

RC1: '[Comment on egusphere-2023-2595](#)', Anonymous Referee #1, 14 Dec 2023 [reply](#)

General comment

The manuscript “Distribution and source attribution of alkalinity in the Dutch Wadden Sea” examines spatial and temporal alkalinity dynamics in the Dutch Wadden Sea. The topic is timely and fits the scope of Ocean Science. The study design is appropriate, and the data set sufficient to answer the stated research questions. However, the manuscript is hard to follow and should be streamlined. The entire manuscript should have 3 to 5 well-structured paragraphs per page that address one specific topic. The introduction reads more like a study site description and does not give a broader context or demonstrates the need for this study. It would be helpful to put some of the results (e.g., most subplots of Figure 2 and Table 1) into a supplementary information and decrease the overall word count by focusing only on most relevant findings. The authors should pick up to three key messages on which they focus through the manuscript. The figures need some improvements. I suggest accepting the article after major revision.

AC: Dear reviewer, thank you very much for your positive and helpful comments, which have really improved our manuscript. In line with your suggestions, we have revised the Introduction, restructured the Methods and Results sections and also revised and improved the figures. Our detailed responses can be found below. As the study of TA generation and its possible pathways is a complex topic, greatly reducing the word count and removing parts of the manuscript would result in an incomplete study approach. We think that using at least all the parameters/stoichiometries we have completes the approach to identify TA-generating pathways. Even if this leads to a more complex and complicated discussion, we would like to stick to this more complex approach. However, we have revised some of the sentences in the discussion to make them more understandable.

Specific comments

Consider a more interesting and specific title.

AC: Done. We have adjusted the title in a shorter and more specific version.

L12 remove: “and compared it with earlier data”.

AC: We would like to stick to the announcement of the data comparison in the Abstract. However, we have rearranged the sentence in line with RC2.

L19-22. This sentence is hard to follow and has too many citations. Consider splitting your sentences into two if they span over several lines and only cite most relevant literature for each statement.

AC: We have revised the Introduction and some sentences, such as the one mentioned above.

L64 – 66 Add dates.

AC: Done.

L75 Which kind of carbon measurements?

AC: We have replaced carbon with the specific carbon terms TA and DIC.

L137 Remove first sentence of caption.

AC: Done.

L201 Remove sentence. Avoid writing “various parameters “through the manuscript and list parameters instead. Try to be more specific.

AC: We have deleted the sentence you suggested and clarified the parameters where it makes sense to do so.

L204-205 Explain how you get to this conclusion.

AC: This sentence is based on plots not shown. We have edited the sentence.

L309 Faber studied mangroves. There is probably a study that is more similar to your study site.

AC: It is true that the study site in the reference is different from ours. However, what is interesting here is not the location, but the use of a tracer, in this case radon, to identify the source of higher TA values in pore water discharge, for which we used silicate instead of radon.

It is very hard to follow your discussion. Suggest reducing to the most interesting findings. Condense the information as much as possible.

AC: As mentioned in our first statement above, we would like to stick to all parts of our discussion. However, we agree with the complexity and have revised parts of the Discussion to make it easier to understand.

Figures and tables:

Fig 1: Remove ESRI source code (in all figures).

AC: In accordance with the Ocean Science’s submission guidelines, we would like to stick to the ESRI source code in Fig. 1. However, Fig. 2 has been fully edited and created in R instead.

Fig. 2: This figure is too big. Show only one figure per page. Choose only most important parameters and put rest into the SI. You could plot all parameters against salinity and/or distance to the coast in one graph with subplots and discuss trends.

AC: We would like to stay with the spatial representation, but we have revised Fig. 2 and included most of the parameters in the Appendix according to your suggestion.

Fig. 4 and 5: Increase font size and point size. Axes should be aligned. Salinity looks strange in Fig 4d.

AC: Fig. 4 has been revised for better readability.

Put Table 1 in SI. Could add averages and standard deviations.

AC: Table 1 has been moved to the Appendix. As Table 1 contains individual observations, average values and standard deviations are irrelevant.

Technical corrections

When you reference two or more citations, the single citations are separated by a semicolon without any spaces. This looks strange. Please double check the citation guideline of the journal.

AC: The citation was made using the reference manager EndNote and the Copernicus style file “Copernicus Publications” as output style, as indicated on the Ocean Science submission website.

Avoid paragraphs with only one or two sentences.

AC: We have deleted some very short paragraphs and also restructured the section on methods section a little.

L81 Remove “.” before citation.

AC: Done.

L191 TA was defined before.

AC: We are not sure what you mean by this comment, as L191 contained Table 1 in the previous version of the manuscript.

L198 Rephrase this sentence, “arrived” does not make sense in this context.

AC: Thank you. We have changed “arrived” to “obtained”.

Do not overuse the term “shed light on...”

AC: Some of the terms have been revised to reduce the use of “shed light on”.

The reference list needs to be edited. E.g. CO₂ with subscript and uniform styles for titles. Include volume and page numbers for all references.

AC: We have revised the reference list.

RC2: ['Comment on egusphere-2023-2595'](#), Anonymous Referee #2, 20 Jan 2024 [reply](#)

Strengths:

I really appreciate that the authors left the location names on Figure 2 for easy reference when going from reading the text in the results to the figures. The manuscript as it stands is well organized throughout and easy to follow. The discussion of the results and considerations is also quite comprehensive and strong, aside from the one reservation I have that is listed below. I suggest accepting it after major revisions.

AC: Dear reviewer, Thank you very much for your very detailed comments, which have really improved the manuscript. You will find our responses below.

Major Concerns:

Results:

Figure 2: Please make points in figure 2 a color gradient from min to max value instead of grouping many values in one color. That way the reader can more specifically see the actual value at each site. The groupings also aren't consistently spaced which could be misleading when analyzing spatial trends. Also, this is entirely a personal preference but generally I think blue=lower and yellow=higher based on the ocean of things color bars so it was confusing at first and they may be better reversed.

AC: Thank you for highlighting this. We agree with your suggestions and have revised Fig. 2 by reversing the color scale and adding a color gradient. As suggested by RC1, we have split Fig.2 and shown only the most important plots in the Results section and moved the other plots to the Appendix.

TA generation section: I think the assumption that TA generation for the entirety of the Wadden Sea does not come from freshwater dilution/river water is not properly supported as stands and is too general. I agree though that this is the correct conclusion for the Ameland region based on the data you've shown in Table 1, Figure 4, & 5. However, the authors previously show in Figure 3 that the TA vs salinity trend for the Ameland region is non-conservative, while the Ems-Dollard & Vlie regions of the Wadden Sea are conservative. Therefore, TA & salinity trends are clearly not consistent across the entire region. Which may be attributed to varying degrees of freshwater discharge across the region, which they mention briefly in the discussion. So while it may be true for the Ameland region that TA sources do not come from freshwater dilution/river water, the same cannot be said for these other regions. If the authors had stationary data during ebb tide for the regions that do appear to have a conservative relationship and saw the same pattern then yes they could reasonably assume this is true for the entirety of the Wadden Sea on average. However, they do not appear to have stationary data for either of the conservative regions. Therefore, this statement needs to be more specific to the Ameland region of the study and not the entire Wadden Sea region. If there are river gauges in the region to support similar river discharge across the region then this assumption may have stronger support but would still be rather bold without ebb tide data from the other regions. They also say later that freshwater dominates in the EMS-Dollard.

AC: Thank you for your detailed description. We agree that an overall statement for the whole Wadden Sea, including areas with freshwater input, could lead to misleading

interpretations. For this reason, we also pointed out in the last part of the Discussion that a comparison between the northern Wadden Sea and the Dutch Wadden Sea is not advisable. To make this even clearer, we have clarified our statement.

Minor Concerns:

Throughout manuscript: Please remove any we's, he's, etc. Instead refer as "this study" "the data" etc.

AC: As this is a matter of taste, but the use of pronouns in the first-person is accepted, we would generally like to stick with it. However, we also feel that it has been used too often and significantly reduced its use.

Methods:

Is there a reason you focus on calcite saturation instead of aragonite? Is it more relevant to local species? Please state.

AC: There was no particular reason why we only reported calcite. Therefore, we have added the aragonite values to complete the data.

Please include how you generated the statistics throughout the paper (i.e. the linear regressions). Did you use Excel, Matlab, R, etc? Also, are these Model I or Model II regressions?

AC: Thank you for pointing this out. We have added a section on Data analyses and also corrected the linear regressions from Fig. 5 to a Model II.

Discussion:

Lines 237-239: Could this also be attributed to seasonal differences or changes in watershed usage over those 30 years?

AC: We can rule out a strong seasonal influence here, as both studies (Hoppema's and this study) took place in May. However, Hoppema's study took place at a time of high eutrophication and high local primary production (Cadée & Hegeman, 2002), and we cannot rule out an increased influence on the catchment and freshwater inflows. However, we have not focused so much on the freshwater influence here, but on TA generation in the sediments of the tidal flats. We have revised this section and will also include a statement to make this point clearer.

Minor Edits:

Line 10: "North Sea is hypothesized to be a source..."

AC: Done.

Line 10-11: "This study measured TA..."

AC: The sentence was reworded to "This study observed..".

Line 12: “compared is with historical data.”

AC: We rearranged this sentence.

Line 14: “ washed out with outgoing tide water.”

AC: Done.

Line 27: “Most of the Wadden Sea is located...”

AC: Done.

Line 28: “which makes it the world’s largest uninterrupted stretch...”

AC: Done.

Line 31: what dynamics? Biogeochemical? Chemistry?

AC: We have added the term “biogeochemical”.

Line 30-33: Split into 2 sentences. One for chemical and one for physical sources of variability.

AC: Done.

Line 35-36: what water masses? What is a ‘strong’ exchange? Do you mean that the water masses are very different?

AC: We have deleted the “strong” and revised the sentence to make it clearer.

Line 37: “The carbon storage capacity of the North Sea is an important atmospheric CO₂ sink as it exports and stores the absorbed...”

AC: Done.

Line 40-43: TA, primarily consisting of bicarbonate and carbonate, is generated by chemical rock weathering (citations), calcium carbonate dissolution, and anaerobic metabolic process, such as...”

AC: We have revised this sentences according to your suggestion.

Line 54-56: during what time of year?

AC: We have added the time (May).

Lines 116-118: please include aragonite saturation values as well. They can simply be added next to calcite values in parentheses.

AC: Done.

Lines 204-205: Please include the R-values for the relationships to back this up.

AC: Done.

Lines 215: “by enhanced water movement” what does this mean? Be more specific.

AC: There, the water movement is driven by tidal forcing. We have added this explanation to the text and also removed the word “enhanced”.

Line 219-220: “which could be traced back on an effect of the first four samplings as mentioned above” move to discussion

AC: This is only the second part of the sentence. The first part is related to the results, which is why we want to leave it in its original place.

Line 221: connect this back to higher denitrification and ammonium production compared to nitrification because your ammonium relationship supports this as well.

AC: We have discussed this in the Discussion section 4.3.2.

Line 243: A TA increase of >70 is quite a bit. I wouldn't say it's only slightly higher.

AC: Yes this is true. We meant it more as a comparison. However, we removed this sentence by editing this part anyway.

Line 271: Where is Marsdiep relative to your study sites? Please add to map.

AC: Since Marsdiep is much further west, it is not visible on the maps, and adding it would enlarge the map too much.

Lines 282-287: I think these sentences probably belong in the discussion.

AC: This is in the Discussion.

Lines 285-287: and more spatial data for the varying TA vs salinity relationships of the different tidal regions in addition to the temporal data mentioned

AC: We have revised the conclusion and added a corresponding explanation.

Line 291: this is not necessarily true. Increased agriculture has led to increased rock and soil exposure, resulting in increased rates of silicate weathering. Also, I'm not sure if this applies to this region but digging of quarries also extracts and exposes silicate minerals during the mining process. However, if the region has little influence from either of these then it could be true. Apologies for I don't know what the land use is like for this region.

AC: In general, it can be assumed that Central Europe and the river catchment areas mainly contain carbonate minerals. High turbidity concentrations in rivers and also the TA concentrations in the rivers, which are far above the general level in the North Sea, indicate a dominance of carbonate minerals and speak in favor of this. The TA generation by silicate weathering is also a very slow process.

Line 290: “insight” not “inside”?

AC: Done. Thank you!

Line 317: what about the ems-dollard region?

AC: The conservative behavior in the outer Ems-Dollard Inlet is mentioned above in the Results (Fig. 3) and in the Discussion section 4.1, where the spatial distribution of TA is discussed. It is true that TA is generated in the upper / tidal river of the Ems Estuary (Norbisrath et al., 2023). However, this site is located further east and shows clearly decreasing TA values with increasing salinities. The focus here is on TA generation in the tidal flats between the barrier islands and the mainland, and in particular on our study site around Ameland island, where we observed constant marine salinities (<30).

Line 403: what necessary data? This is a good place to suggest future work.

AC: Since the Wadden Sea is a well explored area, we cannot clearly say what has been done and what has not, especially with regard to sediment-related work. However, for the surface and water column TA, we have suggested some future work (e.g. seasonal and end-member observations) in the Conclusion.