

Interactive comment on “Diurnal cycle of the CO₂ system in the coastal region of the Baltic Sea” by Martti Honkanen et al.

Anonymous Referee #1

Received and published: 22 January 2021

General comments

The paper presents and discuss one year of continuous measurements of marine CO₂ concentrations, gathered at the marine monitoring station of Utö island, in the northern area of the Baltic sea. Overall this article addresses a timely topic and the results presented can substantially contribute to improving estimates of the CO₂ emitted and absorbed by the Baltic Sea.

Marine data are mainly gathered by a flow through system that pumps seawater from 5 m depth and 250 m from the coast, allowing continuous measurements of the basic physical parameters as well as dissolved oxygen, fluorescence and CO₂ partial pressure (pCO₂) also during harsh wintry conditions. The marine dataset is completed with direct measurements of air-sea CO₂ fluxes gathered by a flux tower on the seashore

and high quality atmospheric CO₂ measurements acquired at the nearby meteorological station, making this dataset new and extremely valuable.

The data are analyzed to highlight the seasonal variability, the diurnal pCO₂ cycle and to identify its main drivers. Finally, the authors estimate the bias that can be introduced calculating annual budget of the Baltic CO₂ air-sea fluxes without taking into account this daily variability.

The main point where the paper needs a substantial improve is the overall writing and presentation of the methods and the results. I also recommend a revision of English style.

Methods used look generally adequate but are poorly written: you have to go back and forth the pages to understand what has been measured and where, and they often lack of detailed information on accuracy both on measured and calculated parameters. The model proposed to separate the different drivers of CO₂ variability needs a better discussion mentioning also the variability that can derive from the advection of different water masses. Some trends presented in figure 6 and 7 are unexpected and need a better discussion.

The conclusions can be improved adding a comparison with other coastal areas / previous studies, where similar data are available.

Specific comments

Please, revise the title: the paper discus the daily variability of pCO₂, and related air-sea CO₂ fluxes, not of other parameters of the CO₂ system as carbonate saturation state, DIC, pH...

Section 2 “Controls on the partial pressure of CO₂”

This section is rather confusing. It summarizes some basic aspects of carbon chemistry and, at the same time, explains which can be neglected in the study area. I would suggest to present here the basic of carbon chemistry, with clear references to the ap-

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pendix, and move the considerations on which process is important for the area, after the presentation of the study site, where the calculation performed are explained.

3 Materials and methods

Please, add a map with the location of Utö island, the station and the different sampling locations mentioned in the paper. The reference (Laasko et al 2018) includes mainly a description of the atmospheric station. This paper could be a good opportunity to present the Utö marine station with a table summarizing instrument type, variable measured, frequency etc.

The description of the instrumental setup and the whole method section is quite confusing and needs a reorganization where the description of measured data is clearly separated from calculated parameters and experimental considerations. I would suggest the following:

Improve the description of the study site providing general physical and biogeochemical settings of the study area. Describe the different stations where data are gathered and sampling strategy of all the data presented and discussed in the paper.

* Measurements from the flow-through system: instrument used, parameters acquired, frequency, accuracy, etc.

* Measurements from other stations: manual samplings, laboratory analysis, method, accuracy.

* Assessment of data quality etc.. you could add a separate section or add a sentence where there is the description of data acquisition.

* Calculated data: describe how you calculated all the derived parameters and estimate the uncertainty on derived carbonate system variables.

P8 The description of the calculation done is rather hard to follow. The DIC derived from mixing with other water masses is not considered in your model. Why? If you

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consider that this is a minor component of DIC variability in the study area, you should explain and justify your choice.

4 Results and discussion

Section 4.2: why did you choose two days one after the other as an example? You could present two days from two different seasons or where the weight of the diverse pCO₂ components is different. Otherwise you can show only one day of pCO₂ data and add a picture with the daily variability of the other variables (temperature, oxygen, . . .).

P13: Add a description of the daily variability of temperature to improve the discussion and to allow a better comparison of your results with other areas

Both in figure 6 and 7 the data reported at h 00:00 are often markedly different from that reported at h24:00: they should be the same number or a very close one. Could you please explain better the data reported in your figures or double check your calculation?

Figures

Figure 1: It contains a lot of information but I found it hard to read. Please, increase the size along the “y” axis. Fig 1 (a): it’s hard to see the red crosses and the black line. Is this temperature from monthly CTD casts in the nearby station? You should mention it in the caption. You could also present just the top of the CTD casts, down to the depth of the seafloor at the inlet position, and highlight the depth of the inlet to the flow-through system. Please add the conversion to local time in the caption as well.

Figure 2: Please, increase the size of the figure and of the symbols in the captions within the figures, especially that of figure 2 (b).

Appendix D

The gas transfer velocity for seawater normalized at 20°C (k₆₆₀) is always a positive value. The direction of the flux is given by air-sea pCO₂ difference: it is directed from the sea to the atmosphere (positive) if pCO₂ sea > pCO₂ atm and vice-versa. When

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k660 is estimated from direct FCO₂ measurements gathered by the eddy covariance method, the absolute value should be used. Making this correction to figure D1 the agreement between the experimental results and the theoretical model will greatly improve.

Technical corrections

Methods:

P.5 L3.: which instruments log data every 15 sec? The ones mentioned at the end of the page?

P5 L12: Is the gas calibration traceable to international CO₂ standards (e.g. WMO, NOAA, ..)? If yes, please, add this information.

P5 L15-27: There is a mix of “calculated values” with measured ones, please, describe here only measured ones. Improve the description of temperature and salinity measurements: frequency, accuracy, frequency of calibration, etc. Describe the thermistor chain when you present the marine station. Add briefly the methods for TA measurements.

P5L 28: Even if in Kilkki et al., 2015 there is a detailed description of the methods, please, add the most important details: instrument model, accuracy, sampling frequency, reference to international standards.

P5 L30-34: Please, add detail on instrument accuracy, frequency of calibration etc..

P6 L1-12: it is not clear which data are reported in Figure 1.

P6 L8-22: move to the section of calculated parameters

P6 L22: delete “be”

P6 L23 Please, define “Fas” when it is used for the first time.

I suggest to delete the division in two subsections or modify the titles. As they are it

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seems that “the flux parametrization” is related to the eddy covariance method, not a different method to calculate fluxes.

P7 L20 – 28: first describe how TA is calculated from salinity and the robustness of the choice done, then describe the calculations of the derived carbon chemistry parameters.

P7 L29 – P8 L3: Please, rephrase and explain better.

P8 L4-6: Please, describe step by step, it is quite confusing

P8 L22: Please rephrase, it is not clear what do you mean with “. . . each day at a time”.

P8 L22-26: it is not clear, what pCO_2,i is

P8 L28-30: please, explain better, this point is not clear.

Results and discussion

P9 L5: A more appropriate title would be “Environmental conditions and seasonal pCO_2 variability”. Conclusions

P18 L30-32: All the parametrizations for gas transfer velocity contain a cubic or quadratic component function.

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