Manuscript bg-2012-402

Biogeosciences Discuss., 9, C6888–C6889, 2012

Author Response:

We thank Anonymous Referee #2 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.

(1) we strongly argue that the paper adds a lot of new data and insight about $CaCO_3$ undersaturation in the western Arctic shelves. In a previous paper (Bates et al., 2009), $CaCO_3$ 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 $CaCO_3$ 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.

Due to low temperature and global circulation pattern, the Arctic Ocean has naturally low pH and carbonate saturation state (Omega) and thus it is and will be the first to be impacted by the ocean acidification (OA) process. The authors added their new data from 2010 and 2011 to their earlier data to show the omega distributions in surface and bottom waters in the Arctic Ocean. They also analyzed possible control mecha- nisms. While there is no major new point brought by the new data, I feel this is a useful contribution to the current literature.

However, the process analysis lacks rigorousness and even with some wrong statements. The conclusions on the contribution to omega by biological process vs OA should be built on a more stringent analysis (currently, text in p.14269-14270 is rather confusing and it is not clear how various terms, in particular that one caused by NCP, were derived). Also the entire base on that OA has decreased omega by 0.3 is based on the sentence (p. 14267, line 22-23) without any reference on where/how it was derived and how reliable it is, making the rest of comparison less convince.

We have clarified this section in the revised paper.

The statement that calcification and dissolution of CaCO3 would have little impact on Omega is clearly wrong (the relative change of TA to DIC should be 2:1 in Fig. 7) though it may be right in the arctic that these processes are of minor importance. Also, in Fig. 7, it is not clear why ice-sea melt increases DIC, and it is even more confusing why in addition to that there is another surface freshening arrow. The text around line 15 in p. 14269 is perplexing.

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 $\Omega_{aragonite}$ occur: (1) calcification should decrease $\Omega_{aragonite}$ (assuming same S and T); (2) temperature increases slightly $\Omega_{aragonite}$ by ~0.08 per 10°C (at same TA, DIC, T and S conditions) so this not significant; (3) sea-ice melt decreases $\Omega_{aragonite}$ 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 $\delta^{18}O$ 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 pCO_2 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 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 CO_2 release/invasion arrows are separated slightly due to the impact of nitrate uptake (regeneration) on alkalinity.