 3D model is the ECOOP IP project WP 10.1.1 report .

5. Finally, I share all the doubts expressed by another reviewer but I'm not satisfied by most of the answers presented in Interactive Discussion by authors.

We are sorry the reviewer was not specific here.

Specific comments

1. "The flow field" and "the velocity components xi" are mentioned both in this manuscript and in Dzierzbicka-Glowacka et al. (2010, Eq. 2) without any explanations how they were implemented in 1D case without violation of the conservation.

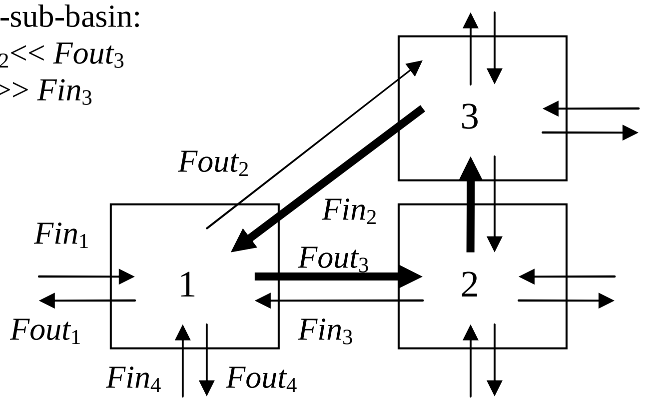
The 1D POC model is an one-dimensional biogeochemical model. The model has a high vertical resolution with a vertical grid of 1m, which is constant at the whole column water. This means that the model calculates the vertical profiles of all its variables and assumes that they are horizontally homogeneous in the studied areas (sub-basins). The dynamical characteristics remain almost unchanged in a horizontal plane in comparison to vertical changes. Hence, the magnitudes of the lateral import/export are lower, and the above assumption can be made. However in the end, the horizontal velocity components (v, u) obtained in ECOOP IP project WP 10.1.1 model for the Baltic Sea (ECOOP IP project WP 10.1.1, Osinski 2008 Ph.D. Thesis) are used for calculation of different hydrodynamical variables as: w, K_z, S and T. In order to include horizontal variations in the Southern Baltic (a larger area) it was divided into three sub-basins (1-Bornholm Deep, 2-Gdansk Deep and 3-Gotland Deep; one of the sub-basin has 64 pixels; 1 pixel = 9×9 km^2).

The main average circulation of the Baltic Sea is called *baltic haline conveyor belt* (BCB, Doos et al. 2004, Meyer 2007). If we take into account BCB, the main flow though the subbasins is assumed to be a part of BCB and other flow could be neglected.

At the scheme of those cells bold arrows represent BCB

In this paper, it was assumed, that for *i*-sub-basin: $\sum_i Fin_i = \sum_i Fout_i$.

for 1-sub-basin:
$Fout_2 << Fout_3$
$Fin_2 >> Fin_3$



In the model, we do not include the inflow of nutrient compounds from the rivers and atmosphere. Hence, in the 1D POC model the boundary conditions (from the land and atmosphere) are zero.

In this model, the sediment module is considered by a simple equation for benthic detritus and therefore the bottom is raised to 70 m (it is an average depth value of the halocline). We realize that it is a large simplification causing the overestimation of the bottom values mentioned by the reviewer in point 3 of this review. This is in future versions of the model the processes occurring on the bottom layer will be described by the standard MIKE 3EU model (we are implementing this model).

The 1D POC model uses data from the POPCICE model for the Baltic Sea (see ECOOP IP WP 10.1.1, Osinski 2008 Ph.D. Thesis) for three selected stations.

2. How deep is modelled domain and what is a vertical resolution (depth step)?

I do not understand exactly what you mean here – you think about 1D POC model (which does not have regular domain) or about POPCICE model. Below is short refer to you question assuming you mean POPCICE model.

A vertical resolution and modeled domain – see point 1 of the Specific Remarks.

The vertical resolution of the 3D hydrodynamic model is at fixed depths, varying with depth. A finer resolution is set in the surface layers (5m in the three layers), then gradually turning coarser towards larger depths.

Model domain and bathymetry (represented by vertical levels) is presented at figure below. There are two images. The left one shows it in the model coordinates, second one presents the same bathymetry as a geographic projection. Color scale represents model levels (not depth). In example 3 means the maximum depth is 15 meters and thickness of this cell is 5 meters, 10 means the maximum depth is ~80 meters and thickness of this cell is ~15 meters. Both models, ice and ocean, work on the same grid, so there are no problems with exchanging fluxes between the models.
The deepest point in the Baltic Sea is the Landsord Deep which is represent by 19 model level. However the deepest place in this domain is located in the North Sea. Horizontal and vertical time steps in the ocean model are identical (8 minutes).

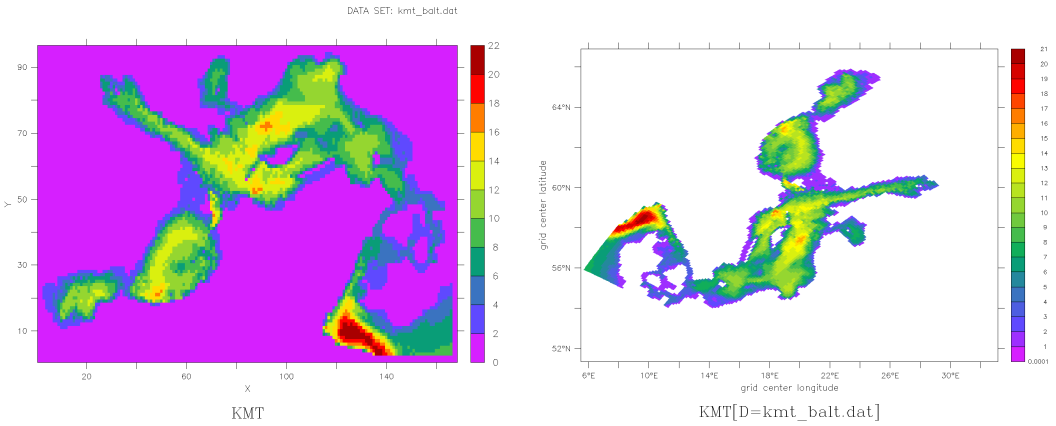


Figure 1. Model domain and bathymetry (model coordinates – left side, stereographic coordinates – right side).

What is a specific reason in a consideration of both surface and upper layers in the Gdansk Deep but only upper layer in the Bornholm and Gotland deeps.

The calculations were made for both surface and upper layers for the all considered areas. The upper layer (0-10 meter depth) illustrates mainly the effect of decreasing radiation on the primary production by exponent function. The results for the surface layer at the Bornholm Deep and Gotland Deep are similar as in the case of the Gdansk Deep considering the quality and shape distributions; however in relation to quantity they are a bit lower.
In this paper, the analysis of the numerical results only for both surface and upper layers in the Gdansk Deep was presented because the parameterization and validation of the model were made for the region of the Gdansk Deep.

2. Formulation of the ecosystem model is also rather unclear. For instance, what are the units (currency) of state variables? In the Gdansk Deep a seasonally variable C:Chl ratio was used for calculation of light extinction (Dzierzbicka-Glowacka et al. 2010). What was used in the Bornholm and Gotland deeps?

I am very sorry, the units of state variables are given in the table 2 and on the figures.
It will be fixed in corrected manuscript. The units of state variables: Phyt, Zoop, Detr, POC are in mg C m^{-3} and NutrN, NutrP are in mmolN m^{-3}, mmolP m^{-3}.
A seasonally vary C:Chl ratio in the Bornholm and Gotland deeps was used exactly like in the Gdansk Deep. We prefer to use non constant value (constant value of C:Chl=50, what is as a common practice)

3. At p. 680: “The average chlorophyll-a concentrations in the southern Baltic Sea (average values for 1965–1998 period) were used in this model for the calculation of primary production (Table 1)” How?

I am sorry for misleading sentence.
The average chlorophyll-a concentrations in the southern Baltic Sea (average values for 1965–1998 period, Table 1) were used for the calculation of primary production after Renk

(2000: eq. 32). The PP values obtained this way were subsequently compared with the simulated ones.
Modeled primary production (PP) values for the 1965-1998 period agree with experimental data for PP as average values during the 1965-1998 period. A new figure showing this will be added to the revised manuscript.

4. “nutrients increase 1% of an average annual value per year.” What is an average annual value for a variable with a pronounced seasonal change, from winter nutrient maximum to (almost) zero in summer?

I am sorry for misleading sentence, this has been corrected. It should be: nutrients increase 1% of an average annual value per year with the exception for the summer when nutrients concentration are close to zero (it means 0.0036 mmolP m^{-3} and 0.022 mmolN m^{-3} at Gdańsk Deep for the period 1965-1998 after Renk (2000); however for Bornholm Deep and Gotland Deep, are assumed the lower values: 0.0034 mmolP m^{-3} and 0.021 mmolN m^{-3}).

5. At p. 679: ”In this model nutrients are represented by two components: total inorganic nitrogen (NO-3 + NO-2 + NH+4) and phosphate (PO3-4 15).” At p. 681:
“Based on the trend indicated above, daily...variabilities of primary production, phytoplankton, zooplankton, pelagic detritus and particulate organic carbon (POC) in different areas... were calculated for the different nutrients concentrations... and wind speed scenarios.”
What does “nutrient scenario mean”, what was estimated with linear trends – initial conditions for annual slices or the entire seasonal curves? In other words, were nutrients seasonal dynamics simulated or just prescribed? If the later, then the entire exercise in calculation of phytoplankton, detritus and zooplankton from prescribed nutrient variations could hardly be considered as an ecosystem modelling. Ignoring mechanisms of the summer nitrogen fixation and regeneration would also make the simulated summer dynamics of POC unrealistic and conclusions based on it unreliable.

'Nutrient scenario' was used in the manuscript in the sense 'nutrient concentrations'. Perhaps the expression is misleading and thus has been replaced accordingly throughout the manuscript.
Model validation proved good agreement between modeled vs measured POC concentrations, all over the year. Thus average POC dynamics in the Gdańsk Deep is well reproduced by the model. As a consequence, we belive, the model can be used as a tool for investigating POC yearly dynamics under varying nutrients concentrations.

Nutrients seasonal dynamics were simulated (see Dzierzbicka-Glowacka et al. 2010).
Here, the linear trend for nutrient is consider as initial condition for annual slices:
$Nutr = Nutr\text{o} + Nutr\text{a}\cdot Yd(Year - 2000)$, where *Nutr*o – simulated values at every time step, *Nutr*a – average annual rise of the *Nutr* (except of summer), *Yd* – time (as a fraction of the year).
The nutrients increasing *Nutr*a include the inflow of nutrient compounds from the river and atmosphere, which is not considered in this model.

In this model phytoplankton was modelled with the aid of only one state variable. The phytoplankton concentration was taken to be a dynamically passive physical quantity, i.e. it

was incapable of making autonomous movements. Cyanobacteria blooms were not incorporated separately at this stage of the model development. The fact that cyanobacteria activity is less intense in the open sea than in the near-shore zone (Voss et al. 2005) provided additional motivation for choosing three stations located away from the coastal zone. Therefore the nitrogen fixation was ignored. The benthic regeneration was included in the model (Dzierzbicka-Glowacka et al. 2010: Appendix A).
The simulated summer dynamics of POC is good enough. This will be shown in the revised manuscript (Figure 9).

6. “Primary productivity and POC concentrations calculated for the period 1965–1998 and 2010 agree well with experimental data.” Such statements must be justified.

I am sorry for misleading sentence: lines 13-14, section 5, page 686.
Should be: Modeled primary production (PP) values for the 1965-1998 period and POC concentration for 2010 agree very good with experimental data for PP as average values for the 1965-1998 period and for POC from the years 2007 and 2008 (see Dzierzbicka-Glowacka et al., 2010) and from next two years 2009 and 2010 (data presented on the Baltic-C Third Scientific Study Workshop, Lund, Sweden, 8-10 November 2010, *POC/DOC for model validation by* Anna Maciejewska). A new figures will be added to the revised manuscript (Figures 8 and 9).

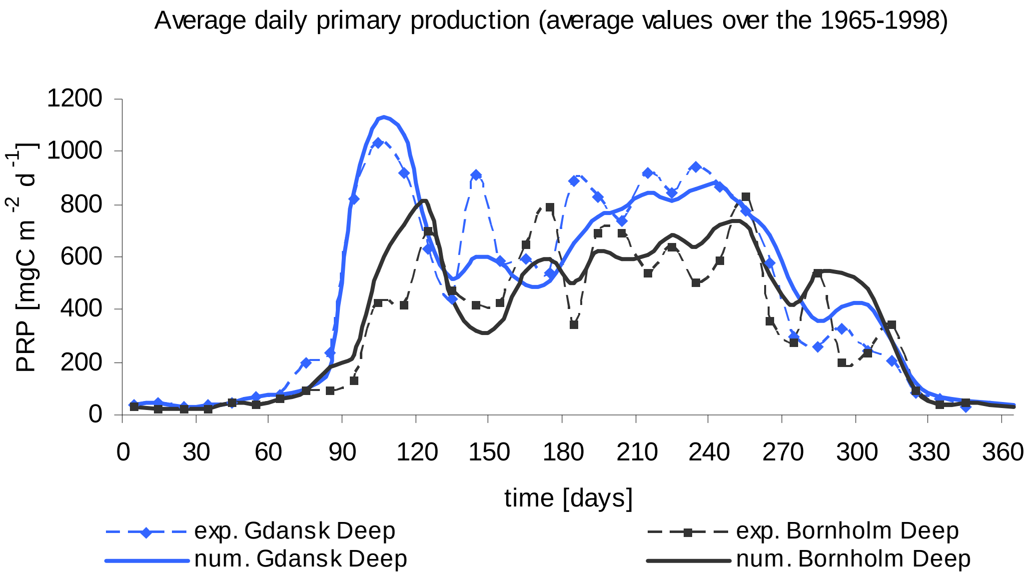


Figure 8. Average, daily primary production in the Gdansk Deep (blue) and the Bornholm Deep (black); numerical simulation (solid line) and experimental results (dashed line).

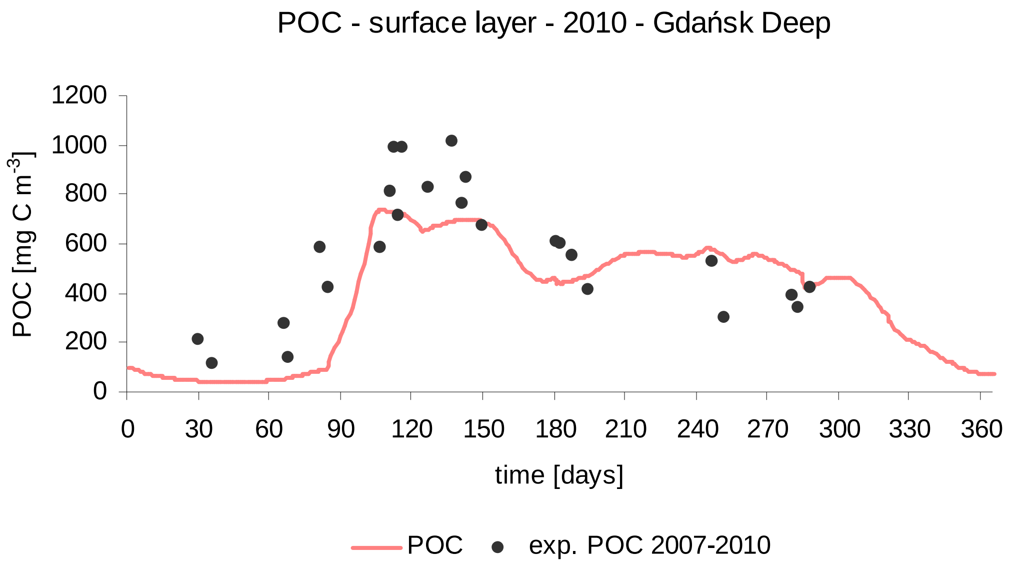


Figure 9. Modelled (red line) and measured (black dots) POC concentrations in the surface layer in the Gdansk Deep.

Model output describes an average state of the ecosystem and provides average results of the investigated variables. When modeled results are compared with the experimental ones, it must be kept in mind that the latter reflect only a temporary state of the ecosystem, i.e. the time of sampling. Thus, the modeled POC concentrations may differ from the measured values, especially in the time of phytoplankton blooms, when the biomass variability is the highest.

7. Just an example of unclear writing: “Contemporary POC concentrations are modelled under a variety of increased temperature and nutrients scenarios” How can contemporary concentrations be simulated under increased scenario forcing?

The word “contemporary” was deleted from the sentence as a misleading

8. Nowadays, there are several Baltic ecosystem models much better suited for scenario simulations and actually performing them, that authors largely failed to mention, unfortunately.

Although there are several numerical models describing the Baltic Sea ecosystem, still little is known about the POC dynamics in the Baltic Sea water. The aim of this paper was to present variability of the POC in the Baltic seawater and simulate how the POC concentrations and seasonality can change under different light and nutrients conditions. Unfortunately, there are no available literature data describing POC variability in the Baltic Sea that might be compared with our findings.

We would like to express our thanks to Reviewer for his/her very instructive and profound comments.