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Biogeosciences Discussions

Interactive comment on "Why productive upwelling areas are often sources rather than sinks of CO_2? – a comparative study on eddy upwellings in the South China Sea" *by* N. Jiao et al.

Anonymous Referee #1

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Upwelling is a physical process that exposes sub-thermocline pools of nutrient elements and CO2 in the ocean to biological productivity in the surface mixed layer and to lower partial pressures of CO2 in the atmosphere. If upwelling is a transient feature and occurs in an isolated system (as is the case with cyclonic eddies in the ocean), a simplified time line of CO2 fluxes between ocean and atmosphere should image an initial pulse of CO2 flux from the ocean surface to the atmosphere, which in the course of time subsides and changes sign due to CO2 and nutrient assimilation (generally in stoichiometric balance) by photosynthetic organisms. They produce sinking organic matter that returns the same amount of CO_2 and nutrients to the deep ocean over time. In this simplified case, the net effect of upwelling should be neutral with respect to CO_2 fluxes over the entire course of the time line (which does not necessarily coincide with the physical lifetime of the eddy). The matter is complicated (or simply prolonged) by biological processes: By different responses (bloom dynamics, nutrient requirements) of potential primary producers to the nutrient injection; and by organisms that shunt part of the assimilated CO_2 into a dissolved organic C pool in the mixed layer rather than into sinking organic matter, and others that take their own good time to mineralise this dissolved pool. In that case, CO_2 from DOC mineralisation will be emitted to the atmosphere some time after the upwelling feature has vanished.

Jiao and colleagues studied the physical, chemical and biological states of two cyclonic eddies and a reference site in the South China Sea with a comprehensive suite of methods. Their aim was to clarify the balance of CO_2 associated with eddy-induced upwelling, and the roles that biological processes have in determining either sink or source function for CO_2 of these transient features. Although they only establish states and fluxes for a limited time window of the eddies′ lifetimes, they also applied radiochemical methods permitting them to estimate integrated particle fluxes from the mixed layer over the eddies′ history. Based on differences in the chemical and biological states of the two eddies, the authors come to the conclusion that the depth of the thermocline induced by eddy dynamics determines the biological community structure, which in turn determines whether or not the system is a sink or source of CO_2.

This is a very ambitious and interesting manuscript that makes an admirable attempt to shed light on some really complex relationships between physics, chemistry and biology in transient upwelling systems caused by mesoscale ocean dynamics. My first thought while reading the manuscript was that upwelling in essence should be neutral with respect to CO_2 fluxes, because the basic stoichiometry between nutrient and CO_2 release and assimilation should even out all the differences seen in the instantaneous data over space and time (see above). My second thought (which I essentially still stick

BGD
10, C5634–C5638, 2013

to) was that all the features can possibly also be explained by a succession of events in the course of/different stages in the life cycles of the two eddies – the authors also hint at this possibility occasionally. My third thought was that the absolute depth of the shoaled thermocline (travel path for thermocline CO_2 to equilibrate with the atmospheric) in relation to light penetration and phytoplankton preferred habitat depth range may be key; this is a variant of the authors′ preferred interpretation.

Many of the details and methods are beyond me and I cannot judge for example, if the particle export reconstructions are sound (although they appear to be). In my opinion, a revised manuscript should discuss the points made above in more detail: a) That the described (instantaneous) states of the two eddies are in effect snapshots of different stages in the life cycle of these features and that an integration over the entire life time may even out the differences. b) That the physical vigour of eddies (whether CO_2-rich water penetrate s to atmospheric contact) as opposed to nutrients only exposed to photosynthesis changes the CO_2 balance. In the latter case the DOC fraction and its mineralisation should be the only mechanism that causes air-sea exchange in the aftermath.

The manuscript is well written and concise, tables and illustrations are all necessary and of good quality. Below are some suggestions on style and wording and some queries.

Abstract line 1: What is the difference between marine and oceanic upwelling regions? Line 14: increasing instead of aggravating? Line 17 delete meanwhile Line 22: sub-thermocline instead of deep water L25: cause upwelling to different extent

13401 L4 . . .). Other studies 13 . . .). Instead, they. . . 14: Eddy age is another control on. . ..(?) the extent of . . .

13402 L1 observations in two L19 monitoring instead of indicating?

13403 24: using a recently. . .

13404 L 7: What do you mean with “assuming no physical transport” in connection with export flux?

13405: L 14: The relationship L15 estimate instead of provide

13406 L4 , residual (or recycled) silicate was present in the mixed layer at station CE1. Can you exclude that silica was present because a diatom bloom has decayed and silica was present from dissolution? L15 upwelling conditions/impacts (?) L16 have different abundances among sites L26 similar pattern in that

13407 L2 consistent with L3 diatoms contribute more to POC. . ...at CE2 that at CE1

Paragraph 3.3 This paragraph is important, because the text addresses the possibility that the two eddies have different stages. It also argues that the state of the microbial loop determines the CO2 flux. However, I do not follow the logic of CE2 having a stronger upwelling than CE1, and how that relates to CO2 outgassing, when there is an ongoing diatom bloom in CE2 and the entire story may be one of different upwelling stages. This paragraph must be carefully structured and precise in wording. It should possibly be expanded to discuss the different possibilities

Line 25 ff In CE1 POC export flux was lowest whereas BR was high, corresponding to. . ... This cannot be attributed to..

13408 Line 14 consuming POC and attenuating POC export flux.

24: Centers of cyclonic eddies in the northwestern . . ..were associated. . . 27. 2005). This was attributed to. . ..maintenance respiration of hetero. . ..

13409 2+3: gradually increasing BR is the prevailing . . .. 11: have shown 12: centers than at the reference 13: In our study (?) humic type 18: organic matter and consuming oxygen

The paragraph 3.5. should be rewritten – sentences are too long and often awkwardly structured and worded. The meaning often is not clear. On the other hand this is a

BGD
10, C5634–C5638, 2013

crucial paragraph. Title of the paragraph is possibly wrong: the theme are transient eddy upwelling situations – you cannot generalise for upwelling at large.

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