Seasonal dynamics and annual budget of dissolved inorganic carbon in the northwestern Mediterranean deep convection region

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Responses to the comments of the anonymous Reviewer 1

First we would like to warmly thank Reviewer 1 for his/her relevant and constructive comments which will help to improve the manuscript.

Answers to reviewers' comments are reported point by point. The questions and comments of the anonymous Reviewer 1 are in black, the answers in blue color and the modifications that we propose for the revised manuscript in red color in italic.

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The authors investigated the dynamics of dissolved inorganic carbon in the deep convection area of the North-West Mediterranean Sea. The study was based on a good coupling between observations from mooring sites and cruises and 3 D coupled physical-biogeochemical model.
The main findings were that the area:
-was a moderate sink of CO2 (0.47 mol C m-2 yr-1) with an increase during the spring phytoplankton bloom, the air sea flux represented only 12% of net community production in the upper lever of the water column;
- both biological processes and physical transport (vertical and horizontal) played a dominant role in the annual DIC budge;
- winter ventilation had a reducing effect of on the atmospheric CO2 uptake;
- the region acted as a source of DIC for surface and intermediate waters.
Overall the approach is innovative and the results are relevant for a better understanding of the CO2 system dynamics in the NW Mediterranean Sea.

We thank Reviewer 1 for this positive general assessment.

I think that the discussion could be improved by a deeper comparison with one of the few other areas of the Mediterranean Sea where deep convection occurs as the Southern Adriatic Sea. The Adriatic Dense Water formation plays an important role for the sequestration and storage of the anthropogenic carbon, as the anthropogenic CO2 is transferred in the deep waters of the Eastern Mediterranean (Krasakopoulou et al., Deep Sea Res., 2011; Cantoni et al. Mar. Geol. 2016; Ingrosso et al. Deep Sea Res., 2017).

Response: We thank Reviewer 1 for this advice and the interesting references. We will add in the discussion a sub-section dedicated to the comparison of our results in terms of air-sea CO_2 flux (also in response to a comment of Reviewer 2). In this sub-section we will include comparisons with other studies carried out in the northwestern Mediterranean which was in Section 5.2 in the submitted manuscript, as well as a comparison with the other major deep convection region of the Mediterranean, the South Adriatic.

"Our estimate is close to the annual flux estimated around 0.5 mol C m^{-2} yr^{-1} by Cossarini et al. (2021) in the South Adriatic Sea, the other deep convection area of the Mediterranean Sea."

Furthermore, in section "Contribution of northwestern deep convection region to the carbon budget of the Mediterranean Sea", we will add a discussion on the exchanges between the two deep convection areas and the surrounding regions, as follows:

"Finally, the transfer of DIC in intermediate waters, estimated here at 73 Tg C yr^{-1}, could represent up to 11% to the Mediterranean DIC export at the Gibraltar Strait towards the Atlantic Ocean, estimated to range between 680 and 1380 Tg C yr^{-1} (Aït-Ameur and Goyet, 2006), and 100% of the net (difference between Atlantic surface inflow and Mediterranean outflow) DIC outflow, estimated between 20 and 70 Tg C yr^{-1} (Huertas et al., 2009).
Our results for the northwestern deep convection area could be compared to those obtained in one of the other major deep water formation areas of the Mediterranean Sea, the Adriatic Sea. This latter has been shown to be a sink of atmospheric CO_2 (Cossarini et al., 2021) and a sequestration region of anthropogenic carbon (Krasakopoulou et al., 2011; Palmiéri et al., 2015; Hassoun et al., 2015; Ingrosso et al. 2017) as the study area (Touratier et al., 2016). In particular, experimental studies showed that the deep layer of the South Adriatic Sea was occupied by dense water rich in DIC and anthropogenic carbon formed in the deep convection regions of South Adriatic Pit and Pomo Pit, as well as on the northern shelf (Krasakopoulou et al., 2011; Cantoni et al, 2016; Ingrosso et al. 2017). The deep dense waters could be then transferred towards the Ionian Sea and the Mediterranean general deep circulation. Krasakopoulou et al. (2011) deduced from in situ measurements over February 1995 inorganic carbon fluxes crossing the Otranto Strait which connects the Ionian Sea to the South Adriatic Sea. They estimated that, on an annual basis, the Adriatic Sea could act as a sink of 314 Tg C yr^{-1} of dissolved inorganic carbon for the Ionian Sea. This net flux resulted from an inflow of 1563 Tg C yr^{-1}, with 27% in the Levantine Intermediate Water, and an

outflow of 1249 Tg C yr^{-1}, with 21% in the Adriatic Deep Water. Thus, the northwestern Mediterranean deep convection region and the South Adriatic that includes shallower areas, could have opposite contributions in the deep and intermediate layers of the Mediterranean general circulation. However, our DIC budget assessment (as the budget studies in the Adriatic Sea) is limited to a single year and will need to be extended to a longer period to investigate in particular the question of carbon sequestration."

Hassoun, A.E.R., Gemayel, A., Krasakopoulou, E., Goyet, E., Saab, C., Guglielmi, M.A.-A., Touratier, V., Falco, C, F., 2015. Acidification of the Mediterranean Sea from anthropogenic carbon penetration. Deep-Sea Res. I 102, 1–15. http://dx.doi.org/10.1016/j.dsr.2015.04.005.

Palmiéri, J., Orr, J.C., Dutay, J.C., Béranger, K., Schneider, A., Beuvier, J., Somot, S., 2015. Simulated anthropogenic CO2 uptake and acidification of the Mediterranean Sea. Biogeosciences 12, 781–802. http://dx.doi.org/10.5194/bg-12-781-2015.

In the Chapter 5.5 "Contribution of north-western deep convection region to the carbon budget of the Mediterranean Sea" the discussion could be improved by taking into account not only the modelling studies but also the experimental studies showing that the Adriatic continental platform acts as a sink for atmospheric CO2 (e. g.: Turk et al., Jour. Geophys. Res., 2010; Cantoni et al., Est. Coast Shelf Sci.,2012; Catalano et al., Jour. Geophys. Res., 2014; Urbini et. al., Front. Mar. Sci., 2020).

Response: We thank Reviewer 1 for these pertinent references. We will complete the discussion on comparisons of the modeled CO_2 air-sea fluxes in the new sub-section 5.3, by expanding it to comparisons with the northern continental shelves which were identified as other water formation areas in the Mediterranean Sea:

"Finally, it is also noteworthy that our estimate is found in the lower range of the annual flux estimated from experimental studies for the northern Adriatic and Aegean shelves, where dense water formation also takes place, and identified as sinks for atmospheric CO_2 most of the year and on an annual basis. With respect to the northern Adriatic shelf, our estimate is found close to the estimate of 0.4-0.5 mol C m^{-2} yr^{-1} for year 2014/15 by Urbini et al. (2020) and between about 2 to 4 folds lower than the estimates of 0.8-0.9 mol C m^{-2} yr^{-1} by Urbini et al. (2020) over the year 2016/17, of 1-1.1 mol C m^{-2} yr^{-1} by Catalano et al. (2014) and Cossarini et al. (2015) and of 2.2 mol C m^{-2} yr^{-1} by Cantoni et al. (2012) and Turk et al. (2013). Regarding the northern Aegean Sea, we found a lower winter flux than the one deduced from observations in February 2006 by Krasakopoulou et al. (2009) (4.9 in our study versus 8.6-14.7 mmol C m^{-2} d^{-1}). Higher fluxes of CO_2 uptake exceeding 1 mol C m^{-2} yr^{-1} were also found for the northern shelves in the modeling studies of Cossarini et al. (2015; 2021). These higher fluxes could be explained by a lower seawater temperature in winter,

riverine nutrient inputs favoring intense primary production, and a transport of DIC associated with dense water outflow towards the deep basin (Cantoni et al., 2016; Ingrosso et al., 2017).”

Cossarini, G., Querin, S., Solidoro, C.: The continental shelf carbon pump in the northern Adriatic Sea (Mediterranean Sea): influence of wintertime variability. Ecol. Model. 314, 118–134. http://dx.doi.org/10.1016/j.ecolmodel.2015.07.024, 2015.

Besides, in Section 4.2, we mentioned the higher air-sea CO_2 flux found in our model results on the shelf of the Gulf of Lion, another Mediterranean region where dense shelf water formation and cascading take place. Based on the model configuration implemented by Many et al. (2011), we plan to investigate the seasonal and interannual carbonate system dynamics on this shelf. We think that, in this future work, it would be very interesting to compare the seasonal and annual budget terms, as well as influences of northern winds and river inputs obtained for the Gulf of Lion shelf, with the observational previous works carried out on the northern Adriatic shelf both presenting many similar characteristics (as winter low temperature, continental winds, physical processes) but with a more enclosed morphology and higher river inputs for the northern Adriatic.

In the sensitivity tests including the carbonate production the authors used a PIC/POC ratio of 0.5 but according to the results reported in the cited paper of Miquel et al. (2011) the ratio is subject to wide interannual variations ranging from 0.31 to 0.78. It would be important to know how these natural variations would affect the sensitivity tests.

Response: Following the comment of Reviewer 1, we have performed sensitivity tests on carbonate production using the minimum and maximum values of the PIC:POC ratio reported by Miquel et al. (2011) to assess the impact of the natural variations of this ratio on the air-sea flux. The difference between air-sea fluxes computed for these two tests, for the first expression of carbonate production, is equal to 0.07 mol C m^{-2} yr^{-1}. We will add the results of these tests in the discussion section on air-sea CO_2 flux, Figure 14, Table S1, Sect. 2.1.4 “Sensitivity tests” and in the conclusion. Moreover, we specify that a correction was made in the calculation of the rate of change of alkalinity (the excess negative charge state variable, see the answer to a following comment) that explains the difference in air-sea flux using the mean PIC:POC ratio given in Miquel et al. (2011) between the new version of the manuscript and the previous one.

Section 2.1.4 Sensitivity tests :

"Following the study of Palevsky and Quay (2017), we first estimated it based on PIC:POC ratio and NCP. Miquel et al. (2011) estimated the ~~ratio~~ PIC:POC ratio at 200 m depth varying between 0.31 and 0.78, with a mean value of~~to~~ 0.5, based on sediment trap measurements at the EMSO-DYFAMED site."

Discussion section:

"They show that not taken into account calcification processes could lead to an ~~underestimation~~ overestimation of the annual air-sea CO$_2$ uptake by ~~23~~16 to ~~58~~57% with estimates of ~~0.72~~ 0.29 mol C m^{-2} yr^{-1}, based on the mean PIC:OC ratio given in Miquel et al. (2011) (varying between 0.19 and 0.36 mol C m^{-2} yr^{-1} based on the measured maximum and minimum PIC:OC ratios, respectively), and ~~0.58~~0.40 mol C m^{-2} yr^{-1}, based on the parametrization used in Lajaunie-Salla et al. (2021)."

Conclusion:

"Moreover, we displayed that neglecting calcification processes could lead to an over~~under~~estimation by ~~23~~16 to ~~58~~57% of the annual uptake, highlighting the need for the refinement of the model in future studies."

In the conclusion the authors state that the air-sea flux represents only 13% of the upper column Net Community Production (NCP) whereas in the chapter 5.4 that state that the flux represent 12% of NCP. The discrepancy should be solved.

Response: The correct value of the air-sea flux / net community production ratio is 13% (=0.47/3.74=12.57%). We apologize for the error. The value will be corrected in Section 5.4.

In the conclusion the authors states that the physical fluxes in the upper layer is of 3.3 mol C m-2 yr-1 but in the figure 12 the difference between the lateral DIC transport and the vertical DIC transfer amounts to 3.4 mol C m-2 yr-1. The data should be checked.

Response: The values of the physical fluxes in the upper layer have been checked. The correct value of the net physical flux is 3.34 mol C m^{-2} yr^{-1}. It results from the sum of a vertical input of 133.18 mol C m^{-2} yr^{-1} and of a lateral export of 129.84 mol C m^{-2} yr^{-1}. Thus, the values in Figure 12 and in the text were correct.

The authors in the conclusion more clearly the in the discussion (L.547-552) state that calcification processes could lead to an underestimation by 23-58% of the annual uptake but the authors should take into account that the calcification processes although reducing the TCO2 will increase the pCO2 in seawater therefore counteracting the CO2 intake from the atmosphere.

Response: We thank Reviewer 1 for raising this point. We acknowledge that there was an error in the sensitivity test on calcification process, by omitting to take into account the process in the rate of change of alkalinity (excess negative charge denoted $\Sigma[-]$). We apologize for this error. We have corrected it by adding in the equation of the rate of change of alkalinity (excess negative charge denoted $\Sigma[-]$) the term of calcium carbonate production added in the DIC equation multiplied by 2 (Middelburg et al., 2019). In the new results, the CO_2 air-sea flux is reduced by 16% to 57% when the impact of calcification processes is modeled. We will modify the text and Figure 14 in the discussion section on the sensitivity tests on air-sea CO_2 flux, in Sect. 2.1.4 "Sensitivity tests" and in the conclusion.

Middelburg, J. J.: Marine Carbon Biogeochemistry A Primer for Earth System Scientists, Springer B., edited by Springer Briefs in Earth System Sciences, Springer Briefs in Earth System Sciences, 2019.

Section 2.1.4 Sensitivity tests:

"Thus, if we assume the ratio of calcium carbonate production to NCP is close to PIC:TOC, we added in Eq. 1 a consumption term representing 36% (for the mean value of PIC:POC ratio, 22% and 58% for the minimum and maximum ratio values, respectively) of NCP. This term, multiplied by 2, was added in the equation of the rate of change of the excess negative charge."

Discussion section:

"Finally, sensitivity tests taking into account supplementary consumption terms in the equation of DIC and excess of negative charge for $CaCO_3$ *precipitation (Sect. 2.1.4) were performed to assess its potential influence on air-sea* CO_2 *flux. They show that not taken into account calcification processes could lead to an ~~underestimation~~ overestimation of the annual air-sea* CO_2 *uptake by ~~23~~16 to ~~58~~57% with estimates of ~~0.72~~0.29 mol C* m^{-2} yr^{-1}*, based on the mean PIC:POC ratio given by Miquel et al. (2011) (varying between 0.20 and 0.36 mol C* m^{-2} yr^{-1} *based on the maximum and minimum PIC:POC ratios, respectively), and ~~0.58~~0.40 mol C* m^{-2} yr^{-1}*, based on the parametrization used in Lajaunie-Salla et al. (2021)."*

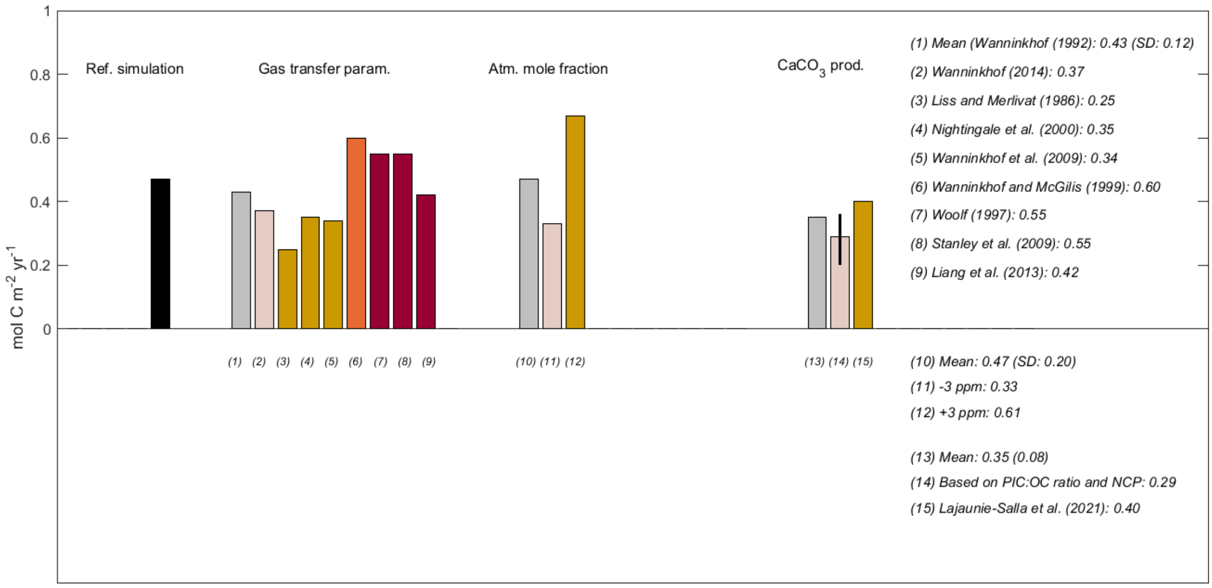


Figure 14: Sensitivity tests to the parameterization of gas transfer velocity, the variability of the mole fraction of CO_2 in the atmosphere, and the calcification processes on the annual CO_2 air-sea flux estimate. The black bar indicates the annual estimate in the reference simulation, grey bars the mean value for each of the three sets of sensitivity tests. For the sensitivity tests on the parametrization on gas transfer (from 2 to 9), relation with a quadratic (2), hybrid (3 to 5), cubic (6) wind speed dependency are, respectively, in light pink, yellow and orange, and relations that includes explicit bubbles parametrizations (7 to 9) are in dark pink. For the test (14) on calcification processes, the bar indicates the result found for the mean PIC:POC ratio, while the black line indicates the range using the minimum and maximum PIC:POC ratios.

Conclusion:

"Moreover, we displayed that neglecting calcification processes could lead to an over~~under~~estimation by ~~23~~16 to ~~58~~57% of the annual uptake, highlighting the need for the refinement of the model in future studies."

The authors use the terms "biogeochemical flow "and "physical flow" which are not very appropriate terms as both are related to a mass flow of carbon generated by biological processes or by physical processes (advection, mixing, particle settling). I suggest to find a more appropriate alternative term e.g.:"physical transport".

Response: We acknowledge that the term "flow" was often inappropriate and apologize for this. We will replace this by another one when it is not appropriate.

Specific comments

L. 49-50, "is one of the region where deep convection occurs" a specific reference to the Southern Adriatic SAD should be added.

Response: The first sentences of the paragraph will be modified in order to add a specific reference to the Southern Adriatic, as follows:

~~“The northwestern~~Northern deep basins of the semi-enclosed Mediterranean Sea, i.e. the northwestern region (Fig. 1, Gulf of Lion and Ligurian Sea) and the South Adriatic, located at mid-latitudes ~~and connected to the Atlantic Ocean through the narrow Gibraltar Strait is~~ are ones of the regions where deep convection occurs (Ovchinnikov et al., 1985; Mertens and Shott, 1998; Manca and Bregant, 1998; Gačić et al., 2000; Béthoux et al., 2002).“

Gačić, M., Manca, B.B., Mosetti, R., Scarazzato, P., Viezzoli, D., 2000. Deep water formation experiment in the Adriatic Sea. WWW Page, http://doga.ogs.trieste.it/doga/jwz/deep_water/mtpnews1.html

Manca, B. and D. Bregant: Dense water formation in the Southern Adriatic Sea during winter 1996. Rapp. Comm. Int. Mer Médit., 35, 176-177, 1998.

Ovchinnikov, I.M., Zats, V.I., Krivosheya V.G., Udodov A.I.: Formation of deep eastern Mediterranean water in the Adriatic Sea Oceanology, 25 (6) (1985), pp. 704-707, 1985.

L. 370-37, “upward flux of DIC into the upper layer of 41.40 mol C m-2…” The units of a mass flux should be used. They should be expressed as the mass of carbon that passes through a defined cross-sectional area over a period of time.

Response: We thank Reviewer 1 for raising this point. In Section 4.1, we give either the daily flux in mmol C m^{-2} d^{-1}, or the cumulative flux, i.e. the flux, expressed as an amount of matter per surface per unit of time, multiplied by the considered period of time: mol C m^{-2}. In the revised version of the manuscript, we will add “cumulative” before “flux” here, and in the whole “4.1 Seasonal cycle of dissolved inorganic carbon” section when there was an oversight, and we will indicate the period over which the cumulative flux is calculated.

“The physical fluxes at the limit of the upper layer of the deep convection area showed similar patterns as during autumn, with a~~n~~ cumulative upward flux of DIC into the upper layer of 41.40 mol C m^{-2} *over a 2.5 month period, almost counterbalanced by a cumulative lateral outflow of DIC of 40.44 mol C* m^{-2} *in the upper layer and a cumulative lateral inflow of DIC of 39.90 mol C* m^{-2} *in the deeper layer.”*

L. 390- 395, L. 469-470; L. 529. same as above.

Response: In Section 4.1, the term "cumulative" was mentioned in L 390 and 394, we will add the period over which the time-integration of flux is done:

"The cumulative biogeochemical flux reached -1.49 mol C m^{-2} *over this sub-period of 68 days."*

" […] and finally cumulative air-sea flux reached 0.28 mol C m^{-2} *over the second winter sub-period of 68 days (a lower value and flux (3.1 versus 7.3 mmol C m*$^{-2}$ *d*$^{-1}$*) than over the first winter period)"*

L 469-470 and L529 and in this whole Section 4.2 , the annual fluxes are given. Therefore we will correct the unit of the fluxes by replacing "mol C m^{-2}" by "mol C m^{-2} yr^{-1}":

"Figure 12 shows a schematic of the annual budget of dissolved inorganic carbon in the deep convection zone. Our model results show that the deep convection area acted as a moderate CO_2 *sink for the atmosphere on an annual scale, over the period September 2012-September 2013. We estimate that it absorbed 0.5 mol C m*$^{-2}$ *yr*$^{-1}$ *of atmospheric* CO_2*. This uptake of atmospheric* CO_2 *displayed spatial variability (Fig. 13). It was greater than 1 mol C m*$^{-2}$ *yr*$^{-1}$ *in the northern edge of the area along the Northern Current flowing over the Gulf of Lion continental slope, and became less than 0.25 mol C m*$^{-2}$ *yr*$^{-1}$ *in the western and eastern edge areas. One can notice that the annual rate remained lower than on the Gulf of Lion's shelf, which is beyond the scope of this study. Within the sea, biogeochemical processes induced an annual consumption of 3.7 mol C m*$^{-2}$ *yr*$^{-1}$ *of DIC in the upper layer and a ~~production~~ gain of 2.3 mol C m*$^{-2}$ *yr*$^{-1}$ *in the deeper layers.*

Our estimate of net physical fluxes (lateral plus vertical) is an input of 3.3 mol C m^{-2} *yr*$^{-1}$ *in the upper layer and an export of ~~-~~11.0 mol C m*$^{-2}$ *yr*$^{-1}$ *in the deeper layer. Specifically, the model indicates a vertical DIC supply of 133.2 mol C m*$^{-2}$ *yr*$^{-1}$ *from the deeper layer to the upper layer, partly offset by a lateral outflow of 129.8 mol C m*$^{-2}$ *yr*$^{-1}$ *in the upper layer and an inflow of 122.2 mol C m*$^{-2}$ *yr*$^{-1}$ *in the deeper layer. The budget in the deep layer masks different signs of physical fluxes: if the deeper layer is subdivided into an intermediate layer (150 m-800 m) and the deeper most layer (800 m-bottom), we find that the former, the intermediate layer, gained an amount 83.1 mol C m*$^{-2}$ *yr*$^{-1}$ *of DIC through vertical transport, while it lost 87.6 mol C m*$^{-2}$ *yr*$^{-1}$ *of DIC through lateral export. Finally, our model shows that the convection zone was a source of DIC of 8.7 mol C m*$^{-2}$ *yr*$^{-1}$ *for the rest of the western Mediterranean Sea. While the DIC inventory in the upper layer remained stable (decrease of 0.07 mol C m*$^{-2}$ *yr*$^{-1}$*), the DIC inventory in the deeper layer experienced a decrease of 8.7 mol C m*$^{-2}$ *yr*$^{-1}$*. This loss occurred mainly during deep convection, and to a lesser extent during the preconditioning period (in autumn and early winter).*

Finally, we complete the inorganic carbon budget with the labile organic carbon fluxes (refractory organic carbon is not considered in our model). We estimate that during the studied period a lateral export of organic carbon of 1.1 mol C m^{-2} *yr*$^{-1}$ *and 0.3 mol C m*$^{-2}$ *yr*$^{-1}$ *took place in the upper and deeper layers, respectively. The modeled downward export of organic carbon amounted to 2.3 mol C m*$^{-2}$ *yr*$^{-1}$*."*

L. 452, "the DIC drawdown due to biological processes decreases and net DIC production events took place": could the authors specify which are the processes driving the DIC production events.

Response: Since we haven’t deeply analyzed specifically these short events, we will remove this and we propose to rephrase this sentence in the revised manuscript, as follows:

“From August onwards, the DIC drawdown due to biogeochemical ~~biological~~ processes decreased, primary production rate becoming close to respiration rate~~, and net DIC production events took place~~ (Fig. 6h).”

L. 465 “an annual consumption of 3.7 mol C m-2 of DIC”: the unit of time is lacking.

Response: We agree, we apologize for this oversight. As mentioned in a previous response, the sentence will be modified as follows:

“Within the sea, biogeochemical processes induced an annual consumption of 3.7 mol C m^{-2} yr^{-1} *of DIC in the upper layer and ~~production~~ gain of 2.3 mol C* m^{-2} yr^{-1} *in the deeper layers. “*

L.549-552. This sentence is not clear and the CO2 production during calcification should be taken into account.

Response: As mentioned in a previous response, we have corrected the sensitivity tests on calcification processes. The sentence will be modify as follows:

“They show that not taken into account calcification processes could lead to an ~~underestimation~~ overestimation of the annual air-sea CO$_2$ *uptake by ~~23~~16 to ~~58~~57% with estimates ~~of 0.72~~0.29 mol C* m^{-2} yr^{-1}*, […]”*

L. 578 physical flow? Do the authors mean physical transport?

Response: “physical flow” will be replaced by “physical transport”.

“[…] and highlights that physical ~~flows~~transports play a crucial role in the DIC budget in this highly energetic region.”

L. 589 DIC exchange flows? Do you mean DIC flows?

Response: “DIC exchange flow” will be replaced by “DIC fluxes at the limits of the zone”.

“Moreover, a detailed calculation of the water and DIC ~~exchanges flows~~ fluxes at the limits of the deep convection area allowed us to […]”

Fig. 7. The units for fluxes are expressed as an inventory: mol C m-2. The mass fluxes should be expressed as the mass of carbon that passes through a defined cross-sectional area over a period of time e.g. mol C m^{-2} y^{-1}.

Response: Figure 7 shows the cumulative fluxes, i.e. the fluxes expressed as the amount of matter per surface and per unit of time, multiplied by the time period over which the accumulation is calculated. In response to a comment of Reviewer 2 we will remove panel (b) with the cumulative seasonal fluxes. In the remaining panels, the cumulative flux at a day d is the flux, expressed in mol C m^{-2} d^{-1} multiplied by the number of days between the 1st September 2012 and day d. We will correct the titles of the panels by adding "cumulative" before "fluxes" and complete the caption.

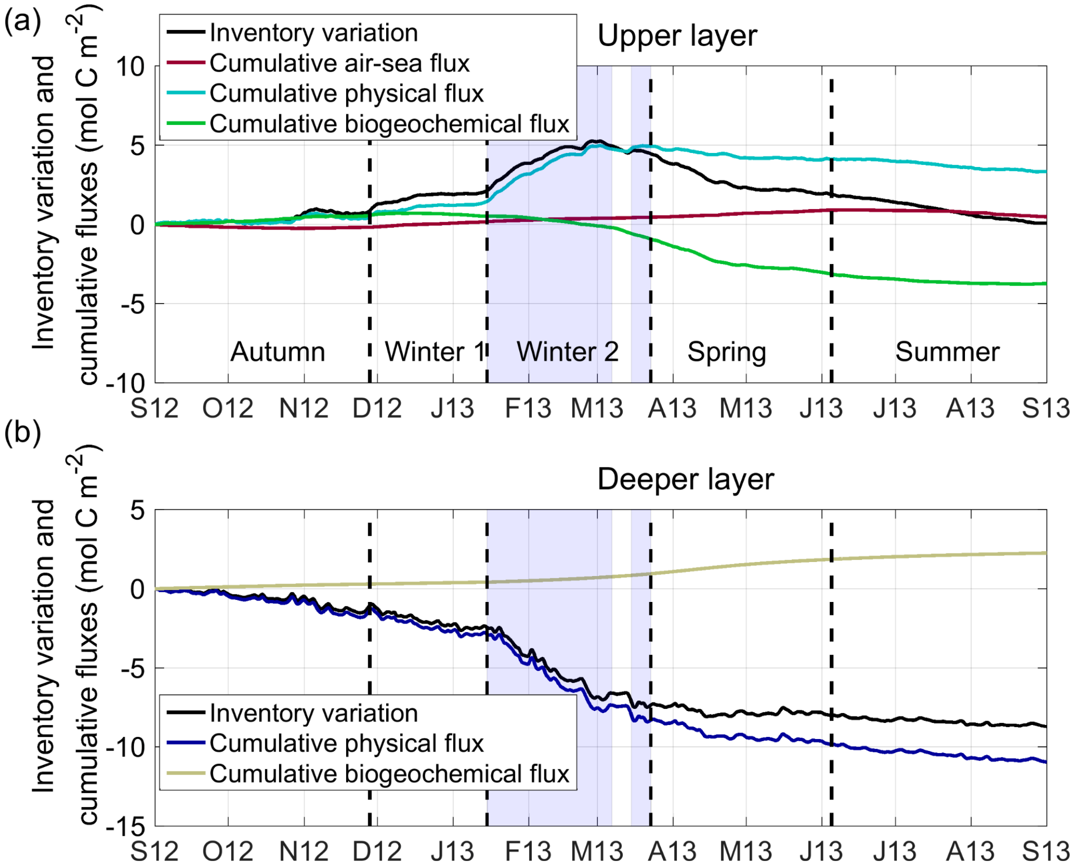
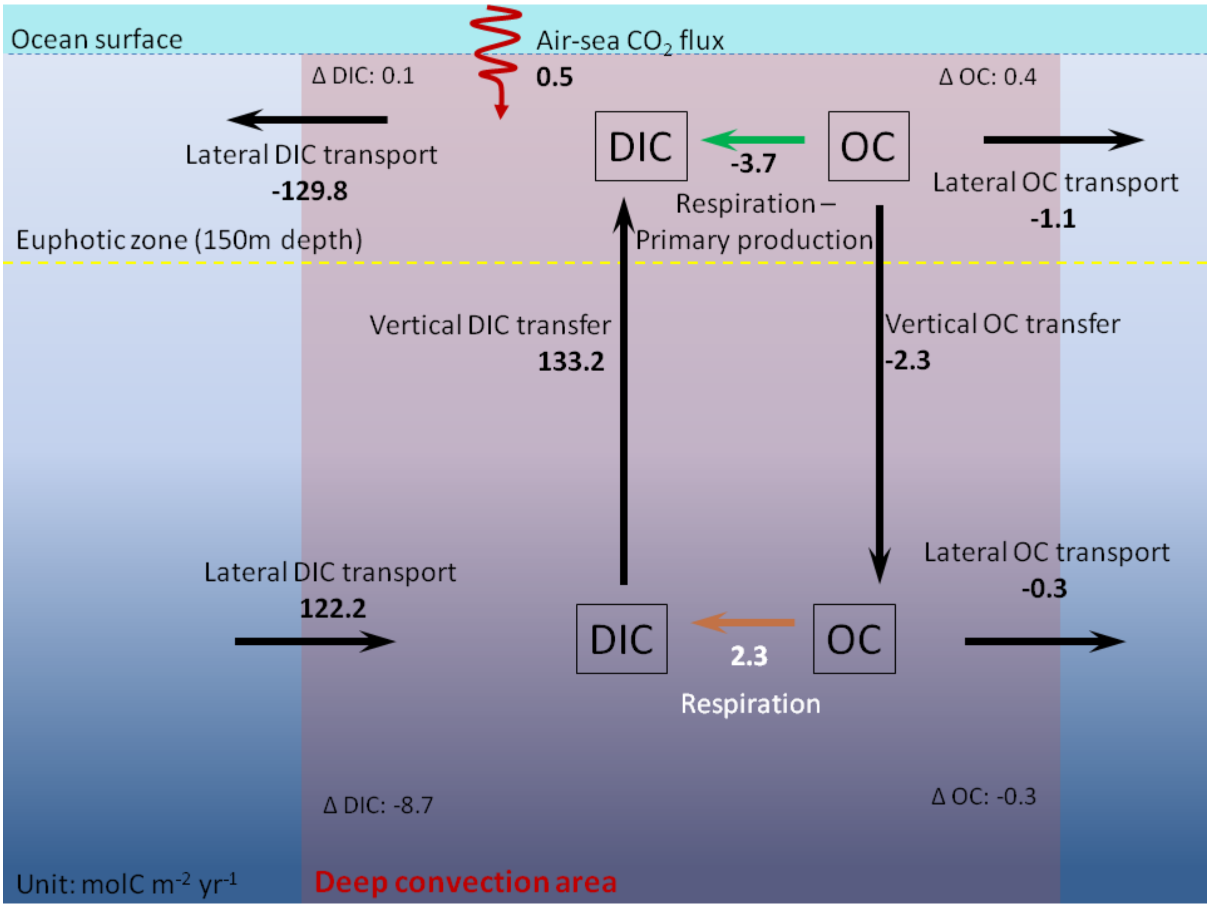


***Figure 7:** Time series of cumulative variation in dissolved inorganic carbon (DIC) inventory (black) and cumulative air–sea (red), physical transfer (light and dark blue), and biogeochemical (bright and brown green) flux of dissolved inorganic carbon in the (a) upper (surface to 150 m) and (b) deeper (150 m to bottom) layers, from September 2012 to September 2013. Unit: mol C m^{-2}. Positive values represent inputs for the deep convection area. The blue shaded area corresponds to the deep convection period (period when spatially averaged mixed layer depth > 100 m). The DIC inventory on 1st September 2012 was 353 and 5560 mol C m^{-2} in the upper and deeper layers, respectively. The cumulative flux at a day d is the time-integrated flux over the period from the 1st September 2012 to day d.*

Fig. 12. The data represented are inventories or fluxes in the latter case they should be expressed as the mass of carbon that passes through a defined cross-sectional area over a period of time e.g. mol C m-^{2} y-^{1}.

Response: We apologize for this error. The unit on Figure 12 and in its caption will be corrected as follows:



“Figure 12: Scheme of the annual carbon budget for the period September 2012 to September 2013 from the coupled model SYMPHONIE-Eco3M-S. Fluxes are indicated in mol C m^{-2} yr^{-1}.”