Interactive comment on "Partitioning of carbon export in the upper water column of the oligotrophic South China Sea" by Yifan Ma et al

Yifan Ma[1], Kuanbo Zhou[1]. Weifang Chen[1], Junhui Chen[1], Jin-Yu Terence Yang[1] & Minhan Dai[1]

[1]State Key Laboratory of Marine Environmental Science, College of Ocean and Earth Sciences, Xiamen University, Xiamen, 361102, China

Correspondence to: Minhan Dai (mdai@xmu.edu.cn)

Anonymous Referee #1

Ma et al. calculated POC export fluxes at the base of the NDL and Ez, as well as discussed the NDL's nutrient source. The data is treasurable for understanding nutrient dynamics and the carbon cycle. The outcome is reliable, and the manuscript is well-organized. However, some points must be clarified before accepting for publication. There are also a number of typos. My specific recommendations are listed below.

[Response]: We appreciate the positive comments from the reviewer. Our point-by-point responses are listed as of below.

Specific recommendations

My biggest concern is about the method calculating the physical transport flux. In eq. 8, V is part of the tendency term shown in eq. 3. To calculate the horizontal transport flux in the NDL or Ez, it needs to implement an integration over the depth. Whereas, the vertical flux is calculated as the wC, where w is the vertical velocity and C is the concentration of the tracer. It isn't necessary to calculate the "integrated vertical transport flux" over the NDL or Ez as shown in L306. Please recheck your method. I listed some references that introduce the method to calculate transport fluxes. The authors need to introduce how they calculated the horizontal and vertical fluxes clearly.

[Response]: The reviewer is correct that integration for calculation of vertical transport flux of ^{234}Th is unnecessary. We have double checked the calculation of vertical transport flux of ^{234}Th at the base of the NDL and the Ez. The *w* and K_z at the base of Ez (110 m) were -0.10 m d^{-1} and 0.86 m^2 d^{-1}, respectively from Gan et al. (2016). The ^{234}Th activity at 125 m and 100 m was 2.44±0.04 and 2.50±0.02 dpm L^{-1}, respectively at station SS1. The physical term *V* of vertical ^{234}Th flux was estimated to be -2.0±0.4 dpm m^{-2} d^{-1} at the base of Ez based on the following equation (adapted from McGillicuddy et al., (2003) as recommended by the reviewer):

$$-V = [w \times (A_{^{234}Th@100m} - A_{^{234}Th@125m})_{Z_{Ez}}] + [K_z \times \frac{(A_{^{234}Th@125m} - 2 \times A_{^{234}Th@Z_{Ez}} + A_{^{234}Th@100})}{\Delta z^2}]$$

where, Δz is the distance between sampling depths. The estimated vertical flux of ^{234}Th at the NDL base was -11.4±0.1 dpm m^{-2} d^{-1} at station SS1. Therefore, the physical term could still be neglected. We will revise the text as: "The vertical transport fluxes were estimated to be -2.0±0.4 and -11.4±0.1 dpm m^{-2} d^{-1} at the base of Ez and NDL, respectively, accounting for <10% of the vertical scavenging fluxes at corresponding layers at the station SS1, which can be considered to be negligible."

In section 4.3.2, the authors calculated the mass balance of ^{15}N (Eqs. 10, 11). In my understanding, PN which denote particulate nitrogen should be interpreted when it occurred for the first time. It is not clear how to calculate the 3 unknows (Fpn, Fno3, Fair) in two equations. Please introduce the calculation carefully.

[Response]: Following suggestions, we will explain "PN" at its first appearance, which will read: "POC and particulate nitrogen (PN) concentrations were determined by an Elemental Analyzer-Isotope Ratio Mass Spectrometer (EA-IRMS) system…".

In addition, we have rephrased the parameters and changed Equations 10 &11 as follows: "

$$1 = f_{NO_3^-} + f_{Air} \tag{10}$$

$$\delta^{15}N_{PN} = \delta^{15}N_{NO_3^-} \times f_{NO_3^-} + \delta^{15}N_{air} \times f_{air} \tag{11}$$

where, $f_{NO_3^-}$ and f_{Air} represent the fraction of PN export contributed by upwelled DIN from the subsurface and by atmospheric deposition and N_2 fixation, respectively. $\delta^{15}N_{NO_3^-}$ and $\delta^{15}N_{air}$ denote the endmembers of $\delta^{15}N$ for DIN in subsurface waters and air-derived N, respectively."

The authors discovered that horizontal transport flux accounts for 20% of total flux. However, the fraction is not negligible. Some stations were shown to be influenced by eddy activities. It is worthwhile to consider the horizontal transport of eddies whose effect is not only vertical. There are some studies discussed the horizontal transport of particles in eddies e.g. Wang et al., 2018 http://dx.doi.org/10.1029/2017JC013623, Ma et al., 2021, http://dx.doi.org/10.1016/j.pocean.2021.102566. Can you separate the nutrients trapped in the cyclonic eddy and transported with the eddy (horizontal transport) and local uplifted nutrients (vertical transport)? Stations B1 and C2 may be affected by the upwelling off the coast of Vietnam.

[Response]: We appreciate these important comments from the reviewer aiming for improving the flux estimate. Meanwhile, we have to recognize that the horizontal transport flux of 20% was an upper limit of estimates, which is overall comparable with the magnitude of the uncertainty from ^{234}Th measurements (could be >10%). Therefore, the horizontal flux of <20% of the total flux have been typically omitted in many prior studies given the difficulty in the estimation therein (e.g., Buesseler et al., 2020; Wei et al., 2011). We will add such reasoning in our revision.

We agree with the reviewer that mesoscale eddies impact flux estimations. Unfortunately, such effects of eddies cannot be resolved from the present study. We will add in our revision such potential impacts of mesoscale eddies. The reviewer also made significant comments on different pathways of nutrient trapping. But again, distinguishing these processes is extremely challenging (Guo et al., 2017; Zhao et al., 2021). Nevertheless, we considered the comments from the reviewer and will add the following text: "It is also worthwhile to consider that influences from mesoscale and sub-mesoscale processes in eddies in the SCS basin. Prior studies showed that the concurrence of the vertical transport of particles supported by local uplifted nutrients and the horizontal transport of particles supported by the nutrients trapped in eddies (Wang et al., 2018, Ma et al., 2021). In this study, we found enhanced POC export fluxes at stations with high nutrient inventories, which might infer that the POC export flux might also be supported by nutrients from the subsurface based on the signal of $\delta^{15}N_{PN}$. However, our current study was unable to diagnose the pathways of nutrients fuelling the primary and export production.".

Minor concerns:

L36: Siegel et al., 2021

[Response]: Corrected

L41-42: Need references

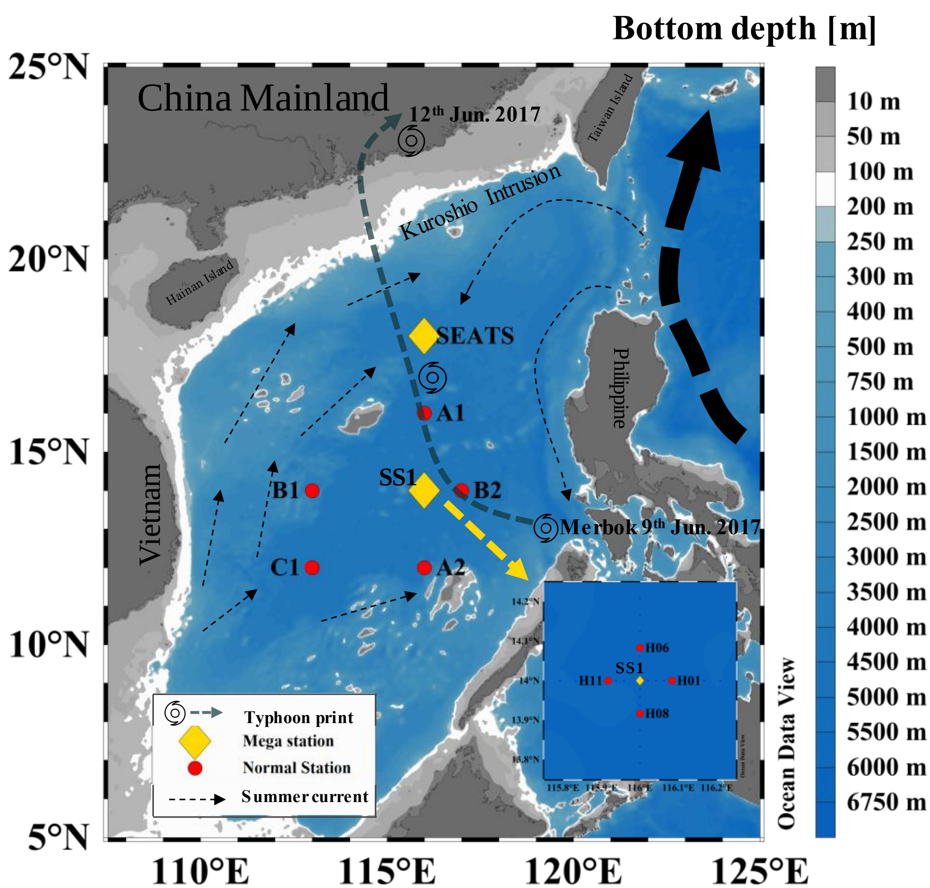
[Response]: Accepted. We will add the relevant references in the revision. “(Benitez-Nelson et al., 2001; Cai et al., 2015; Zhou et al., 2020).”

L53: the references are not recent ones. Don’t use the word recently.

[Response]: Accepted and revision will be made accordingly.

Figure 1: Denote the shading and add a color bar.

[Response]: Accepted. We redraw the map and add a color bar in the revised version.



Please consider to make a new table to show the location, water depth, sampling depth, sampling time etc.

[Response]: As suggested by the reviewer, three tables: the location of sampling stations with arriving and leaving time, water bottom depth, parameters and data utilization in the Table R1 and sampling depth with the ^{234}Th and POC data in Table R2 are available in the revised manuscript.

Table R1: Sampling logs and site information along with the accessed parameters and their utilizations.

Station	Arriving time	Latitude [ºN]	Longitude [ºE]	Bottom depth [m]	Parameters: Total ^{234}Th	Parameters: Trap	Data utilizations: Partitioning POC flux estimate	Data utilizations: Nutrient source diagnosis
SEATS	2017-06-07 00:06	18	116	3907	√	√	√	√
A1*	2017-06-11 23:55	16	116	4205	√		√	
SS1	2017-06-12 20:08	14	116	4107	√		√	
H06	2017-06-20 02:28	14.1	116	4289	√		√	
H08	2017-06-20 07:51	13.9	116	4063	√		√	
H01	2017-06-20 23:41	14	116.1	4139	√		√	
H11	2017-06-21 05:18	14	115.9	4297	√		√	
B1	2017-06-22 11:43	14	113	2537	√		√	
C1	2017-06-23 04:40	12	113	4313	√		√	
A2	2017-06-24 03:05	12	116	4079	√		√	
B2	2017-06-24 21:42	14	117	3947	√		√	

* Sampling station might be influenced by the typhoon event passing through the South China Sea. Station A1 was visited after typhoon Merbok, which was generated on June 9, 2017 at 13.1ºN, 119.8ºE in the southern China Sea. Merbok landed on June 12 at 27.5ºN, 117.3ºE.

Table R2: The list of total and particulate ^{234}Th activity and POC concentration at sampling depth at stations

Station	Latitude degree (N)	Longitude degree (E)	Depth m	Tot. ^{234}Th dpm L^{-1}	Tot. ^{234}Th error dpm L^{-1}	POC μmol L^{-1}	Part. ^{234}Th dpm L^{-1}	Part. ^{234}Th error dpm L^{-1}
SEATS	18	116	130	2.55	0.06	0.6	0.13	0.01
SEATS	18	116	100	2.47	0.06	0.8	0.20	0.01
SEATS	18	116	95	2.73	0.07	2.0	0.32	0.01
SEATS	18	116	85	2.41	0.05	2.1	0.39	0.01
SEATS	18	116	75	2.29	0.06	2.4	0.47	0.01
SEATS	18	116	65	2.30	0.06	2.2	0.43	0.01
SEATS	18	116	55	2.03	0.05	1.8	0.41	0.01
SEATS	18	116	45	2.22	0.06	1.3	0.30	0.01
SEATS	18	116	35	2.13	0.05	1.4	0.16	0.01
SEATS	18	116	25	2.30	0.05	1.6	0.12	0.01
SEATS	18	116	15	2.03	0.05	1.2	0.15	0.01
SEATS	18	116	5	2.27	0.05	1.1	0.11	0.01
A1	16	116	100	2.59	0.05	1.1	0.26	0.01
A1	16	116	75	2.47	0.05	2.5	0.26	0.01
A1	16	116	50	2.17	0.05	1.8	0.29	0.01
A1	16	116	25	1.70	0.25	1.3	0.15	0.01
A1	16	116	5	2.34	0.06	1.3	0.11	0.01
SS1	14	116	125	2.44	0.05	0.8	0.25	0.01
SS1	14	116	110	2.42	0.10	0.9	0.27	0.01
SS1	14	116	100	2.39	0.06	1.3	0.42	0.01
SS1	14	116	95	2.50	0.06	1.3	0.41	0.01
SS1	14	116	85	2.32	0.06	1.7	0.41	0.01
SS1	14	116	75	1.98	0.06	1.3	0.30	0.01
SS1	14	116	65	2.06	0.05	1.5	0.35	0.01
SS1	14	116	55	2.35	0.05	1.4	0.23	0.01
SS1	14	116	45	2.15	0.06	0.6	0.20	0.01
SS1	14	116	35	2.04	0.05	1.3	0.14	0.01
SS1	14	116	25	2.15	0.05	1.1	0.18	0.01
SS1	14	116	15	1.99	0.05	1.2	0.17	0.01
SS1	14	116	5	2.15	0.07	1.2	0.19	0.01
H06	14.1	116	100	2.41	0.05	1.4	0.50	0.01
H06	14.1	116	75	2.05	0.05	1.5	0.42	0.01
H06	14.1	116	50	2.33	0.05	1.1	0.19	0.01
H06	14.1	116	25	2.21	0.05	1.0	0.13	0.01
H06	14.1	116	5	2.27	0.05	1.0	0.11	0.01

Station	Latitude degree (N)	Longitude degree (E)	Depth m	Tot. ^{234}Th dpm L^{-1}	Tot. ^{234}Th error dpm L^{-1}	POC μmol L^{-1}	Part. ^{234}Th dpm L^{-1}	Part. ^{234}Th error dpm L^{-1}
H08	13.9	116	100	2.39	0.05	1.4	0.30	0.01
H08	13.9	116	75	2.15	0.05	1.9	0.30	0.01
H08	13.9	116	50	2.25	0.05	1.4	0.23	0.01
H08	13.9	116	25	2.21	0.05	1.1	0.25	0.01
H08	13.9	116	5	2.27	0.05	0.9	0.16	0.01
H01	14	116.1	100	2.45	0.05	1.8	0.53	0.01
H01	14	116.1	75	2.25	0.05	1.3	0.22	0.01
H01	14	116.1	50	2.29	0.05	1.8	0.34	0.01
H01	14	116.1	25	2.25	0.05	1.6	0.24	0.01
H01	14	116.1	5	2.10	0.05	1.3	0.15	0.01
H11	14	116.1	100	2.46	0.05	1.3	0.30	0.01
H11	14	116.1	75	2.23	0.04	1.1	0.40	0.01
H11	14	116.1	50	2.25	0.05	1.3	0.13	0.01
H11	14	116.1	25	2.29	0.05	1.0	0.08	0.01
H11	14	116.1	5	2.09	0.04	1.0	0.11	0.01
B1	14	113	100	2.44	0.05	1.4	0.23	0.01
B1	14	113	88	2.08	0.04	2.0	0.52	0.01
B1	14	113	75	2.30	0.08	1.8	0.41	0.01
B1	14	113	50	2.21	0.05	1.4	0.40	0.01
B1	14	113	25	2.24	0.04	1.2	0.08	0.01
B1	14	113	5	2.24	0.05	0.9	0.06	0.01
C1	12	113	100	2.55	0.05	0.7	0.21	0.01
C1	12	113	88	2.49	0.05	0.8	0.25	0.01
C1	12	113	75	2.38	0.04	1.9	0.30	0.01
C1	12	113	50	2.05	0.04	1.5	0.23	0.01
C1	12	113	25	2.10	0.09	1.6	0.25	0.01
C1	12	113	5	2.06	0.04	2.1	0.29	0.01
A2	12	116	100	2.63	0.05	1.1	0.21	0.01
A2	12	116	88	2.21	0.04	0.9	0.42	0.01
A2	12	116	75	2.16	0.04	1.5	0.25	0.01
A2	12	116	50	2.01	0.04	1.5	0.23	0.01
A2	12	116	25	2.18	0.04	1.2	0.09	0.01
A2	12	116	5	1.85	0.06	1.2	0.14	0.01
B2	14	117	108	2.51	0.04	1.1	0.13	0.01
B2	14	117	100	2.49	0.04	0.9	0.27	0.01
B2	14	117	75	2.24	0.04	1.3	0.15	0.01

Station	Latitude degree (N)	Longitude degree (E)	Depth m	Tot. ^{234}Th dpm L^{-1}	Tot. ^{234}Th error dpm L^{-1}	POC μmol L^{-1}	Part. ^{234}Th dpm L^{-1}	Part. ^{234}Th error dpm L^{-1}
B2	14	117	50	2.22	0.05	1.8	0.27	0.01
B2	14	117	25	2.40	0.05	1.1	0.12	0.01
B2	14	117	5	2.25	0.05	1.3	0.28	0.01

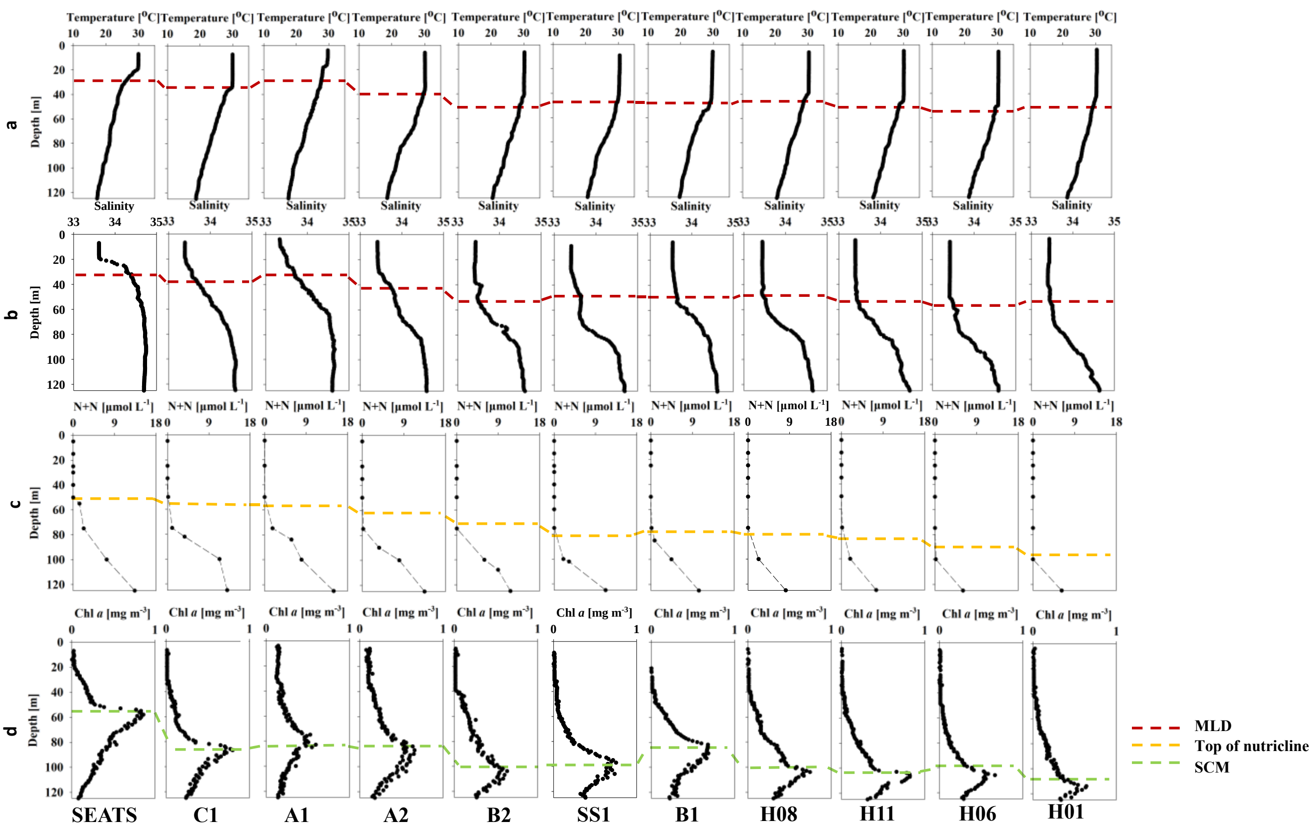
Eq. 3 is the same as Eq. 1.

[Response]: Fixed. We will revise the equation as:

$$F_{Th}^{Ez} = \int_{0}^{Ez} \left(A_U - A_{Th}\right) \times \lambda dz \tag{3}$$

The font is too small in Figure 4.

[Response]: We appreciate the reviewer's comment. We have enlarged the font sizes as of below.



Eq9. What's the delta x and delta y.

[Response]: We appreciate the reviewer's comment. Eq. 9 aimed to resolve the horizontally diffusive flux of ^{234}Th. The Δx and Δy are the distance between the normal stations to evaluate the influences of physical terms (Δy was the distance between station H06 and H08 and equal to 18 km) in this study.

We will explain the Δx and Δy in our revision: "The Δx and Δy are the distance between the normal stations to evaluate the influences of physical terms (i.e., Δx is the distances between stations H01 and H11; Δy is the distances between stations H06 and H08). Δx and Δy were equal to 18 km in this study."

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