Ocean Science
Discussions

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Interactive comment on "Aragonite saturation states and pH in western Norway fjords: seasonal cycles and controlling factors, 2005–2009" *by* A. M. Omar et al.

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This study presents seasonal cycling and controlling factors of the ocean acidification parameters, aragonite saturation and pH, in fjords of western Norway. The data and discussions are an important contribution to CO_2 research in a relatively undersampled region and the methods used to determine the whole carbonate system from underway pCO_2 data form a novel approach and are complimentary to future studies in this field. The choice of the journal fits very well and I recommend publication of this article. In the version reviewed here there are a number of ameliorations that can be made in terms of clarity, coherence and rigour before proceeding with publication. The authors may find comments, questions and linguistic corrections analytically below.

General comments:

1. A very minor comment regarding language; as it is a European journal I would suggest replacing the use of "fall" with "autumn".

2. Make sure it is clear how TA is derived from SSS(sst) and SST, i.e, how strong is a relationship between SSS and SST to make such a derivation and secondly what steps are carried out to determine TA?

3. Include a clear statement of the precision and accuracy of the measured parameters. This would fit well before the detailed description of the propagation of errors and further place them in context.

4. The influence of sea ice and glacial ice dynamics has not been explicitly considered. Is this area free from ice influences and if so perhaps state this or does sea ice formation in winter and melt during spring-summer contribute to the correlation in SST and SSS?

5. For salinity normalised DIC, the terms DICS and nDIC are both used. Perhaps try and use one term for consistency and clarity throughout the paper and include a statement of how the normalisation was carried out, i.e., what salinity reference is used, if the standard correction was made or non-zero endmembers were included, as described in Friis et al. (2003).

6. Figure 2: in relation to the various regression analyses made, a statement on the interpretation of the regression and the significance of the relationships is required. This would make the comparisons of the parameters more relevant and strengthen the choice of those used in other calculations.

7. Check Table numbering; Table 2 is absent.

Specific comments:

Abstract

Page 1

Line 9 write "carbon dioxide (CO2)" in full (first time use in main text). Line 10 insert "the" between "lowers" and "aragonite saturation state". Line 19 change to "carbon-rich". Line 24-25 replace "brings up" with "enables" and add "reach" between "to" and "the". Line 32 define "SSS" for first time use.

1. Introduction

Page 2

Line 38 replace "incur" with "cause". Line 39 replace "ocean" with "oceanic". Line 43 insert "," after the reference. Line 51 insert "," after "regions". Line 63 insert "a" between "is" and "prerequisite".

Page 3

Line 64 remove the "s" on "latitudes". Line 65 insert "CO2" between "be" and "sources". Line 76 delete "important" to refrain from using the same word twice in one sentence. Line 81 delete "the" between "in" and "surface". Line 89 insert "the" between "present" and "mean".

1.1 The Study Area

Page 3

Line 93 instead of capital letters use lower case "n" and "s" for "north" and "south", respectively. Line 95 replace "at" with "along".

Page 4

Line 103 delete "the" at the end of the line. Line 106 replace "it" with "Korsfjord" to reduce the use of generic "it" and be specific to the subject under description. Line 108 remove full-stop and replace with and to join sentences for better flow. Line 109 correct "witch" to "which". Line 118 replace "mix" with "mixes". Line 119 insert second

bracket ")" after "(NCC". Line 121 change "wind" to "winds" and insert "the water in" after "circulation of". Line 122 replace "that follows" with "following". Line 124 suggestion to add "forcing" after "wind". Line 125 replace "," with "and inputs of". Line 125-126 between "seasonal time scales," and "during spring-summer" replace text with "salinity drives stratification". Line 126 add "the water column is" between "and" and "more".

Page 5

Line 129 specify what "the temperature" refers to, i.e., a certain depth or depth range in the water column or certain location in the fjord. Line 131 delete "the" start line with "Water". Line 132 following "oxygen" insert "to the area". Line 132-133 delete "the fjords enhance their" and insert "is enhanced in the fojrd" between "production" and "which". Line 133 replace "enables them to host" with "supports". Line 137 replace "decisive" with "dominant controls of" and delete "for the". Line 140 write "nutrient-rich" and add "on from" after "follows". Line 142 insert "upper" before "water column", i.e., assuming that the sub-surface/ deeper waters remain nutrient rich? Line 143 insert 2 "," either side of "with its adjacent waters". Line 149 replace the extra "of" with "the" and make the 2 on "CO2" a subscript. Line 152 replace "It" with "The ship". Line 153 replace "." after "(Fig. 1)" with "," and delete "It".

Line 6

Line 161 replace "in" with "during". Line 166 add SOCAT reference: Bakker, D. C. E., Pfeil, B., Smith, K., Hankin, S., Olsen, A., Alin, S. R., Cosca, C., Harasawa, S., Kozyr, A., Nojiri, Y., O'Brien, K. M., Schuster, U., Telszewski, M., Tilbrook, B., Wada, C., Akl, J., Barbero, L., Bates, N. R., Boutin, J., Bozec, Y., Cai, W.-J., Castle, R. D., Chavez, F. P., Chen, L., Chierici, M., Currie, K., De Baar, H. J. W., Evans, W., Feely, R. A., Fransson, A., Gao, Z., Hales, B., Hardman-Mountford, N. J., Hoppema, M., Huang, W.-J., Hunt, C. W., Huss, B., Ichikawa, T., Johannessen, T., Jones, E. M., Jones, S., Jutterstrom, S., Kitidis, V., Körtzinger, A., Landschützer, P., Lauvset, S. K., Lefèvre, N., Manke, A. B., Mathis, J. T., Merlivat, L., Metzl, N., Murata, A., Newberger, T., Omar,

A. M., Ono, T., Park, G.-H., Paterson, K., Pierrot, D., Ríos, A. F., Sabine, C. L., Saito, S., Salisbury, J., Sarma, V. V. S. S., Schlitzer, R., Sieger, R., Skjelvan, I., Steinhoff, T., Sullivan, K. F., Sun, H., Sutton, A. J., Suzuki, T., Sweeney, C., Takahashi, T., Tjiputra, J., Tsurushima, N., Van Heuven, S. M. A. C., Vandemark, D., Vlahos, P., Wallace, D. W. R., Wanninkhof, R., Watson, A. J. (2014) An update to the Surface Ocean CO2 Atlas (SOCAT version 2). Earth System Science Data 6: 69-90. doi:10.5194/essd-6-69-2014. Line 169 replace "in the period" with "during". Line 171 write "CarboSchools (CS)" in full (first time use in main text). Line 186 write "Conductivity Temperature Depth (CTD)" in full (first time use in main text) and maybe specify what "data" was acquired and/ or used in this study.

Page 7

Line 192 instead of capital letter use lower case "s" for "station". Line 200 clarify the estimated pH values – estimated from what source? CO2SYS?

2.4 Methods

Page 7

Line 206-207 insert "an" before "empirical" and define the parameters used to derive the empirical relationship. Line 217 replace "Second" with "Secondly". Line 217 clarify how TA is derived from SSS(sst), see general comments.

3. Results and discussion

3.1 Correlations and validations

Page 8

Line 236 insert "the" before "data". Line 237-239 Is sea ice present in the region? see general comments. Line 239 clarify where the "runoff" originates. Line 240 insert "degree of" between "high" and "scatter". Line 244 reverse order of "indeed is" to "is indeed". Line 247 delete "a" after "As" and re-write sentence following "verification"

as "that the RF SST dataset is spatially representative,". Line 249 replace "in" with "across". Line 256 replace "statics" with "statistics". Line 257 replace "functions" with "acts" and insert "an" between "as" and "indicator". Line 259 add a space to separate "with" and "values". Line 260 add commas to read "data ,i.e., pH(sss)". Line 265 insert "closely" between "ΩAr(sst)" and "reproduce" and delete "very well". Line 269 replace "show" with "shown". Line 274 insert "through the calculations" between "propagated" and "to".

3.2 Spatiotemporal variations

Page 10

Line 281 replace "collapsed" with "condensed". Line 284 delete "the" following "after". Line 286 replace "outweighs" with "counteracts". Line 287 replace "begins" with "begin" and also specify what processes are being referred to. Line 288 insert "the" after September replace "SSTs" with "SST". Line 289 re-phrase sentence between "mixing," and "as mentioned" to read "which enables deep, carbon-rich coastal water to penetrate the surface layer,". Line 290 replace "as" between "and" and "reflected" with "is" and delete "the" before "increasing". Perhaps specify which DIC values are increasing by the autumnal mixing, i.e., sea surface, surface layer, upper ocean... Line 293 replace "drives up the " with "enriches". Line 294 insert "the" before "concentration", delete "the" between "of" and "carbonate" and add an s to read "ions". Line 296 re-phrase to read "due to inputs of run-off" and replace "reinforces" with "enhances". Line 297 replace "over" with "exhausted". Line 298 replace "The" with "However," and delete ", on the other hand,". Line 300 replace "mismatch" with "decoupling of". Line 307 correct "embody" to "embodied".

3.3 Controls of seasonal variability and trends

Page 10

Line 310 replace "arranged the data into" with "computed". Page 11 Line 315 re-write

C6

the reference to "Lauvset et al. (2015)". Line 316-317 replace "are shown on Fig. 4 (left panels) where it can be seen" with "show" – removes the double Fig. reference in the sentence. Line 326 replace "letting one of the drivers" with "varying them independently". Line 327 delete "to vary" and replace "drivers" with "controls" – removing double word use in the same sentence. Line 329 replace "for" with "of" and correct "driver" to "drivers". Line 331 correct "induce" to "induces". Line 332 insert "other" between "the" and "hand". Line 333 correct "induce" to "induces". Line 334-335 re-write to "We therefore conclude that variations in DIC, followed by TA, are the most important drivers for changes in ΩAr(sst)." Line 337 replace "have" with "has" and delete "In terms of processes" so that the next line starts with "This means". Line 338 correct to "carbon-rich". Line 339 insert "inputs" after "runoff". Line 343 replace "changes" to "change". The first use of nDIC – how is defined and how are the normalised values determined, perhaps add reference, e.g., Friis et al. (2003).

3.4 Inference of OA parameters from VOS underway data

Page 12

Line 353 the use of DICS is not specifically defined in the text and is an additional term to nDIC – do they both refer to salinity normalised DIC determined in the same way? Please clarify to be sure. Line 355 remove the space after (2010). Line 359 reference to equations 4 and 5 might not be correct, i.e., should it be equations 3 and 4. Please check and amend if necessary. Line 362 remove ", while the CO2 system is fully determined only occasionally," as I don't think it adds anything it would reduce the length of the sentence. Line 368 delete the spare "and" after "Fig. 5" and add "to" between "conform" and "tight". Line 371 replace extra "," with ";" after "10.354" in equation 5.

Page 13

Line 372 check for extra spaces and uses of "," and/ or ";" in separation of terms and consistency with equation 5. Line 377 delete "and" before "thus" and replace "min-

imise" with "minimizing". Line 380 replace "with" by "to". Line 391 change to "carbon-rich". Line 392 rearrange the line to read "surface water also reflects the properties of the deeper water". Line 394 replace "can" with "could" and insert "to occur" after "expected". Line 399 replace "development" with "CO2 concentrations" and replace "follows" with "follow". Line 400 add "driving oceanic CO2 uptake" after "atmosphere".

4. Summary and concluding remarks

Page 14

Line 402 insert "worth" after "four years" and replace "less" with "sporadic". Line 403 delete "frequent". Line 413-414 use the same number of decimal places for quoted numbers. Line 415 insert "the" before "phytoplankton" and replace ", which" with "that" and delete "levels". Line 417 replace "brings up" with "allows"; correct to "carbon-rich"; insert "mix into" between "to" and "the". Line 418-419 replace "and reinforces the decrease in pH" with "reduces" and delete ", which continuous throughout fall". Line 430-431 finish sentence after "carbonate system".

Page 15

Line 435 replace "development" with "concentrations" and remove "f" from "fCO2", i.e., referring to concentrations of CO2 rather than the concentrations of the fugacity of CO2 that wouldn't be quite correct. Line 436 finish the sentence after "atmosphere".

5. Acknowledgements

Page 15

Line 438 replace "supports" with "support" and replace "by" with "from". Line 440 insert "the" after "and help of".

Tables

Table 1

Page 20 Line 598 replace "about" with "of". Line 599 insert "which" after "for".

Page 21 Line 603 replace "(continue)" with "(continued)".

Table 3

Page 22 nDIC – "DIC normalised to the mean salinity"; please include somewhere in the main body of the text what value was determined for the mean salinity and how.

Figure texts

Page 23 Line 620 replace "which" with "where" and replace "tick" with "thick". Line 635 check "ln(nfCO2ts)" – is the "n" correct and currently it doesn't match with the X-axis labelling in Figure 5 (B).

Figures

Figure 2 (A) Y-axis can be expanded to open up the visual regression trend, i.e., range in SSS of 25-35. Confusion of the colour bar underneath is too close to the X-axis and on first inspection looks like it is referring to SST values. Add "month" as the unit to clarify the colour bar and move it closer to panel (A) if possible. Figure (3) 4 time series panels are presented but only 2 parameters mentioned in the Figure text and all colour bars are unlabelled. Add parameter labels and units (where relevant) to each of the coloured panels.

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