Biogeosciences Discuss., referee comment RC1 https://doi.org/10.5194/bg-2022-86-RC1, 2022

Comment on bg-2022-86

Anonymous Referee #1

Referee comment on "Interannual variability of the initiation of the phytoplankton growing period in two French coastal ecosystems" by Coline Poppeschi et al., Biogeosciences Discuss., https://doi.org/10.5194/bg-2022-86-RC1, 2022

Main manuscript modifications are highlighted in red.

In this manuscript the decadal years variability of the IPGP (Initiation of the Phytoplankton Growing Period) is analyzed at two coastal stations located in the northern (Iroise Sea) and eastern Bay of Biscay (Bay of Vilaine). The phytoplankton biomass is related to fluorescence measured by instrumented buoys. The sensitivity analysis for identifying the major causes of the variability is made through a 1-D biogeochemical model applied to the year 2015. The major result of this work is that, despite different environments, the IBGP days are very similar at the two stations. No significant trend in the IPGP is observed in the time series However the variability is high and seems to show an earlier IGBP in the middle of the period -around year 2010- (at about day 60 against day 90 for the beginning and the end of the period). The results are interesting but this manuscript presents some flaws.

We thank the reviewer for the constructive reviews. We considered each point below.

The data used are fluorescence-derived Chlorophyll-a, the identification of the factors influencing the IPGP is made through a model and the conclusions are evasive.

The conclusions have been rephrased to be more detailed and less evasive in the first paragraph of part 5 conclusions and in the abstract. We then describe main conclusions built on model results but also on *in situ* observations.

On the first point, auxiliary analysed Chl-a concentrations collected bimonthly (which is a large interval for this purpose) corroborate nevertheless the IBGP derived from fluorescence data. The main issue comes therefore from the discussion based on model results. The model is considered as perfect and the causes of the variability are discussed from its outputs. From the introduction to the conclusion and throughout the discussion the real issues of the IGBP have not been considered with sufficient care. Blooms at local stations in river plumes may or may not occur, the true question is what happens at large scale? What is the connection with the dynamics of phytoplankton in the whole area?

The aim of this study was to investigate the initiation of the IPGP in nearshore waters under the influence of rivers highly rich in nutrients. The bathymetry (< 30 m) and the hydrodynamics of the Bay of Vilaine (Mor Braz) and the Bay of Brest do not allow them to be compared at larger scale respectively to the Bay of Biscay and to the Iroise sea. The late winter phytoplankton blooms reported in the northern Bay of Biscay by Labry et al.

(2001) and Gohin et al. (2003) were observed respectively in isobaths 60-30 and 120-80 m. According to the satellite observations, the phytoplankton dynamic in nearshore of south Brittany (Gohin 2010; Gohin 2012; marc.ifremer.fr website) is clearly different from the rest of the Bay of Biscay while the difference between the Gironde plume and the Bay of Biscay is less true (Figure 1). The maps of the monthly mean chl-a concentrations, as well as the annual cycles of chl-a, also show that it is in the nearshore of the Bay of Biscay, and in particular in the plumes of the Loire and Vilaine rivers, that the concentrations are the highest. For all these reasons, it does not seem appropriate to extend spatially (at the scale of the continental shelf of the bay of Biscay) our results obtained at one nearshore HF instrumented station.

In the manuscript introduction with the objectives have been modified to explain the local scale addressed in the study. We also add a specific sentence in section 2.1 "coastal temperate ecosystems".

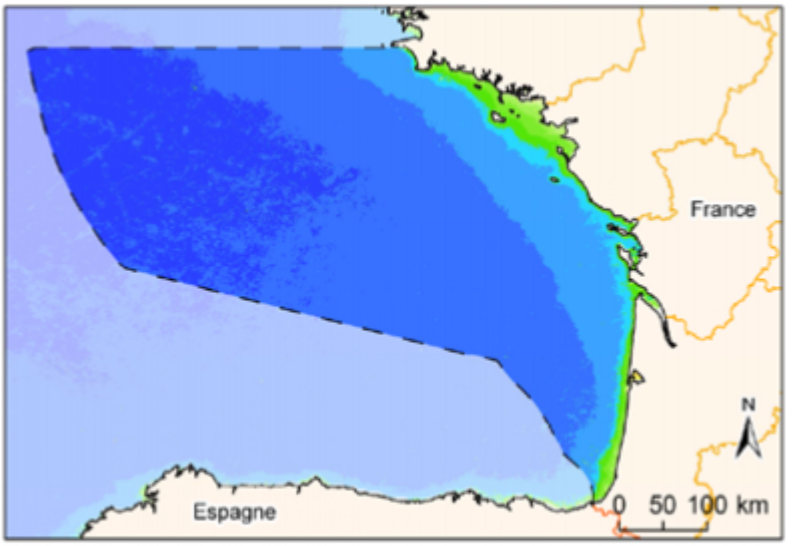


Figure 1: Mean Chl-a concentrations in January/February during 2003-2010 (from Gohin, 2012)

Gohin Francis, Saulquin Bertrand, Bryere Philippe (2010). Atlas de la Température, de la concentration en Chlorophylle et de la Turbidité de surface du plateau continental français et de ses abords de l'Ouest européen.https://archimer.ifremer.fr/doc/00057/16840/

Gohin Francis (2012). Répartition spatio-temporelle de la chlorophylle a. Sous-région marine Golfe de Gascogne. Evaluation initiale DCSMM. MEDDE, AAMP, Ifremer , Ref. DCSMM/EI/EE/GDG/12/2012, 13p. https://archimer.ifremer.fr/doc/00329/44009/

Labry Claire, Herbland Alain, Delmas Daniel, Laborde P, Lazure Pascal, Froidefond J, Jegou Anne-Marie, Sautour B (2001). Initiation of winter phytoplankton blooms within the Gironde plume waters in the Bay of Biscay. Marine Ecology Progress Series, 212, 117-130.

Morin, P., Le Corre, P., Marty, Y., L'Helguen, S., 1991, Evolution printanière des éléments nutritifs et du phytoplancton sur le plateau continental armoricain (Europe du Nord-Ouest). Oceanologica Acta 14:263-279.

We know since the end of the 90's that strong early blooms within the Gironde plume may consume a large part of the winter Phosphorus stock at the beginning of March or even earlier. This has been attested also by satellite observations at broader scale.

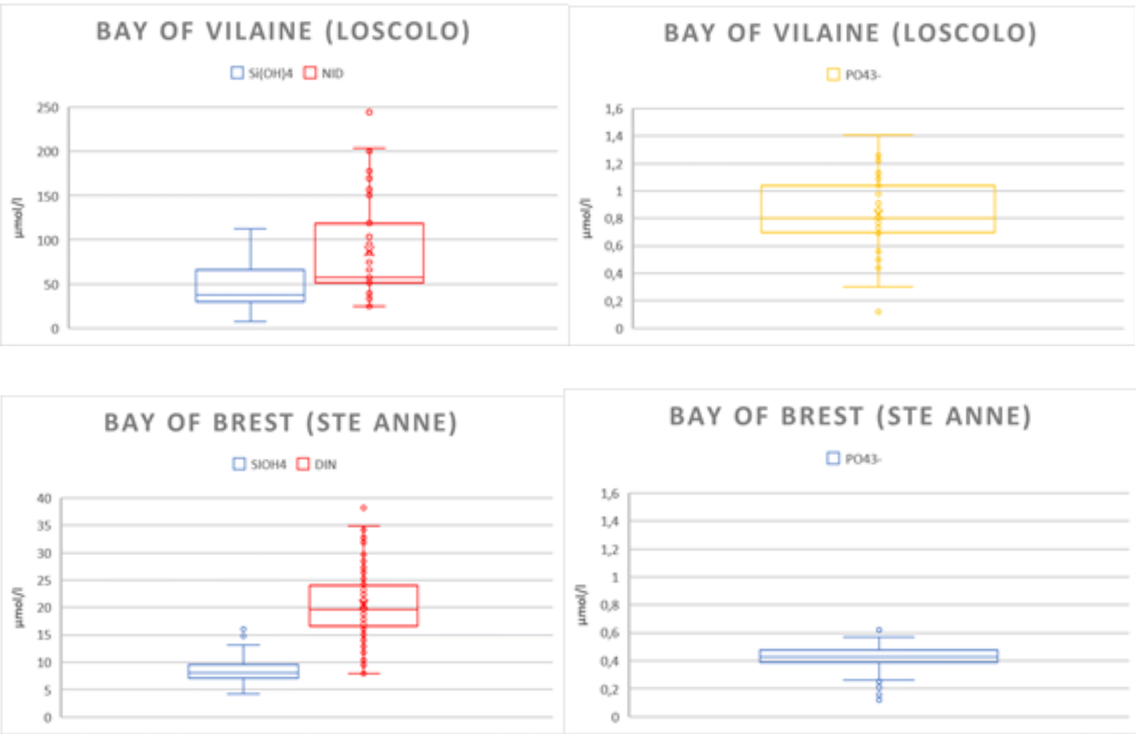
According to the results of Labry et al. (2001) - Table 1, we agree that the late winter bloom consumes a large part of the winter phosphorus stock at the beginning of March within the Gironde plume. The situation is completely different in the Bay of Vilaine and in the Bay of Brest where nutrient concentrations remain high until late March. When Labry et al. (2001) observed phosphate concentrations close to the limit of detection of the analytical method (< 0.05 µmol/l) in February, the median phosphate concentration is equal to 0.83 µmol/L in the Bay of Vilaine and to 0.43 µmol/L in the Bay of Brest (Figure 2). The median silicate concentration (Figure 2, respectively 38.1 and 8.1 µmol/L in the Bay of Vilaine and the Bay of Brest) is highly above the half-saturation constant required for their assimilation by diatoms (Ks = 2 µmol/L, Del Amo and Brzezinski 1999). The waters are also not limited by silicate before the IGPG date, which accredits the presence of large diatoms at the IPGP date and not a phytoplankton population dominated by small cells.

		PO_4 µM	NO_3 µM	NH_4 µM	$Si(OH)_4$ µM	NO_3:PO_4 at:at	N_{min}:PO_4 at:at	NO_3:Si at:at	*n*
1998	**Turbid plume**								
	January	0,586 ±0,086	26,2 ±3,7	1,7 ±1,5	17,9 ±3,3	47 ±6	50 ±8	1,4 ±0,1	*4 - 5*
	Start March	0,215 ±0,064	13,1 ±1,5	0,2 ±0,2	8,1 ±2,2	67 ±25	69 ±26	1,7 ±0,6	*4*
	« girondines » waters								
	January	0,320 ±0,087	9,9 ±3,6	1,1 ±1,0	7,5 ±2,0	31 ±9	36 ±9	1,3 ±0,2	*17 - 19*
	Start March	< 0,020	4,9 ±2,6	0,1 ±0,2	1,9 ±1,0	> 100	> 100	2,4 ±1,1	*20 - 22*
	June	< 0,020	0,8 ±0,5	0,3 ±0,2	2,3 ±0,6	-	-	0,4 ±0,4	*21 - 23*
	« oceanics » waters								
	January	0,213 ±0,042	2,8 ±0,5	0,9 ±0,5	2,7 ±1,0	14 ±3	19 ±3	1,2 ±0,3	*27 - 46*
	Start of March	0,034 ±0,027	0,9 ±1,2	0,1 ±0,1	1,0 ±0,7	> 100	> 100	0,8 ±0,8	*40*
	June	< 0,020	0,3 ±0,3	0,2 ±0,2	1,6 ±0,5	-	-	0,3 ±0,3	*18*
1999	**« girondines » waters**								
	End February	0,289 ±0,236	9,8 ±4,1	0,5 ±0,3	6,2 ±2,2	51 ±33	55 ±36	1,6 ±0,4	*19 - 21*
	End April	< 0,020	4,3 ±2,1	0,7 ±0,3	1,9 ±1,2	> 100	> 100	3,5 ±3,1	*45*
	End May	< 0,020	6,6 ±5,9	0,9 ±0,7	3,2 ±4,6	> 100	> 100	16 ±30	*18 - 22*
	End June	< 0,020	1,3 ±1,6	0,2 ±0,1	3,3 ±1,7	-	-	0,3 ±0,3	*10 - 26*
	Mid July	< 0,020	0,5 ±0,9	0,5 ±0,3	3,6 ±2,1	-	-	0,1 ±0,2	*32*
	Start October	0,284 ±0,062	4,9 ±2,5	1,1 ±0,2	6,6 ±1,7	17 ±7	23 ±7	0,7 ±0,2	*12*
	« oceanics » waters								
	End February	0,127 ±0,041	3,4 ±1,0	0,4 ±0,2	2,6 ±0,9	30 ±16	35 ±18	1,5 ±0,9	*25 - 27*
	End April	< 0,020	1,8 ±0,6	0,7 ±0,1	0,8 ±0,3	> 100	> 100	2,7 ±1,4	*4*
	End May	< 0,020	1,0 ±0,3	1,0 ±0,3	2,0 ±1,0	> 100	> 100	0,6 ±0,4	*2*
	Start October	0,022 ±0,031	0,2 ±0,2	0,9 ±0,3	1,6 ±0,7	-	-	0,1 ±0,1	*43*

Table 1: Nutrients concentrations within the Gironde plume in late winter (from Labry et al. 2001)

(a)

(b)



<u>Figure 2: Box-plot representation of nutrient concentrations (DIN, PO43- and Si(OH)4) between January and March (day 0 to day 69) measured (a) at the REPHY West Loscolo station (Bay of Vilaine) during the period 2011 -2019, (b) at the SOMLIT Ste Anne station (Bay of Brest) during the period 2001-2019</u>

Del Amo Y., Brzezinski M.A. (1999) The chemical form of dissolved Si taken up by marine diatoms, Journal of Phycology, 35, 1162-1170.

Gohin Francis, Lampert Luis, Guillaud Jean-Francois, Herbland Alain, Nezan Elisabeth (2003). Satellite and in situ observations of a late winter phytoplankton bloom, in the northern Bay of Biscay. Continental Shelf Research, 23(11-13), 1117-1141. Publisher's official version : https://doi.org/10.1016/S0278-4343(03)00088-8

Labry Claire, Herbland Alain, Delmas Daniel, Laborde P, Lazure Pascal, Froidefond J, Jegou Anne-Marie, Sautour B (2001). Initiation of winter phytoplankton blooms within the Gironde plume waters in the Bay of Biscay. Marine Ecology Progress Series, 212, 117-130.

Here, the studied areas (Bay of Brest and Bay of Vilaine) are eutrophied bays with high nutrient concentrations. In our coastal waters, silicates are consumed first, then phosphates, then nitrates, but this occurs at the end of the first spring bloom, not at the onset. This is why our study focuses only on the physical conditions responsible for the IPGP. We clarify the information of a non-limitation of nutrients more clearly in our study by adding them for example in the Table 4 of the manuscript with the other environmental parameters and also in some parts in the text:

Abstract - "coastal temperate ecosystems under the influence of rivers highly rich in nutrients"

Introduction - "The river influence induces waters highly rich in nutrients."

Results part 4.1 - "However, at the beginning of the phytoplankton growing period (IPGP), the system is not nutrient limited in terms of nitrate, phosphorus and silicates."

There is in the understanding of these late winter blooms (between day 50 and 90) a critical issue for identifying the "major cause" of the "major disturbance" of the biological environment over the continental shelf of the Bay of Biscay. For the initiation of early offshore blooms, the light is the prevailing factor, not the SST; hence a verification of the critical depth hypothesis as formalized by Sverdrup.

Indeed, we agree with the referee that the light is one of the prevailing factors in the initiation of phytoplankton growth. However, in our system, the sea temperature is also a prerequisite of the phytoplankton growth and cold water temperature avoids earlier blooms in the season.

The critical depth hypothesis formalized by Sverdrup (1953) is based on the fact that phytoplankton blooms occur when surface mixing shoals to a depth shallower than a critical depth. In our studied region, the ecosystem does not evolve with mixed layer dynamics as observed in deeper environments (i.e. deep mixed layer depth in winter mainly due to wind forcings and shallower mixed layer depth in spring linked with the onset of stratification and weakening of wind induced mixing). Indeed, shallow waters(< 30m depth) in both bays are permanently vertically mixed mainly by the tides and the intensity of the mixing mainly fluctuates with tidal amplitude and wind intensity. The vertical stratification only occurs on a thin surface layer due to river runoffs in those bays for short time scales (few hours to few days during a flood event for example).

To avoid reader confusion, we rephrased the introduction of the manuscript to describe the local factors driving the phytoplankton growth dynamics.

Although criticized with real arguments, this simple theory may be locally verified in the bay of Biscay. The blooms occur in the clear, relatively cold, and stratified waters of the outer river plumes (Loire, Vilaine, Gironde). These blooms, sometimes very strong, have a high impact in biology as they provide foods for benthos at the end of winter and they consume a large part of the phosphorus stock in the surface layer with consequences in the phytoplankton size. As the concentration of Phosphorus in the rivers has been declining at high pace for these last twenty years, these blooms could have a stronger impact in the future.

Despite the decrease in winter phosphate concentrations in rivers (Ratmaya 2019), phosphate concentrations measured in the Bay of Vilaine and in the Bay of Brest before the IPGP date (day 68 = median day of the IPGP) are still high (Figure 2) and are not limiting phytoplankton growth (Ks = 0.09 µmol/L, Labry et al. 2001). We add the concentrations of nutrients in Table 2 of the manuscript.

My feeling is therefore that this study presents some interesting results but they have to be considered as a very local representation of much larger dynamics.

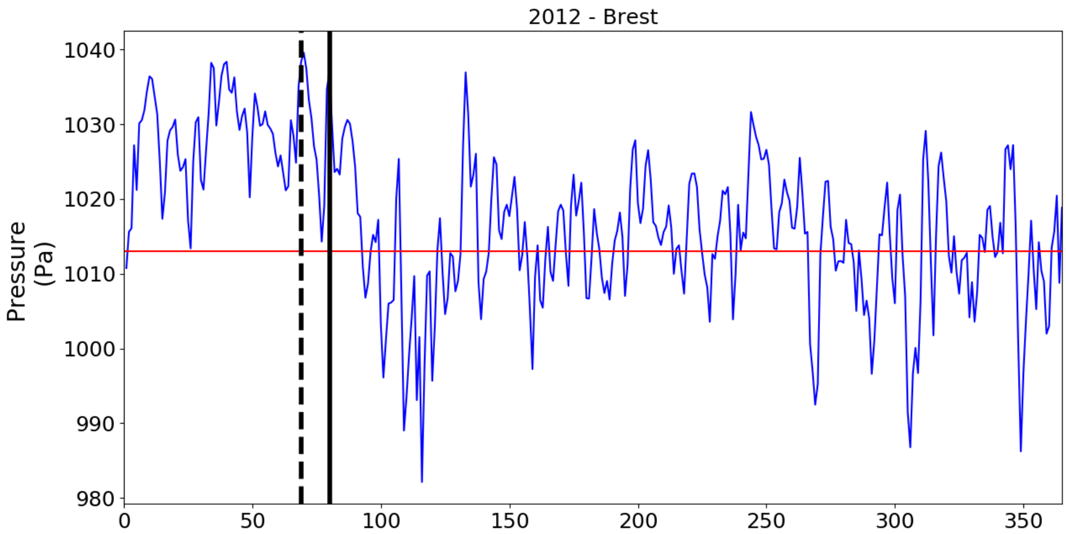
One of the aims of the project was to connect local phytoplankton dynamics with larger scale dynamics. However, in those shallow environments (<30m), the ecosystem dynamics is driven by a combination of local factors under influence of continental (rivers) and atmospheric forcings. The phytoplankton growth dynamics is then independent of large scale blooms observed in the bay of Biscay or the Iroise sea.

Considering these time series at the stations together with satellite data of chlorophyll-a and a 2 or 3-D model appear to be the next steps to propose for future investigations.

Thank you for this comment, we totally agree. We detailed the perspectives of this work in the new manuscript in the second paragraph of part 5 conclusions. Our first approach was based on *in situ* observations and a simplified 1DV modeling but we are indeed planning to extend our analyses to a 3D modeling approach for future investigations as well as satellite data.

A better consideration of the atmospheric environment would also benefit the understanding of these late winter blooms as anticyclonic conditions associated to high solar irradiance and low wind (hence lower turbidity) generally prevail at the onset of the late winter blooms in the Bay of Biscay.

We thank you for this comment. In our study, we concentrate on constraining components from the atmosphere for the ecosystem (solar irradiance, wind intensity). However, we explored the atmospheric conditions by looking at the atmospheric pressure time series (Figure 3). However, in our case, for both bays, the atmospheric conditions are not the same at each IPGP. The IPGP can occur during low pressure conditions (e.g. 2019) or during high pressure conditions (e.g. 2012) as for example in the Bay of Brest (Figure 3). We then consider the temperature and wind separately rather than considering the atmospheric pressure.



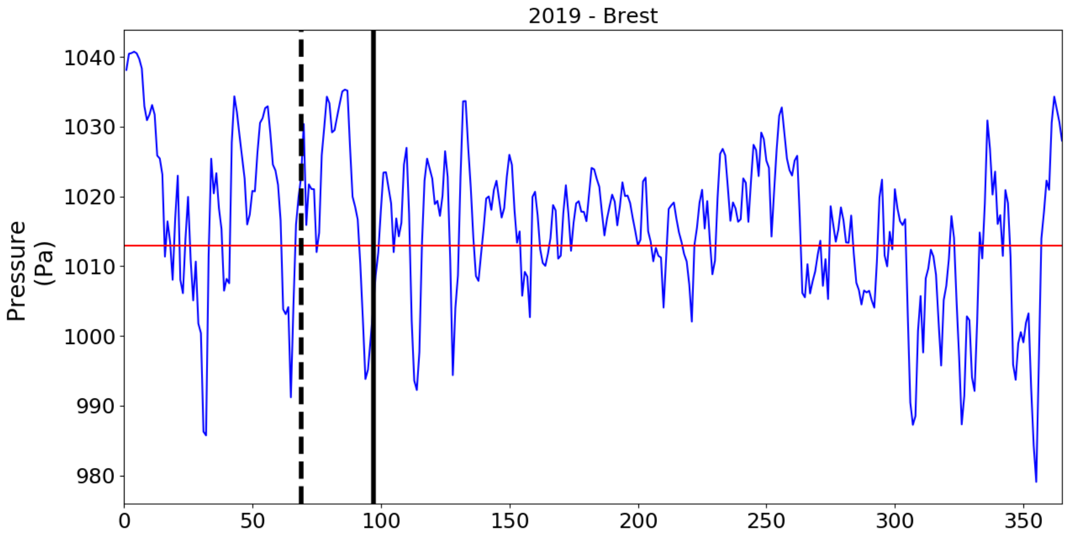


Figure 3: Two examples of atmospheric pressure time series (from AROME-Meteo-France model simulations) in the Bay of Brest with the date of IPGP for each year (black vertical line) and the median date of IPGP (day 69, black dashed vertical line) and the threshold of cyclonic/anticyclonic conditions at 1013 hPa (red horizontal line).

Specific comments: My general comments have implications in the abstract, the introduction, the discussion and the conclusion.

Abstract: "The use of a one-dimensional vertical model coupling hydrodynamics, biogeochemistry and sediment dynamics shows that the IPGP is generally dependent on the interaction between several drivers. Interannual changes are therefore not associated with a unique driver (such as increasing sea surface temperature)." Nobody would dare say that temperature is the unique driver of the IGPB. "Extreme event also impact the IGPB". Obvious but how is it quantified in the text? Not useful mentioning it.

We agree and the sentences have been deleted and reworded as follows in the abstract:

"*In situ* observations and a one-dimensional vertical model coupling hydrodynamics, biogeochemistry, and sediment dynamics show that the IPGP generally depends on the interaction between several environmental factors. IPGP is mainly conditioned, at the local scale, by sea surface temperature and available light conditions, controlled by the turbidity of the system before first blooms. "

"In both bays, IPGP can be delayed by cold spells and flood events at the end of winter if these extreme events last several days."

Introduction: "Moreover, theories proposed for the open oceans are not relevant in coastal zones." Really?

Following your comment this sentence has been deleted from the introduction and the following sentence reworded as follows:

"Coastal waters remain highly dynamic and productive ecosystems at the interface between land and sea and are distinguished from the waters of the open sea (*e.g.* Gohin *et al.*, 2019; Liu *et al.*, 2019)."

Discussion Extreme events: "In coastal stratified regions (e.g. under the influence of river plumes), strong wind and tidal mixing can enhance the mixing and break down stratification. Such conditions can also enhance phytoplankton production (Joordens et al., 2001). During the IPGP, except during floods, both regions are weakly stratified and are then less sensitive to combined wind/tidal short events." Not useful. In fact the stratification acts positively for initiating blooms in coastal and open waters at the end of winter.

Thanks for the comment, this part has been changed to:

"In coastal stratified regions (e.g. under the influence of river plumes), strong wind and tidal mixing can enhance the mixing and break down stratification thus distributing phytoplankton (Joordens et al., 2021). During the IPGP, except during floods, both regions are weakly stratified and are then less sensitive to combined wind/tidal short events."

Conclusion: You could imagine something of higher ambition than adding horizontal advection in the model ...!

Indeed, we thought to change the second paragraph of the part 5 conclusions in the manuscript and develop our ideas in terms of perspectives of this study.

Figure 7: From the legend we are looking for the Chl curve. It would be better to change the legend for something similar to "Day at the IGPB and environmental drivers: . Illustrations in 2011, 2013 and 2014. ...."

Thank you for your remark, the updated legend has been modified in the manuscirpt and in the supplementary part like this:

"Figure 7: IPGP dates and environmental drivers: flow of the Aulne, Vilaine and Loire rivers, Sea Surface Temperature (SST), wind intensity, PAR, turbidity and sea level. Illustrations in 2011 for a mean IPGP date in (a) the Bay of Brest and (b) the Bay of Vilaine; in 2013 for an early IPGP date in (c) the Bay of Brest; in 2014 for a late IPGP date in (d) the Bay of Vilaine. The mean IPGP date of each bay is represented by a dotted black line and the IPGP date of the year is represented by a straight black line. Thresholds of each environmental driver are represented by grey vertical lines corresponding to the mean conditions calculated 30 days around the IPGP date. Grey areas are time periods favorable to IPGP."