Biogeosciences Discuss.,
https://doi.org/10.5194/bg-2020-313-AC1, 2020

Biogeosciences
Discussions
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Interactive comment on "Enhancement of the North Atlantic CO_2 sink by Arctic Waters" *by* Jon Olafsson et al.

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Received and published: 28 October 2020

Interactive comment on "Enhancement of the North Atlantic CO2 sink by Arctic Waters" by Jon Olafsson, Solveig R. Olafsdottir, Taro Takahashi, Magnus Danielsen and Thorarinn S. Arnarson

Author responses to Ref#1 comments We thank the referee for a thorough review and constructive suggestions for improvement. In our respone we first address general comments and follow those with specific comments.

General comments We respond to four issues raised by Ref#1 under General comments. 1 The referee introduces new and informative papers on the knowledge about the North Atlantic carbon chemistry and CO2 sink, the background of our study. This is

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much appreciated and we take note of and incorporate these in the revised introduction section. 2 The referee expresses concern about the clarity of the data description. We address this, organize and expand section 2.1 Data acquisition. 3 The referee suggest we examine other data e.g. from SOCAT. The focus of our presentation is on DpCO2 which is evaluated from measurements of pCO2(sw) in discrete surface layer samples and from recorded underway pCO2(sw) measurements. We use no pCO2(sw) data calculated from other observed variables. The results give clear signs of the different sink/source characteristics of the three water masses examined. Inclusion of further data from e.g. SOCAT or GLODAP was therefore not considered advantageous for this presentation. This response relates also to specific comments C-06, C-29, C-31, C-33 and C-33. 4 Both Ref#1 and Ref#2 call for information on TCO2 and alkalinity to support the analysis. The discrete sea water sample pCO2 data we present generally include TCO2 results. ALK may thus be calculated. The call for information on TCO2 and ALK brings a complex temporal and biogeochemical variability in the Polar Water into focus. We intend to present another paper on that subject which we find too extensive to be added to the present paper. However, the referee suggestions may perhaps be met by adding summary information in figures of a kind similar to Fig. 6a and expand accordingly the Results and Discussion sections? That may still leave detailed observation materials for another presentation. This response relates also to specific comments C-14, C-33, C-35 and C-41.

Specific comments C-01 We agree with the referee that the carbonate chemistry processes in the Atlantic Water of the North Atlantic region and the CO2 sink are relatively well observed and understood compared to other ocean regions. Our aim is to present an unrecognized feature, the contribution of the Polar Water to the CO2 sink. The referee correctly notes that we have preferred to evaluate long term trends from winter observations when biological activity is low and a reference is added to the description of Fig.6b (Olafsson et al., 2009).

C-02 The referee brings our attention to new ways to define N-Atlantic regions or biomes. We take note of these in the Introduction. We agree with the referee that comparison of seasonal data with recent pCO2 climatology might be suitable for another presentation.

C-03 The Holliday et al. (2020) description of freshwater in the N-Atlantic is certainly relevant and is added to the Introduction and the treatment on Fig. Fig.6b.

C-04 NAO describes the difference in the atmospheric pressure between the Icelandic Low and thge Azores High. Its relation with oceanographic variability in Iceland is weak (Ólafsson, 1999). The relations of NAO with the hydrographic conditions in the Iceland Sea 1994 – 1995 are discussed in two papers referred to (Flatau et al., 2003;Våge et al., 2015).

C-05, C-06 The 2006-2007 UW pCO2 covers one calendar year and was acquired with that as a goal and to cover the three main water masses. That effort was not extended for further years but UWpCO2 data assembled on later cruises in Icelandic waters will be used for further analysis and another presentation. We agree that hydrographic variations such as described by Holliday et al. 2020, are of importance. We take note of these in the description and discussion of the results in Fig. 6b. C-07, C-11 and C-21. Corrected

C-08 The accuracy of UW pCO2 measurements is evaluated in the SOCAT data processing. This is noted in 2.1 Data acquisition.

C-09 EXPOCODES have beed added to tables listing cruises.

C-10 Typo corrected by deleting: and S1. The UW data selection procedure is described on page 8, lines 212-217.

C-12 We never mention fCO2 in the manuscript. The consistent use of pCO2 is noted in secton 2.2 CO2 air-sea flux calculations.

C-13 Correct, lines 171 and 172 do not apply to underway measurements and have been deleted. A sentence on the UW pCO2 precision has been added.

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C-14 The stations in the Polar Water collection are marked in Fig. 1. In Methods is a section on this data and another section is added the calculation of alkalinity. Data from 64N 28W, which is the IRM-TS location are not in this collection.

C-15 Corrected.

C-16 Corrected.

C-17 Reference added.

C-18 Lines 198 to 211 describe considerable work involved in processing data and flux calculations. Much more than how winds were selected. We prefer to keep these lines. A figure showing the gas transfer coefficients associated with the three water masses is added to Fig. 5.

C-19 Figure has been moved to Supp. Mat.

C 20 Reference added.

C-22 and C-28 A sentence comparing our results with the climatological Arctic and Atlantic Water fluxes is added. However, and as for C-02, comparison of seasonal data with recent pCO2 climatology might be suitable for another presentation.

C-23 and C-25 The intention here was to refer to Våge et al, 2015. Corrected. A figure showing the density variations with time and depth is added as a supplemenatry Figure S2.

C-24 Corrected

C-26 A figure with the gas transfer coefficient for the 2006-2007 UW periods has been added.

C-27 The Polar Water collection stations are shown in Fig. 1 and section has been added: 2.1.4 Polar Water data collection.

C-28 There is no previous assessment of the Polar Water annual flux. The comparison is to show how far the Polar Water flux is from the regional mean. A sentence comparing our results with the climatological Arctic and Atlantic Water fluxes is added.

C-29 The data section has been expanded to clearly describe the data sets used.

C-30 Corrected.

C-31 Agree and a sentence noting that the Atlantic Water pCO2 follows the atmospheric increase is added.

C-32 The relatively few Polar Water results in the climatology weigh little in the gridded presentation.

C-33 and C35 See General Comment 4. An overview covering the regional carbon chemistry variations is really beond the scope of this presentation.

C-34 Lee et al(2006) reference deleted and the important Broullón et al. (2019) added.

C-35 The Takahashi PALK presentation and its potential difference from ALK in the waters discussed is noted.

C-37 The sentence has been shortened to clarify the statement.

C-38 Cooper et al (2008) report flow weighted average alkalinity without uncertainty. Noted in the Discussion.

C-39 Not in Supplement but now added to text. See also C-40.

C-40 A table and equations explaining the estimates can be added,

C-41 The figure is intended as a basis for a discussion. It illustrates merely the effect of excess alkalinity on Atlantic Water, S:35 and t: 5°C, reaching the Nordic Seas. The figure gives no indication of how the excess is generated or how it acts in the transformation of Atlantic Water to Polar Water. We add elaborations on this issue in the Discussion.

C-42 Corrected figure number. In order to conclude on the state of the Atlantic Water in comparison with Arctic and Polar Waters we expand the sentence: "The Atlantic Water seasonal pCO2 variations we observe are primarily driven by regional thermal and biological cycles but without much net influx of CO2“.

C-43 We rewrite the Conclusions taking note of the constructive remarks.

C-44 Section on "Data availability“ is added.

References Flatau, M. K., Talley, L., and Niiler, P. P.: The North Atlantic Oscillation, surface current velocities, and SST changes in the subpolar North Atlantic, Journal of Climate, 16, 2355-2369, 2003. Olafsson, J., Olafsdottir, S. R., Benoit-Cattin, A., Danielsen, M., Arnarson, T. S., and Takahashi, T.: Rate of Iceland Sea acidification from time series measurements, Biogeosciences, 6, 2661-2668, 2009.

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