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Biogeosciences Discussions

Interactive comment on "Seasonal calcium carbonate undersaturation in shelf waters of the Western Arctic Ocean; how biological processes exacerbate the impact of ocean acidification" *by* N. R. Bates et al.

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RESPONSE

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Author Response:

We thank Anonymous Referee #1 for posting a very helpful review of the paper. The

referee comments were very minor in nature. In the revised paper we have addressed all of the comments brought forward by the reviewer and this has improved the paper. The reviewer comments focused on two issues; (1) whether this paper adds to previous knowledge about OA impacts on the Western Arctic shelf, and (2) clarifications focused on Figure 7 and text associated around this figure.

(1) we strongly argue that the paper adds a lot of new data and insight about CaCO3 undersaturation in the western Arctic shelves. In a previous paper (Bates et al., 2009), CaCO3 undersaturation was only found on the northern slope of the Chukchi Sea for the period 2002-2004; Shelf-Basin Interactions data) and not in the bottom waters on the shelf. In this paper, we discuss new data, collected over the Chukchi Sea and western East Siberian Sea (ESS) shelf (2009-2011) that shows extensive summertime bottom water CaCO3 undersaturation across much of the Western Arctic shelves, a feature not observed before in earlier datasets. The paper thus shows rapid changes in seawater carbonate chemistry during the first decade of the 21st century, particularly over the shallow shelves of the Chukchi Sea (and part of the ESS) with implications for the shelf benthos.

(2) Although we added Figure 7 to try to make it easier to interpret changes in seawater carbonate chemistry, from both reviewers comments, we realized that the Figure 7 arrows were incorrect and this added to the confusion of the figure. We apologize for this error and have redrawn the figure below. We are currently evaluating whether this figure is actually needed in the paper. We have also clarified some of the statements in the text.

Our responses are interspersed with the comments by the referee (in black), and we have used indented blue Arial font for ease of review.

COMMENT General comments: This study by Bates et al. address a very topical issue, ocean acidification, and focuses on the region first impacted, the cold Arctic Ocean. It is largely well written and summarizes recent publications by some of the authors and

BGD

9, C7533–C7538, 2013

add data from three new cruises to the picture. The new data does not add any substantial knowledge relative to earlier publications. However, some new approaches in illustrating the changes of the carbon system parameters, and its impact on the solubility of calcium carbonate, are included. Unfortunately these new approaches have some fundamental errors. The first ones are obvious when looking at figure 7. Dissolution/precipitation of calcium carbonate will change TA with twice the DIC change, not equally as it looks like in the arrow of the figure. This has a direct effect on the impact on omega. Next the arrow in sea ice melt increases DIC, and decreases TA, not consistent with the text of the manuscript (line 15, page 14269). Finally it is not possible to represent omega in a TA-DIC plot in a situation when salinity change, as this also will cause a change in calcium ion concentration. As it now is drawn it assumes a constant calcium ion concentration, which obviously is not the case in a region where salinity changes by up to âĹij20%. The change in calcium ion concentration is something that is lacking in the discussion of the whole manuscript.

RESPONSE As mentioned above, we realized the arrows in Figure 7 were incorrectly drawn. In the revised paper, we have clarified and added a figure below for clarification. Using typical TA 2200 μmol kg-1; DIC 2000 μmol kg-1; S 33 and T of -1°C are initial source water (winter/early spring water), the following "direction" of change in Ωaragonite occur: (1) calcification should decrease Ωaragonite (assuming same S and T); (2) temperature increases slightly Ωaragonite by $\sim$0.08 per 10°C (at same TA, DIC, T and S conditions) so this not significant; (3) sea-ice melt decreases Ωaragonite in the net direction shown on figure (i.e., seawater with source S, T, TA and DIC mixed with either 5% or 10% sea-ice melt, assuming no change in temperature). 5% sea-ice melt is a high proportion given unpublished δ18O data and previous SBI observations in 2002-2004. In another paper of Western Arctic sea-ice melt (and melt ponds), we find that the sea-ice DIC:TA ratio is greater than 1 (yes!, DIC exceeds TA thus very low pH, Ω and high pCO2 of melt water), and; (4) freshening (due to river input/precipitation) should also slightly decrease (i.e., S, TA and DIC change proportionately while T remains at -1°C; thus carbonate ion changes). As noted by the reviewer, the change is

BGD

9, C7533–C7538, 2013

curvilinear on a TA-DIC plot but close to the “source” seawater, such freshening is close to linear in the direction noted. We also added a net (freshening/P/melt) direction but dashed to show uncertainty. The photosynthesis/respiration and CO2 release/invasion arrows are separated slightly due to the impact of nitrate uptake (regeneration) on alkalinity.

COMMENT In figure 8 it should be stressed that the change due to anthropogenic emissions of CO2 is from preindustrial to the present situation, while the others are only for a seasonal change. In the text it is argued that the magnitude of some of the physical- biochemical processes also might have changed as a result of anthropogenic effects (sea ice cover, surface water temperature, etc.). These facts needs to be spelled out in the figure legend in order for the reader not to misinterpret the message. Finally the line representing the effect of summer heating is drawn in the wrong direction. It should be an increase in omega not a decrease, see the text (last line page 14268) where it is correct. Unfortunately the error is still in the equation (line 21, page 14269).

RESPONSE The reviewer makes a very good point about clarifying the figure 8 caption. In the revised paper, the separation of anthropogenic CO2 contribution from other physico-biogeochemical factors will be made clear. We very much appreciate spotting the temperature line in the wrong place. The uploaded figure “should” have had the temperature line above zero omega line. The figure and equation have been corrected in the revised figure.

COMMENT Technical aspects: There also are a number of editorial errors, like missing references in the list, missing labeling of figures (2 & 5), no reference to figure 1 in the text, no identification of the term "Siberian Sea Current (page 14263). Throughout the text there are also expressions like "relatively" and "higher" without stating compared to what, as well as "appears" without any reference what the basis is. A scientific paper needs to be more stringent. One of the more amusing mistakes is that there is a reference to the late 2000s on page 1427. That far does not even modelers go!

BGD

9, C7533–C7538, 2013

RESPONSE The revised paper is also corrected for the minor editorial errors. Firstly, the paper references have been fully checked and missing reference added to the citation list. The figure label in Figure 2 and 5 is also corrected, a direction to Figure 1 added in the correct place in the text added and better reference to the Siberian Sea Current on page 14623. We have carefully revised the paper to correct/clarify the use of qualitative terms such as “relatively” and “higher” where appropriate. The year date was also a typo and thus corrected. . .we’ve made sure it’s reference to the later part of the first decade of the 21st century! Many thanks for spotting this.

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/9/C7533/2013/bgd-9-C7533-2013-supplement.pdf

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Interactive comment on Biogeosciences Discuss., 9, 14255, 2012.

BGD
9, C7533–C7538, 2013

Interactive Comment

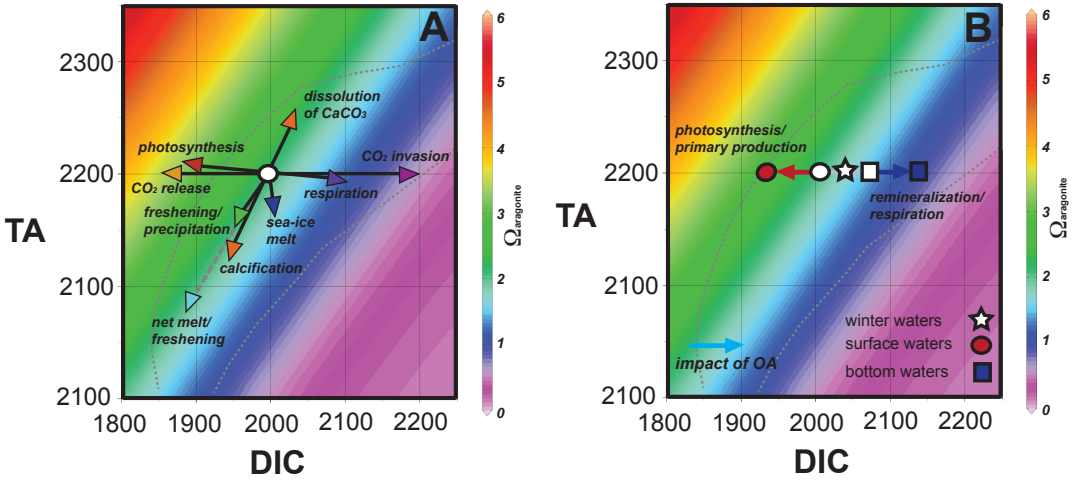

Fig. 1.

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