Dear Reviewer,

We are grateful for your thoughtful and thorough evaluation of our manuscript. Below, we respond to each of your comments and concerns, identifying how we intend to address them in a revised version of the manuscript. Our responses are indicated with a blue font. We have endeavoured to address all of your comments as you recommended. Overall, we believe that our manuscript will be improved by addressing your comments and we thank you again for your time reviewing this document.

Sincerely,
R. Izett & co-authors.

Specific comments:
Line 44: choose a different word than 'sinks' as not all export is a sinking flux

Thank you for the suggestion. We will change the sentence from "*When measured over sufficiently large temporal and spatial scales, NCP quantifies the amount of photosynthetically produced organic matter that sinks from the upper ocean (Laws 1991)*" to "*When measured over sufficiently large temporal and spatial scales, NCP quantifies the amount of photosynthetically produced organic matter that is removed from the upper ocean (Laws 1991)*"

Equation 1,2,3: it seems counterintuitive to have CR added to GPP in equations 1 & 2 rather than subtracted. I think the reason it is shown this way is because CR is assumed to have a negative value. However, on page 8 it is stated that the first term on the right of equation 5.1 = GPP and the second term on the right = CR, making the relationship GPP – CR, which is inconsistent with equations 1 & 2. It also seems nonintuitive in equations 1 and 3 to have a + sign in front of the last term on the right for equation 1 and a minus sign for the last term of equation 3. Should these both be '+/-' since they represent source and sink terms?

Equation 7.1: should '+/-' be used in front of the final term on the right rather than '-' ?

Thank you for looking closely at the equations. In response to your suggestions, we will change all respiration terms (AR, HR, CR) to have positive notation throughout the manuscript, such that NPP = GPP-AR and NCP = GPP-CR. To clarify this notation, we will change the last sentence of the second introductory paragraph (around L45) from "*All PP fractions are often expressed as volumetric equivalents of organic carbon or O2 production (e.g., mol C or O2 m-3 d-1), such that respiration has negative values*" to "*GPP, NPP and NCP are often expressed as volumetric equivalents of organic carbon or O2 production (e.g., mol C or O2 m-3 d-1), and respiration terms are expressed in terms of organic C or O2 consumption. Accordingly, GPP, NPP and CR can only have positive values, while NCP may assume positive or negative quantities*"

We will also change the "- other source/sinks" term in the equations to "± other sources and sinks"

As a result of these changes, equations 1-3 and 7 will become:

$$d[T(t,z)]/dt = GPP(t,z) - CR(t,z) \pm \text{other sources/sinks}(t,z) \qquad (1)$$

$$d[T(t,z)]/dt \approx GPP(t,z) - CR(t,z) \qquad (2)$$

$$NCP(t,z) = d[T(t,z)]/dt \pm \text{other sources/sinks}(t,z) \quad (3)$$

$$NCP(t,z) = (h_{i+1}-h_i)[T(t_1,z)]-[T(t_0,z)]\ t_1-t_0 \pm \Sigma F(t,z) \quad (7)$$

Line 160 – 164: Here it is stated that POC is estimated from published relationships (Loisel et al, Cetinic et al, Graff et al.). I would suggest explicitly giving these relationships in a table in the appendix. The Graff et al. paper, for example, is primarily focused on estimating phytoplankton carbon from bbp and the POC relationship is a secondary result. Explicitly providing the equations used will prevent any confusion.

Thank you for the suggestion. We will include the following supplementary table, and associated references, in the appendix of the manuscript.

Table A3. A comparison of selected c_p- and b_{bp}-to-POC algorithms. Resulting POC units are mg m^{-3}. Units of c_p and b_{bp} are both in m^{-1}, and the wavelength of the c_p and b_b measurements is indicated with a subscripted number (e.g., $c_{p,660}$ indicates measurements at 660 nm). This table is not a complete list; the equations were selected to illustrate variability in POC relationships.

POC Equation	**Region**	**Reference**
$POC = 367\ c_{p,660} + 31.2$	N. Atlantic	Marra et al. (1995)
$POC = 391\ c_{p,660} - 5.8$	N. Atlantic	Cetinić et al. (2012)
$POC = 35422\ b_{bp,700} - 14.4$	N. Atlantic	Cetinić et al. (2012)
$POC = 48811\ b_{bp,470} - 24$	N. and S. Atlantic, Equatorial Pacific	Graff et al. (2015)
$POC = 841\ b_{bp,532}^{0.395}$	N. and S. Atlantic	Balch et al. (2010)
$POC = 39418\ b_{bp,470} - 13$	S. Atlantic; Southern Ocean	Thomalla et al. (2017)
$POC = 501.81\ c_{p,660} + 5.33$	Equatorial Pacific	Claustre et al. (1999)
$POC = 585.2\ c_{p,660} + 7.6$	Equatorial Pacific	Behrenfeld and Boss (2006)
$POC = 661.9\ c_{p,660} - 2.168$	Pacific and Atlantic (incl. upwelling)	Stramski et al. (2008)
$POC = 71002\ b_{bp,555} - 5.5$	Pacific and Atlantic (incl. upwelling)	Stramski et al. (2008)
$POC = 458.3\ c_{p,660} + 10.713$	Pacific and Atlantic (excl. upwelling)	Stramski et al. (2008)
$POC = 53932.4\ b_{bp,555} - 5.049$	Pacific and Atlantic (excl. upwelling)	Stramski et al. (2008)
$POC = 574\ c_{p,555} - 7.4$	Mediterranean	Oubelkheir et al. (2005)
$POC = 404\ c_{p,660} + 29.25$	Mediterranean	Loisel et al. (2011)
$POC = 37550\ b_{bp,555} + 1.3$	Mediterranean	Loisel et al. (2011)
$POC = 31200\ b_{bp,700} + 3.04$	Southern Ocean	Johnson et al. (2017)
$POC = 977760\ b_{bp,770}^{1.166}$	Southern Ocean	Johnson et al. (2017)
$POC = 17069\ b_{bp,555}^{0.859}$	Antarctic Polar Frontal Zone	Stramski et al. (1999)

POC = 476935.8 $b_{bp,555}^{1.277}$	Ross Sea	Stramski et al. (1999)
POC = 381 $c_{p,660}$ + 9.4	Global Ocean	Gardner et al. (2006)

Line 493: Check the wording of the sentence beginning 'Our calculation…', something is wrong here

Thanks for pointing this out. We will change the sentence from "*Our calculations, we extend the work of Johnson and Bif (2021) and Stoer and Fennel (2022)*" to "*Our calculations extend the work of Johnson and Bif (2021) and Stoer and Fennel (2022)*"

General: When calculations of production are made where nighttime changes in a given tracer are assumed to be applicable to daytime rates, what error might be introduced because of impacts of diel vertical migrators?

In section 4.1, we discuss potential uncertainty in diurnal-cycle based GPP calculations. In the second paragraph (beginning L572), we discuss uncertainty resulting from non-photosynthetic processes that vary diurnally, such as air-sea gas flux, grazing, and sinking. In response to your feedback, we will modify this paragraph to specifically include grazing and diel vertical migration. A revised paragraph is as follows (new text is underlined, with additional re-phrasing throughout to improve clarity):

Diurnal cycle GPP methods are based on the presumption that day-night variations in photosynthesis are the primary driver of diurnal variations in O_2 or POC concentrations in the upper ocean. Other than accounting for potential diurnal solubility impacts on O_2 (through expressing O_2 as its concentration anomaly, ΔO_2) no attempts have been made to reconcile for additional diurnal variations in float O_2 or POC observations that are not caused by photosynthesis. For O_2, these include potential impacts due to air-sea exchange or vertical mixing, and for POC, sinking, diel vertical migration and grazing, or PER. Yet, these processes vary throughout the day, and the extent to which they do depends on the season and region. Diurnal variability in solar heating and wind forcing influence mixed layer dynamics on hourly, or longer, timescales, with impacts on air-sea gas exchange (Briggs et al., 2018; Barone et al., 2019) and near-surface vertical mixing (Price et al., 1986). Moreover, particle sinking, grazing, and DOC production, have been implicated as a mechanism for decoupling O_2- and POC-based PP estimates, particularly in high-productivity (e.g., diatom-dominated) regions (e.g., Rosengard et al., 2020). For example, regions of high POC sinking rates, grazing or PER will decouple O_2 and POC concentrations, leading to observations of high-O_2 and low-POC in upper ocean waters, with implications for resulting GPP and CR estimates (White et al., 2017; Rosengard et al., 2020; Briggs et al., 2018). Similarly, day-night variations in grazing, resulting from diel vertical migrations, could amplify the nighttime decline in POC, thereby artificially inflating nighttime respiration estimates, and decoupling O_2- and POC-based GPP calculations. Independently or in combination, these non-photosynthesis diurnal processes likely imprint on the daily signals detected by BGC-Argo floats, whether by single assets or the composite of the array, and therefore constitute a source of uncertainty to the resulting GPP estimates.

Line 760: Since the previous statements include assessments of satellites, it is not clear what is implied by stating that float data are 'publicly available' since satellite data are also publicly available.

Our intention in this statement was to compare the availability of float data versus ship/bottle data. While recent efforts towards FAIR data principles have improved the availability of ship/bottle data, they remain less accessible (e.g., spread over multiple, disconnected repositories) and not standardized (e.g., bottle/ship PP datasets are often published individually with a single paper/project, and therefore follow no archiving or metadata guidelines). We will clarify these points in the opening sentences of the conclusions, as in the following revised paragraph (new text is underlined).

The BGC-Argo fleet offers global observations of real-time ocean biogeochemistry, enabling widespread PP measurements that are independent of, yet complementary to satellite and ship-based approaches. However, compared with PP methods that rely on traditional sampling infrastructure, float-based methods confer significant advantages in detecting PP. Float-based methods, for example, provide simultaneous horizontal, vertical, and temporal PP coverage, presenting the opportunity to fill key gaps in the existing PP data record (Fig. 1). Moreover, while recent efforts towards FAIR data principles (Tanhua et al., 2019) have improved the availability of ship and bottle data, resulting PP datasets remain generally inaccessible (e.g., spread over disconnected repositories) and non-standardized (e.g., datasets are often published individually with a single paper/project, and therefore follow no archiving or metadata guidelines). Float data, in contrast, are generally made available within 24 hours of collection, are publicly available and are archived following agreed-upon guidelines (Bittig et al., 2019), enabling cost-effective, open-source PP calculations that can be independently verified and applied by the entire science community, including those without the resources to perform traditional PP methods. Lastly, float-based methods facilitate enhanced detection of the biological response to unpredictable or episodic events like wildfires, volcanic eruptions, or bloom periods, which often cannot be sufficiently characterized using traditional in-situ datasets (Tang et al., 2021).

Bittig, H. C., Maurer, T. L., Plant, J. N., Schmechtig, C., Wong, A. P. S., Claustre, H., Trull, T. W., Udaya Bhaskar, T. V. S., Boss, E., Dall'Olmo, G., Organelli, E., Poteau, A., Johnson, K. S., Hanstein, C., Leymarie, E., Le Reste, S., Riser, S. C., Rupan, A. R., Taillandier, V., Thierry, V., and Xing, X.: A BGC-Argo Guide: Planning, Deployment, Data Handling and Usage, Frontiers in Marine Science, 6, https://doi.org/10.3389/fmars.2019.00502, 2019.

Tanhua, T., Pouliquen, S., Hausman, J., O'Brien, K., Bricher, P., de Bruin, T., Buck, J. J. H., Burger, E. F., Carval, T., Casey, K. S., Diggs, S., Giorgetti, A., Glaves, H., Harscoat, V., Kinkade, D., Muelbert, J. H., Novellino, A., Pfeil, B., Pulsifer, P. L., Van de Putte, A., Robinson, E., Schaap, D., Smirnov, A., Smith, N., Snowden, D., Spears, T., Stall, S., Tacoma, M., Thijsse, P., Tronstad, S., Vandenberghe, T., Wengren, M., Wyborn, L., and Zhao, Z.: Ocean FAIR Data Services, Frontiers in Marine Science, 6, https://doi.org/10.3389/fmars.2019.00440, 2019.

Line 775: I'm not sure I would advocate using BioArgo production products to train satellite algorithms as my guess is that there is more error/uncertainty in the former than in the latter. I do not see evidence in the current manuscript to conclusively demonstrate otherwise.

We believe that as float-based PP methods mature - and their uncertainties become reduced or better constrained - it will become feasible to train and validate satellite algorithms using float PP data. The resulting algorithms would constitute an entirely independent method to quantifying PP that does not rely on ship-based observations. Similarly, given the on-going expansion of the BGC-Argo array and the continued generation of significant amounts of biogeochemical data, the algorithms can be continually re-trained and evaluated using new methods and datasets. We will incorporate these comments in the final paragraph of the conclusions as follows (new text is underlined):

Ultimately, <u>continued efforts towards expanding and refining float-based PP datasets will reduce uncertainties in the present methods, yielding widespread, in-situ PP estimates in most ocean basins. As uncertainties are further constrained, the resulting estimates will convey significant tangential benefits</u>, like the ability to improve numerical model predictions through data assimilation (e.g., Wang et al., 2020a) and to train <u>and/or validate</u> satellite PP algorithms, as has been done previously using ship data (e.g., Li and Cassar, 2016; Huang et al., 2021). <u>Given the on-going expansion of the BGC-Argo array and the continued generation of significant amounts of biogeochemical data, the resulting products can be continually re-trained and evaluated using new methods and datasets. Achieving these milestones</u> will enable unprecedented, in situ classification of the response and variability of marine PP to various environmental perturbations over a range of space and time scales.

<u>Grammar</u>

Line 223: add 'relationship' after photosynthesis-versus-irradiance

Line 229: Define OSP on first use

Line 348: replace 'are' with 'is'

Line 445: add 'is' after 'values'

Figure 5: define 'Y17', 'H22' and 'H20'

Line 532: replace 'of' with 'our'

Line 569: add 'between' after 'observed.'

Line 690: Delete 'And' at the beginning of the sentence and just begin with 'To'

Line 771: add 'be' after 'can'

Thank you for identifying these mistakes. We will make all of these changes as you have suggested, including defining Y17, H22 and H20 in the figure 5 caption.