We appreciate the thoughtful and helpful comments on our manuscript. We reply below. Original text from reviewers in black color and our answers are in blue color. Some contents were added in the supplementary materials, which are referred to in our answer.

1) The present limitation to only organic SPM is not acceptable to describe the dynamics of suspended matter realistically enough, in particular in the southern North Sea.

We agree that inorganic SPM has the potential to reduce primary production, specifically in tidally influenced shallow water. We considered this effect through a slightly elevated background attenuation (line120 in the submitted version, Eq.S2 in the supplementary materials). We further assumed that the spatial variability in SPM can be neglected for the sensitivity study performed here. However, the reviewer is right and our assumption needs to be verified. We agree that the impact of inorganic matter on light attenuation merits further analysis and have performed further sensitivity experiment to verify our assumption, which we discuss below. We will include a respective discussion as outlined below in a revised version of the manuscript.

To address the uncertainties related to SPM, we tested the effect of spatial-temporal varied inorganic SPM on our findings while performing an additional numerical sensitivity experiment. Here we implemented a climatological SPM filed (daily resolution, with 31 vertical layers) (Fig.S1) and added the SPM's contribution explicitly in the light attenuation scheme. Details of the SPM data set and implementation are given in the supplementary material. By running the tidal/non-tidal scenarios again using the new light attenuation scheme, we evaluated the impact of tides on NPP firstly by comparing annual mean NPP between tidal scenario and non-tidal scenario. We found the most significant change appearing in the frontal area where the tidal induced NPP elevation was decreased by about 10 $gCm^{-2}y^{-1}$ (Fig.S2) compared to the original version (Fig. 2c), which indicates that in the frontal area SPM's impact dampens the promotion process on NPP by nutrients pumping. However, the positive and negative responding pattern as identified by the original simulations remain consistent even after considering spatial and seasonal variations in SPM (Fig.S2). This confirms that the general mechanism discussed in the manuscript and our conclusions regarding the former parameterizations remain valid.

Many earlier published studies support our assumption and the conclusion of the additional sensitivity experiment. First, with regard to the seasonality, SPM concentration and contribution to turbidity are low during summer (see also Fig.S1), (Capuzzo et al., 2013; Dobrynin et al., 2010), which is critical in our analysis since most differences in NPP actually occur and accumulate in summer. Measurements suggested that in the central North Sea, the water body itself triggers most of the attenuation; in Oyster grounds, attenuation has been controlled to a large extend by CDOM and phytoplankton; SPM in the surface layer decreases after the onset of stratification (Jones et al., 1998). The SPM is more relevant to attenuation in nearshore area due to cliff erosion and river input. Astoreca et al. (2009) suggested that CDOM is mainly derived from local autochthonous rather than terrestrial source in offshore waters (salinity>34). The relevance to turbidity of fluvial SPM is confined to river mouths because SPM deposits quickly (Pleskachevsky et al., 2011; Siegel et al., 2009). In spring, simulation study in the German Bight found that implementing SPM is only critical at the onset of bloom, given reasonable parameterization, similar bloom amplitude was achieved in both scenarios including or omitting

SPM (Tian et al., 2009). Horizontally, organic suspended matter shares a high fraction of total suspended matter (TSM) in most areas in the southern North Sea except in very near shore areas. The area where inorganic matter dominates reaches $8.5°E$ in stormy season (autumn) and are confined further inshore in summer (Schartau et al., 2018). The inorganic suspended matter dominating areas are in the negative responding regions based on our simulation results (Fig.2c). Considering enhanced resuspension and further attenuation caused by tidal forcing, the NPP in the near shore area would also respond negatively.

The distribution of inorganic suspended matter is influenced by many factors, such as transportation with residual currents, aggregation with organic matter, type of benthic sediments and so on. Clearly, interaction processes as mentioned above cannot be resolved by implementing a climatological SPM field. Thus, the numerical experiment presented can are a first step towards understanding tidal impacts, and future studies are suggested, given reasonable boundary conditions of inorganic matter from benthic sediments and river inputs as well as a more reasonable representation of bio-physical interactions related to inorganic matter. However, this is beyond the scope of the current study and should be emphasized more thoroughly in future work.

(2)As stated, compared to their reference paper Daewel & Schrum (2013), the implementation of the SPM dynamics was significantly modified. If this is the case, a thorough validation of this strongly modified scheme is indispensable, in particular since SPM dominates the light attenuation.

Yes, we agree that due to the modification of the parameterization, an assessment of the changed model performance is necessary. New parameterizations of sedimentary respiration and light shading have been implemented in the new version (following Nissen, 2014)). Therefore, we will add a discussion of changes in mean primary production pattern and we will repeat the validation exercise proposed by Daewel and Schrum, (2013)) focusing on surface nutrient concentration, and compared results from with and without the new parameterizations. We found only small changes in production pattern from the new parameterization introduced (Fig S4). Frontal production is slightly enhanced and production increased slightly in deeper stable stratified waters and decreased weakly near the coast. The rigid validation of nutrient surface concentrations also revealed only small changes (Fig.S3). Here we found that the performance of the model in the North Sea region is rather stable and changes only marginally. The validation will be included in the revised manuscript.

(3) General criticism of minor importance is the missing predation by fish and higher trophic levels. This deficit is only mentioned in the conclusions. However, a more serious discussion of this aspect would definitely be appropriate, in particular since it was noted in line 129 that the predator - prey interaction is considered, which at the first glance is even misleading.

We agree that the definition of predator-prey interaction is misleading and will define this more appropriately as predator-prey interaction at lower trophic levels between the considered functional groups of zooplankton and phytoplankton in the model.

Since the North Sea can in general be considered as bottom-up controlled (Daewel et al., 2014; Heath, 2005), using a lower trophic level model for investigating tidal impacts on NPP is a valid approach. Although situations with clear top-down control on zooplankton has been observed (Munk and Nielsen, 1994), these events occurred highly restricted in time and space and assumed to be only of minor relevance for the general processes described in this manuscript. However, we will include a more thorough discussion about the relevance of fish predation in the discussion. In previous studies, which addressed similar scientific question, constant grazing rate (Sharples, 2008) or grazing loss being proportional to phytoplankton biomass (Cloern, 1991) were prescribed in their simulations. In this study, we utilize a lower trophic level NPZD-type model only considering lower trophic level dynamics up to zooplankton, which is simulated as a state variable considering feeding preference, growth, excretion and mortality. Fish predation is only implicitly considered as part of the zooplankton mortality rate. Simulations with ECOSMO E2E (an updated version of the ECOSMO model) including functional groups for fish and macrobenthos revealed that temporal and spatial variations in zooplankton mortality due to fish predation are determined by the specific hydrodynamics of the North Sea (Daewel et al., 2018). Repeating a similar study with an NPZD-Fish model would be interesting, however, beyond the scope of our study.

(4) Line 138: The term "southern coast" should be specified more clearly.

Yes, we agree that this term is ambiguous. In the updated version, we change it as "European continental coast".

(5) Line 280: The sentence is not clear. How can the "energy" of tidal currents interact with the atmospheric forcing? Moreover, it is not clear whether this specific interaction process is considered in this study. I guess so, but however, this should be stated.

We agree that it is necessary to change the way this is expressed and a similar comment was added by reviewer 2. To address the comments of both reviewers, line 280 was changed to "In addition to tidal forcing, atmospheric forcing and bathymetry modulates stratification (Van Leeuwen et al., 2015) and productivity pattern (Daewel and Schrum, 2017); consequently tidal impacts on stratification and hence primary production are subject to spatial-temporal variability."

(6) Line 540: Obviously, the difference to observation is larger than one order of magnitude. The arguments, which are presented to defend this inconsistency are not fully convincing to explain such a very large discrepancy. In particular, the argument given at line 547 that observations over a few days between July and August cannot be compared with seasonally averaged model data is not acceptable. It should be easy to extract the actual observation period from a 25 years' model results data set.

This seem to be a misunderstanding. Here we explore a discussion and conclusion by Richardson et al. (2000). The upscaling of the short-term observation to seasonal pattern was initially proposed by Richardson et al. (2000). They upscaled their measured NPP (4-6 gCm^{-2}per spring neap cycle during 29 July to 4 August, 1997, in their publication) to the whole stratified season (May to October) which contains 6-8 times of spring neap cycle as they assumed. Based on this simple upscaling, they suggested NPP contributed by the spring neap cycle of about 24-48 $gCm^{-2}y^{-1}$. We believe that this upscaling is too simplistic and discussed the mean local impacts based on our simulations to provide dynamically consistent estimates. Making use of our simulations, we have analyzed monthly variability regarding to the NPP contributed by tides. As we have pointed out in our manuscript (line 547-553), the strongest contribution by tides to NPP

is in June, July and August; in other seasons, the contributions are weaker or even negative. In the supplementary materials, we also provided monthly mean contribution to NPP by tides to prove that the monthly variability is considerable and has to be considered (Fig. S5). To avoid misunderstanding, we replace the sentence in line 536: "The subsurface NPP attributed by nitrate fluxes driven by spring-neap tides by Richardson et al. were 4-6 gCm^{-2} for one spring-neap cycle; considering 6-8 times of spring neap cycle during the whole stratified season per year, they did an upscaling and proposed that the additional NPP contributed by the spring neap cycle was in the range of 24-48 $gCm^{-2}y^{-1}$."
We added a direct comparison between our results with the observations made by Richardson. For the comparison between our simulation and Richardson's observation, we have extracted NPP at the exact location where they did their measurements for the same period (29/07-04/08 1997 in Richardson et al., 2000. We extended it to 26/07/1997-08/08/1997 to cover a full spring-neap cycle). In the previous version, we only used the NPP generated in the subsurface layer to make comparison, since they stated that the NPP was mainly generated in the subsurface layer (Richardson et al., 2000). However, in their study, they used the integrated oxygen surplus in the whole water column to estimate NPP. We think it would make more sense to use integrated NPP in our simulation to compare with Richardson et al.'s results. It is true that our simulated changes in NPP is smaller than the observed changes at the same location (the magenta transect, Fig.S6, Table S1). However, we found substantial small scale variability in the response to tidal forcing at the order of a gird cell (Fig. S6) and only at a distance of several grid points further south where the front exactly locates in our simulation (the black transect, Fig.6), the modelled tidal contribution (M2+S2) reaches the level with the observed value (Table. S1). We think that the discrepancy stem from uncertainties introduced by unresolved sub-scale processes, which remain unconsidered in a 10km x 10 km model resolution and coarse scale atmospheric forcing (NCEP/NCAR reanalysis); intensity of simulated fronts is likely influenced. Keeping the uncertainties in estimating the exact location of a front in mind when comparing to point-observations, we think that the overall response of the model is rather consistent with observations and can be used to assess the overall tidal vs the spring-neap tidal impact to update Richardson et al. estimates of tidal impacts on primary production and to conclude improved seasonal mean estimates.

We will improve the discussion in the revised manuscript to clarify our point.

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Supplementary materials

1) **Impact of SPM**. To estimate the impact of SPM on the under-water light climate in the simulation, we implemented a climatological SPM filed of the North Sea (with daily resolution and 31 vertical layers) in our simulation. This SPM filed was derived from statistical regression model which considers tidal currents, salinity and water depth (Heath et al., 2002). This SPM filed is able to resolve spatial distribution pattern and seasonal cycling of SPM concentration in the North Sea (Fig.S1). This SPM field has been applied in many hydrodynamic-biogeochemical coupling (Große et al., 2016; Kerimoglu et al., 2017).

   Taking the parameterization scheme in (Tian et al., 2009), we evaluate shading effect due to SPM as:

$$Kd_{spm} = k_{spm} \cdot \sqrt{SPM} \quad \text{(S1)}$$

   The k_{spm} was set as 0.02 m^2g^{-1}. We added the contribution of SPM to the light shading scheme as described in the paper (Eq.1 in the submitted version). We decreased the background attenuation co-efficient k_{w1}, 0.03 m^{-1}, to 0.025 m^{-1} (k_{w2}) and subsequently generated the new light shading scheme:

$$Kd_1 = k_{w2} + k_p \cdot P + k_{DOM} \cdot DOM + k_{Det} \cdot Det + k_{spm} \cdot \sqrt{SPM} \quad \text{(S2)}$$

   We implemented the new light shading scheme (Eq.S2) in the simulation and evaluated the difference in NPP contributed by tide, by comparing the annual mean NPP in tidal and non-tidal scenarios (Fig.S2). The general pattern remain. The positive and negative responding area hold the same distribution pattern, except for frontal areas where elevated NPP decreases slightly when SPM impact is explicitly considered. This is because the elevated NPP fueled by pumped up nutrients are partly offset by increased shading effects due to SPM. However, the changes are minor and do not affect the general sensitivity pattern.

2) **Subsurface NPP compared to observation**.

   Table S1. NPP contributed by tidal forcing in the transect where Richardson did their observation (Northern edge of DB) and in the transect where fronts locate in our simulation (frontal transect), a few grid points away

	Difference Tide (M2 +S2) – Tide (M2) (gCm^{-2}per spring-neap cycle)	Difference Tide (M2 +S2) - no-tide (gCm^{-2}per spring-neap cycle)
Northern edge of DB	0.11	3.03
Frontal transect	0.14	5.987

Reference:

Große, F., Greenwood, N., Kreus, M., Lenhart, H. J., Machoczek, D., Pätsch, J., Salt, L. and Thomas, H.: Looking beyond stratification: A model-based analysis of the biological drivers of oxygen deficiency in the North Sea, Biogeosciences, 13(8), 2511–2535, doi:10.5194/bg-13-2511-2016, 2016.

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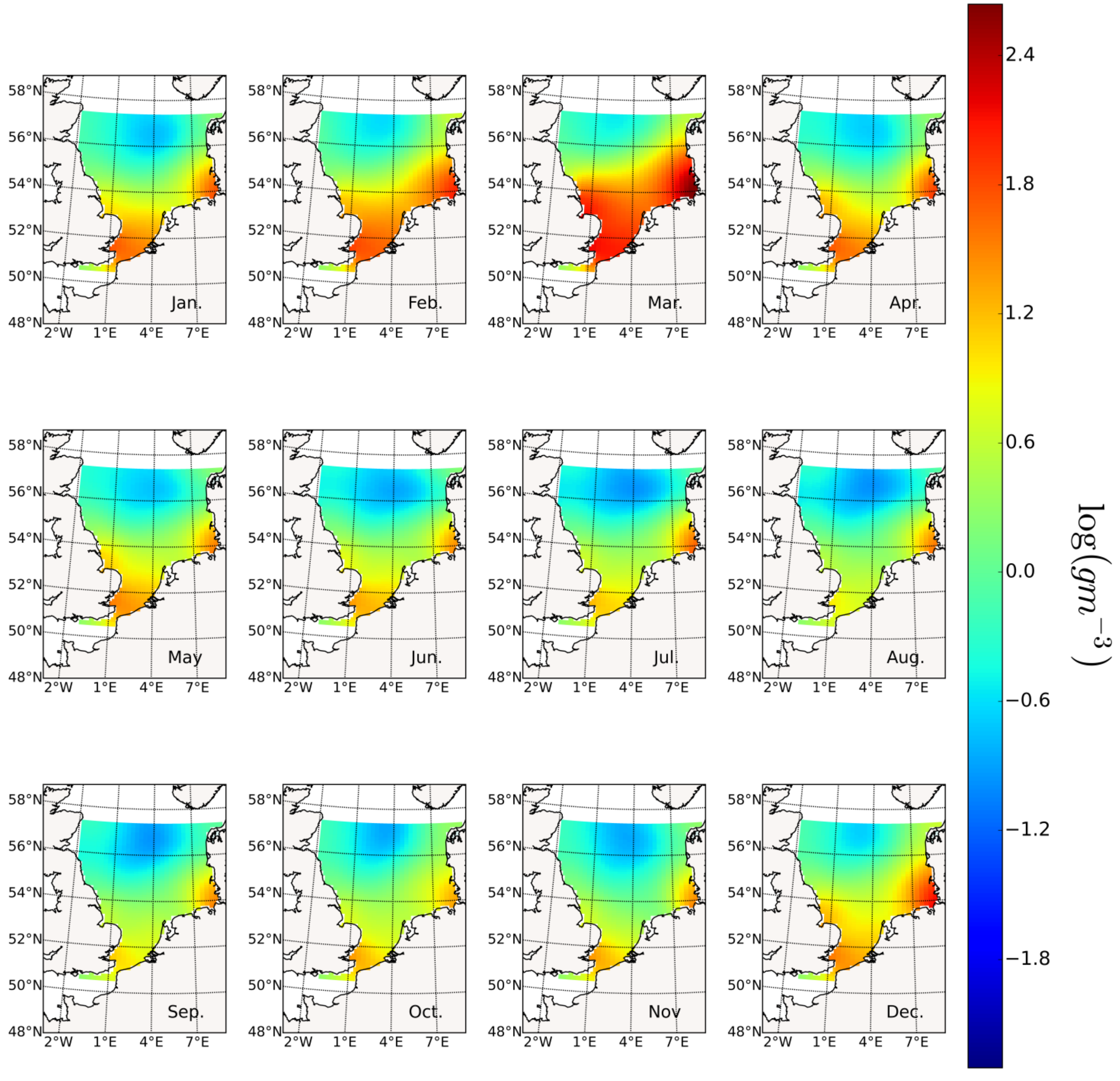

Figure S1. Monthly mean of inorganic SPM concentration in the first layer (upper 5 meters)

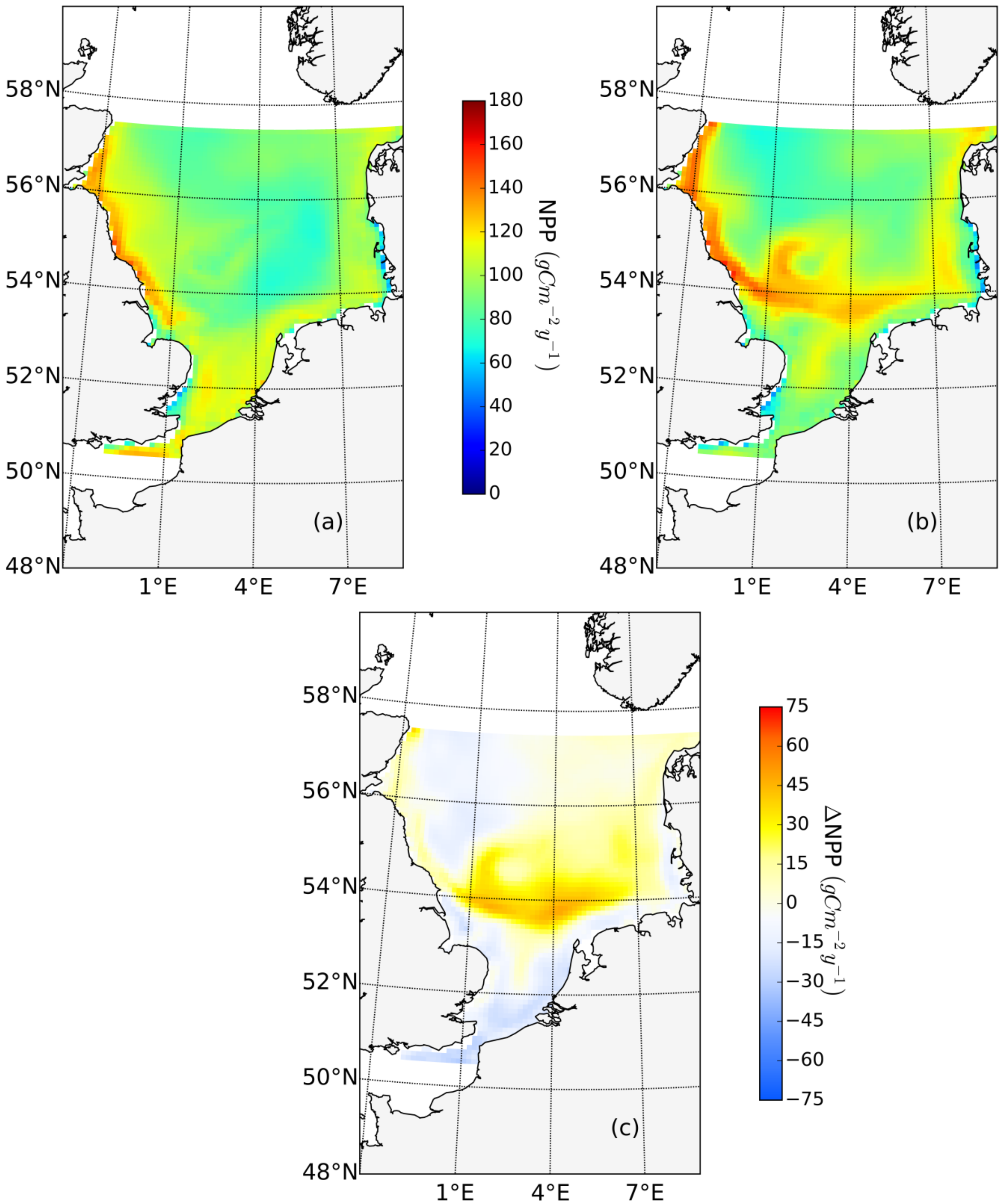

Figure S2. Mean annual net primary productiotn for the *analysed period* (1990-2015) of the *non-tidal scenario* (a), and t*idal scenario* (b), both with SPM filed implemented. The difference in the mean annual NPP of both scenarios is in (c). The spatial coverage is smaller than original simulation domain since the SPM filed data is available from $50.5°N - 57.5°N$

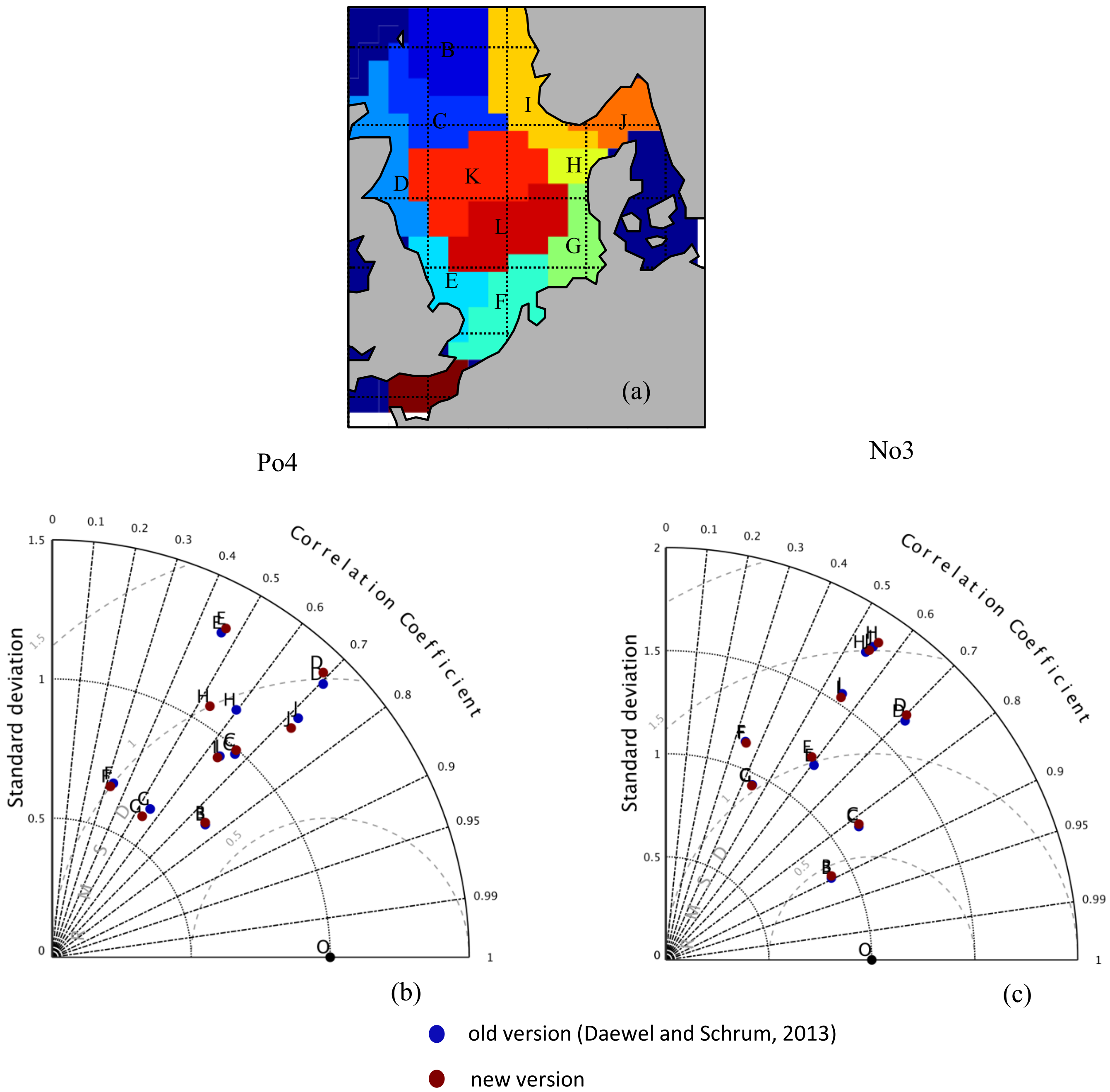

Figure S3 Taylor diagram for surface (above 20 m) nutrient validation (model versus ICES data) in different areas of the North Sea for phosphate (b) and nitrogen (c). Area separation is given in (a).

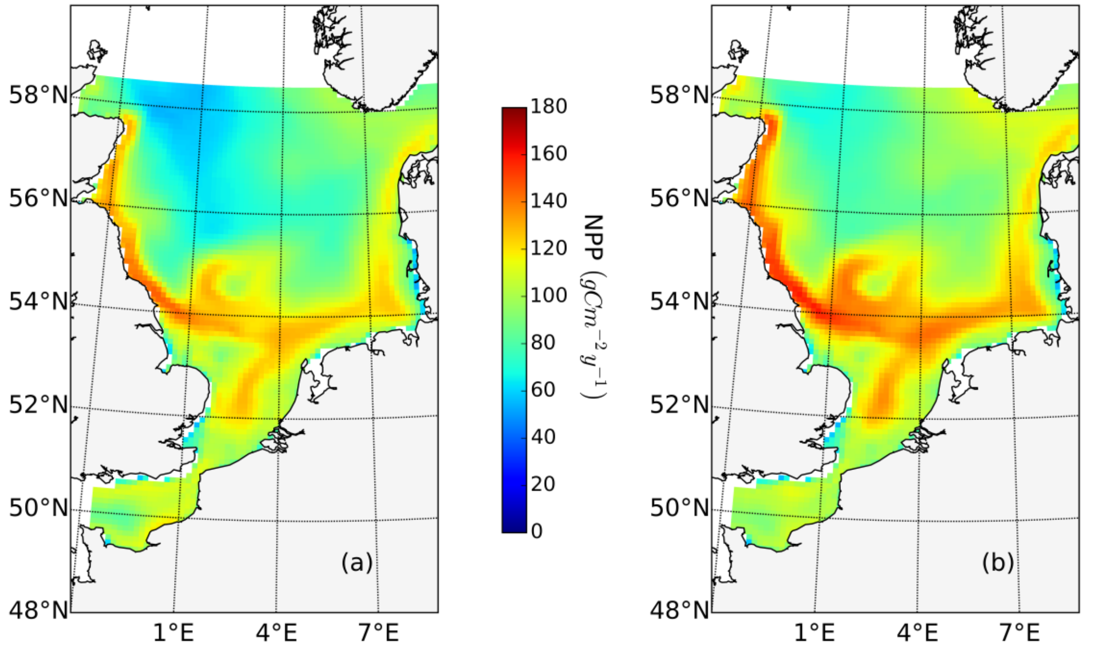

Figure S4. Mean annual net primary production for the *analysed period* (1990-2015) of the former setup (Schrum and Daewel, 2013) (a) and the setup in this study (b)

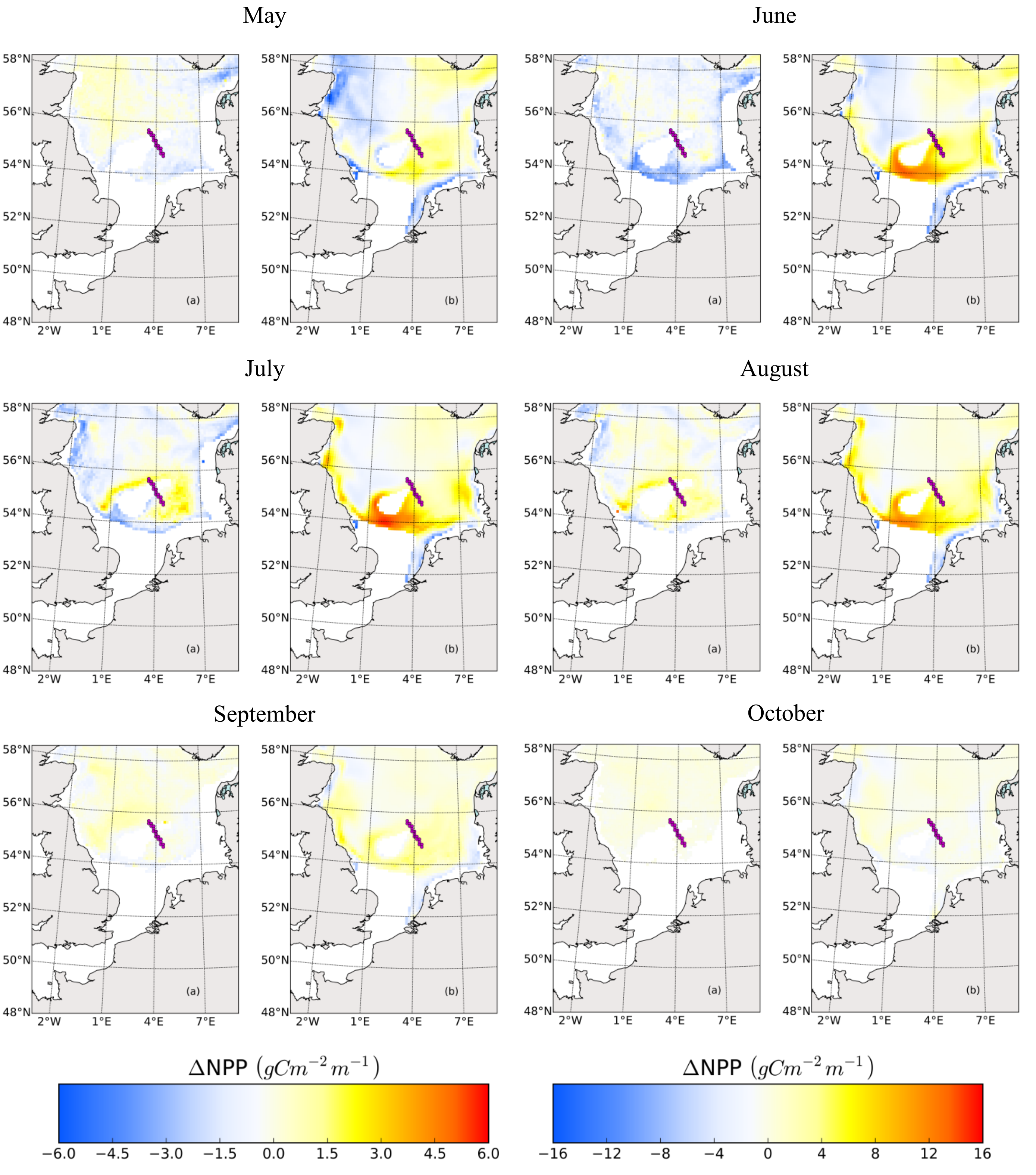

Figure S5. Monthly mean of NPP's response to tide (M2+S2). In the subsurface layer (a) , with colorbar ranging from -6~6 gCm^{-2}; for the surface layer (b), the colorbar ranges from -16~16 gCm^{-2}

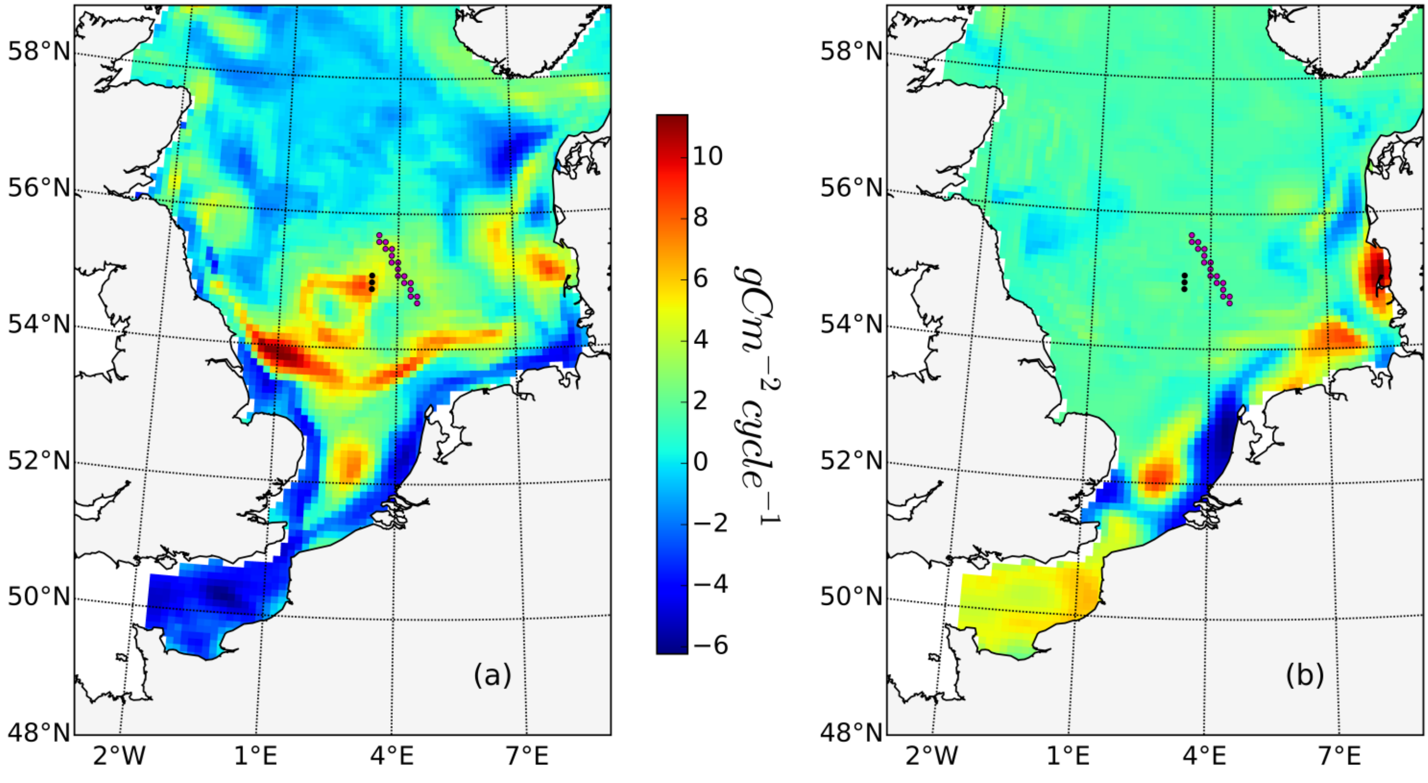

Figure S6. Vertically integrated NPP contributed by tide (M2+S2) (a) and spring-neap tidal cycle (b) for one spring neap cycle (26/07/1997-08/08/1997) as the same period when the measurements were taken in Richardson et al., 2000. Magenta dots depict the location of the transects which Richardson et al. (2000) has analyzed. Black dots depict the exact location of fronts in our simulation.