



EGUsphere, referee comment RC1
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Comment on egusphere-2022-861

Anonymous Referee #1

Referee comment on "Underestimation of oceanic carbon uptake in the Arctic Ocean: ice melt as predictor of the sea ice carbon pump" by Benjamin Richaud et al., EGU sphere, <https://doi.org/10.5194/egusphere-2022-861-RC1>, 2022

The manuscript by Richaud et al., "Underestimation of oceanic carbon uptake in the Arctic Ocean: Ice melt as predictor of the sea ice carbon pump" investigate how the oceanic carbon uptake is strongly modulated by sea ice. They base their work on previous studies showing that the ratio of alkalinity to dissolved inorganic carbon in sea ice is higher than in the underlying water and previous suggestions that this storage amplifies the seasonal cycle of sea water pCO₂ and leads to increased carbon uptake in the ocean. They have two independent approaches; a theoretical framework and a simple parameterization of carbon storage in sea ice in a 1D physical-biogeochemical ocean model. Sensitivity simulations show a linear relationship between ice melt and an amplified seasonal carbon uptake. In addition, they estimate a 30% increase in carbon uptake in the Arctic Ocean compared with no ice amplification. Applying this ice melt parameterization to future scenarios of an Earth System Model suggest that the Arctic Ocean carbon uptake is underestimated by 5 to 15%.

Overall comment:

The paper provides new and valuable results for our understanding of the biogeochemical processes in sea ice and how sea ice modulate the air to ocean carbon transfer in the Arctic Ocean and ice covered seas. The paper is well structured, well written and the results highly interesting to a broader scientific audience interested in global warming. Therefore, I will recommend the publication of this work if the authors consider the minor comments below.

Specific comments

Line 37. Suggest to provide an additional reference to Rysgaard et al. 2013 (doi:10.5194/tc-7-707-2013) where the link between ikaite crystals trapped within the sea ice matrix and the distribution of alkalinity are shown for winter ice conditions.

Line 42. After DIC ratio, I suggest to provide a reference to Rysgaard et al. 2012 (doi:10.5194/tc-6-901-2012) where ikaite dissolution is shown for melting sea ice and how this affect pCO₂ and pH levels in Arctic surface waters.

Line 89. I'm not sure DIC and alkalinity are homogeneous in sea ice. They are probably more C shaped. However, it is a fair assumption considering the few existing observations in different forms of sea ice.

Line 188-190. I am surprised the biological terms had a negligible impact on carbon uptake. Could you elaborate a little more why that is?

Line 325. The assumption of a constant mixed layer is a good beginning. However, I expect leads and polynyas (ice fabrics) could elevate the carbon uptake. I'm aware that this will require very high-resolution modelling, but could be very interesting thing to look into after your present work. Looking forward to a follow up study later.

Line 355. Here you state that models without the ice pump parametrization may underestimate carbon uptake over seasonally ice-covered areas by 10-15%. In the abstract this number is 5 to15%.

Line 360. I'm happy to see that your estimated supplementary carbon flux is consistent with numbers provided by Rysgaard et al 2011. Do your model also include the Southern hemisphere and would it be possible to provide a number for sea ice Antarctica? Could be a really interesting follow up study after this work.

Line 370. Your statement regarding the importance of high vertical resolution in the model to represent the shallow mixed layer is an important one. In order for the carbon pump to work, the CO₂ released from ikaite production in sea ice only has to go below a thin mixed layer to prevent (or greatly reduce) exchange with the atmosphere in the Arctic Ocean due to an impermeable sea ice cover (autumn, winter and spring). As this cold water below the mixed layer meets warmer and saltier Atlantic water on its way out of the Arctic Ocean it will sink in the Denmark Strait. At the same time melting sea ice in

the summer will be in contact with the atmosphere and result in dissolution of ikaite and release of excess alkalinity to surface waters and hereby stimulate CO₂ uptake from the atmosphere. Could be interesting to look into regional differences in air-ocean CO₂ uptake.

Line 395. Polynyas and leads. Interesting and I would love to see more on this modelling in the future.

Summary: I really enjoyed reading this study.