

Interactive comment on “Ocean acidification state in western Antarctic surface waters: drivers and interannual variability” by M. Mattsdotter Björk et al.

Anonymous Referee #2

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General comments: The manuscript by Mattsdotter Björk and co-workers builds on a four year dataset of the surface water carbonate system (including pH, total alkalinity and dissolved inorganic carbon) combined with environmental parameters (including SST, salinity, chlorophyll a fluorescence and sea ice concentration) from the Amundsen and Ross Sea, Antarctica. Interannual differences in surface water carbonate chemistry are presented against the background of the prevailing hydrographical regime and biological production and the consequences for the current and projected aragonite saturation state (Ω_{Ar}) discussed. Given the poor spatial-temporal data coverage of the study area the large dataset by Mattsdotter Björk et al. is of high relevance for comparative studies and the detection of climate change induced shifts in the acidifica-

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tion state this important region of the Southern Ocean. However, in its current state the manuscript is not convincing because the main objective(s) gets lost in the overly long introduction, the abstract and conclusions lack a clear focus and the main message(s) not clearly highlighted. The results and discussion sections suffer from a superficial description of the hydrographical/sea ice/productivity regime and would benefit from a more comprehensive, detailed description. The authors use a lot of abbreviations for geographical locations and water masses throughout the text which makes it difficult to read. The authors should consider an additional table with geographic/water mass abbreviations. Some of the figures are difficult to read due to their small size and small font of the axis labels.

Specific comments:

Abstract:

The abstract is not well focused and not coherently written. Despite the fact that the first half of the abstract is concerned with the study sites and methodological issues, the results and conclusion presented in the second half of the abstract are not well connected. First it is stated that SST and chlorophyll a (it should be mentioned that the latter is used as a proxy for productivity since it is productivity and not chlorophyll a which determines biological CO₂ drawdown) were the main drivers of the Ω variability while later the effect of melt water from out-flowing glaciers is highlighted. In between the position of the ice edge and the area of open polynyas is presented for 2007 and 2010 without any clear connection what was stated in previous (SST and chlorophyll a drivers) and latter sentences (future projections). It is also not clear why only 2007 and 2010 are explicitly mentioned and not 2006 and 2008.

Introduction:

The introduction is overly long and should be shortened considerably.

Page 7881, line 5: A decrease in pH by 0.1 units from ~ 8.2 to ~ 8.1 does not corre-

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respond to a 30% decline. I assume the authors are referring to the increase in H⁺ ion concentrations. This needs to be clarified.

Page 7881, lines 6-8: The authors present a one-sided view of the effects of OA on marine organisms by highlighting the adverse effects but it has been shown that some organisms are either not or even positively affected. Furthermore marine organisms face seasonal changes in pH that are much larger than the 0.1 decline due to oceanic uptake of anthropogenic CO₂, as is also evident from this study. It is therefore likely that marine organisms have evolved some form of adaptation to changes in the carbonate system.

Page 7882, lines 3-4: Western Antarctica is facing dramatic climatic changes not the entire Southern Ocean/Antarctica as correctly stated further below.

Page 7884, lines 8-10: With respect to the effect of OA on iron availability the authors should also cite the study by Shi et al. 2010 (Effect of Ocean Acidification on Iron Availability to Marine Phytoplankton, Science, Vol. 327).

Page 7884, line 15: Despite being relatively unexplored the authors should look into some of the publications related to the maiden voyage of the Korean ice-breaker Araon to the Amundsen Sea and Amundsen polynya (e.g. Lee et al. 2012 Polar Biology, vol. 35, issue 11 or Dolan et al. 2013, Polar Research, vol. 32).

M&M:

Page 7886, lines 10-13: In Chierici et al. 2012 it says that the calibration was made in 2006 not 2007/08. Furthermore, to extrapolate a calibration curve from one year and area based on only 35 discrete Chl a measurements to the entire data set covering four seasons and a large spatial area seems inappropriate especially since the fluorescence yield (the ratio of the fluorescence signal to the chlorophyll concentration) can be highly variable due to differences in phytoplankton species composition, photoadaptive state (e.g. light quenching), nutrient supply and physiological state.

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Study area:

Page 7887, lines 14-15: It states that all OSO expeditions started in December. However, in the legends of figures 1, 2, 5 and 6 it says August for 2007, September for 2008 and November for 2010.

Page 7888, line 6: If covered in all years why is the Ross Sea and RSP not listed for 2007/08 and 2008/09 in Table 1?

Hydrography:

This section starts with a brief and rather incoherent paragraph on the general hydrography in the area followed by a longer paragraph with SST and salinity data.

Page 7888, lines 8-10: The sharp gradient is not really evident in 2006 and seems rather located at 59°S in the other years. Explain!

Page 7888, lines 10-15: Quite a jump from the APF to the coastal shelves.

Page 7888, lines 18-19: Was the minimum SST of -2°C associated with unusually high salinities.

Page 7888, lines 26-27: Freezing temperature at just below -1.2°C seems rather high even at minimum salinities of 33.3.

Sea ice extent and concentration:

Page 7889, lines 11-13: The relative decline (from September to December) looks quite similar in both areas.

Results:

The results section lacks detail and proper explanation of the patterns seen e.g. in figure 6. Furthermore, the mean values given for the different carbonate system parameters in Table 3 are not very useful given the large area and seasonal time span covered during the study.

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Discussion and conclusions:

The discussion is not very focused and the conclusions based on some general assumptions about the factors responsible for changes in carbonate saturation state instead of evidence based on the presented data.

Since organisms already experience large seasonal/interannual variability in pH, Ω etc. the authors should concentrate their discussion on the magnitude and duration of the period when Ω_{Ar} actually falls below 1, particularly in the future, since this will be the critical "window" for aragonite-precipitating organisms.

What about changes in Ω_{Ar} in subsurface waters? Pteropods will spend part of their life cycle at greater depth and thereby "escape" corrosive surface waters.

Page 7893, line 26: On which emission scenario is the 10 $\mu\text{mol kg}^{-1}$ CO₂ increase based?

Page 7894, lines 18-19: Indirect inference only. It has been shown that the MIZ is not necessarily productive in the Southern Ocean and that iron availability seems more important than melt water stratification (Bathmann et al. 1997, DSR II, vol. 44, issues 1-2).

Figures and tables:

Axis font is too small and difficult to read in figures 2, 5, 6 and 12.

Page 7900, Table 1: Start location not really necessary here.

Page 7902: Table 3: Annual mean values and range not very meaningful (see comment above).

Page 7904, Figure 2: Figure is missing labels (a, b).

Page 7906, Fig. 4: Figure is missing labels (a, b, c, d). Indicate position of Amundsen polynya.

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Page 7907, Fig. 5: Note that chlorophyll a fluorescence values in the RSP and AmP are out of the range of the sensor.

Pages 7909-7912, Figs. 7-10: Numbers are difficult to read against the grey background. Why are some numbers in bold and why are only data for 2007 and 2010 plotted?

Page 7914, Fig. 12: The allocation of the x-variables (SST, salinity etc.) with respect to the vertical bars is not clear.

Technical comments:

Page 7881, line 5: decreased by instead of decreased with

Page 7882, line 3: The commonly used term is Southern Ocean (SO) not Southern Polar Ocean (SPO). The abbreviation should be introduced here and not later in the text.

Page 7882, lines 14-17: Sentence reads funny. Re-write!

Page 7884, line 3: sensitive to instead of sensitive for

Page 7887, line 24: except for instead of except for in

Page 7889, line 25: was used to instead of was used as to

Page 7890, line 8: 10 $\mu\text{g L}^{-1}$ instead of 10 μL^{-1}

Page 7890, line 26: were relatively stable at instead of were relatively stable of

Interactive comment on Biogeosciences Discuss., 10, 7879, 2013.

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