

Interactive comment on “Factors controlling pCO₂ variability in the eastern Gulf of Cádiz (SW Iberian Península)” by Dolores Jiménez-López et al.

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Reviewer 3:

The authors are very grateful for your constructive comments and suggestions on the previous version. We think that the manuscript has been significantly improved thanks to all the contributions made. Below you will find the comments you made and our comments as authors (marked AC) on each point. In response to all the comments the manuscript has been modified, resulting in changes to line numbers. Therefore, we have included the new line numbers (whenever applicable) so that you can refer to either the current or (former) version if you wish.

Thank you very much for your consideration. Sincerely, Dolores Jiménez-López, on

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behalf of all co-authors.

The authors investigate factors controlling pCO₂ variations in the Gulf of Cadiz. They use high quality data from 8 cruises incorporating underway data of pCO₂, SSS, SST, and wind speed as well as discrete data for pH, AOU, and nutrients taken along three repeat transects during the cruises. They present spatiotemporal distributions of the underway data, the cruise averages of the discrete data, and the seasonal changes of the computed air-sea CO₂ flux. The authors then discuss the factors influencing the pCO₂ variability. Specifically, they quantify thermal/non-thermal controls of pCO₂. They conclude that temperature and biological activity are the two principal factors that explain the temporal variability of pCO₂. They also point out that continental inputs and mixing with water originating from warm ocean currents influence the spatial variability of pCO₂.

The work is OK structured, includes original research based on high quality data, and suits for publication in this journal. However, there are several things that need improvements and/or clarification and I recommend major revision.

*General comments

-1- The main subject of the study is the controls of pCO₂ variations. The authors correctly write “In addition to influence of temperature, the spatiotemporal distribution of pCO₂ in surface seawater is affected by the biological utilization of CO₂, the vertical and lateral transport, the sea-air exchange of CO₂ and terrestrial inputs.” However, they do not quantify the relative importance of these controls in their data although there are published methods for such quantification (e.g. Olsen et al 2008). Specifically, the importance of fresh water input and air-sea exchange need to be quantified. This should be feasible since they have seasonal data of two parameters of the CO₂-system in addition to SST, SSS, and nutrients.

AC: Thank you very much for your suggestion, which is very interesting. The Olsen et al. (2008) method has been taken into account in the revised manuscript and the

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contributions of SST, air-sea CO₂ exchange and mixing plus biology on pCO₂ change have been quantified. This method also considers change due to SSS variations but we have not included this quantification, since we do not have available the variations of total alkalinity and dissolved inorganic carbon, and the spatial changes of SSS are only significant near the Guadalquivir River mouth (a point included in the text, Line 186-187). The manuscript has been edited in Material and methods (Line 174-191) and Discussion sections (Line 374-391) to include this quantification. A new figure has been added (Figure 7).

-2- The readability of the manuscript need to be improved. For instance, the study area is quite small, but quite complicated in terms of processes and interactions. Hence, there are a lot of names used in the manuscript (e.g. Gulf of Cadiz Current; AZORES Current; Guadalquivir River; Bay of Cádiz; Cape San Vicente), but locations of these are not shown anywhere in the manuscript. Including these names in the maps/figures would enhance the readability of the manuscript. It is also my opinion that it would be much easier to read the paper if the authors present results in seasonal maps (they do that for CO₂ flux in Fig. 10) and then discuss the controls of pCO₂ changes between seasons and places.

AC: Thank you for your suggestion. Fig. 1 has been edited to add different processes and names used to improve the readability of the manuscript. However, it is not possible to present results in seasonal maps, except for the spatial distribution of CO₂ fluxes, since for example in Fig. 2, the data interpolated in our database for the same season would not be right.

*Specific comments

-Line 19, “On the other side” do you mean “on the other hand?”

AC: Corrected.

-Line 48, after “all other organisms” please add “which increases the concentration of

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inorganic carbon”

AC: This point has been added in the text, thank you (Line 46).

-Line 50 “generate uncertainty” please replace with “is not clearly defined”

AC: Corrected.

-Lines 62-65 I do not understand the sentences between “Finally, the inner..” and “: : .:towards offshore (Walsh 1991).”

AC: These sentences have been modified (Line 57-62). The effect of the continental inputs on pCO₂ variation are explained.

-Line 193, “T values were significantly different among all cruises ($p < 0.05$)” why is this important result to mention?

AC: Yes, you are correct. In any case, p-values have been removed from the manuscript and a brief reference has been added to the Statistical analysis section. Line 207-209: “The threshold value for statistical significance was taken as $p < 0.05$. Moreover, all reported linear correlations are type I and they are statistically significant with p-values smaller than 0.05 in the entire manuscript unless indicated otherwise”.

-Line 96-97 “Spatially T tended to increase from coastal to offshore areas” during all seasons? Or during winter?

AC: This sentence has been modified in the text. It was not clear in the previous version of the manuscript. Line 217-218: “In general, spatially SST tended to increase from coastal to offshore areas during spring and winter, while in summer and autumn this SST gradient was inverse (Fig. 2A)”.

-Lines 211-215. I do not understand. Do you mean that both underway and discrete data are shown in Fig 2B? if so please clarify this in the caption and explain more about the reasons for differences between different data.

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AC: Fig. 2B only show the underway measurements, but we have observed an increase of these pCO₂ values in the areas that coincide with the position of the discrete water samples (Fig. 1). This sentence has been edited in the manuscript: Line 239-241: "In Fig. 2 a sharp variation of SST and pCO₂ can be observed in some zones that coincides with the stations where discrete water samples were taken. This may be due to the different sampling time at these stations, which varied between 2 and 8 hours in function of the depth of the system".

-Line 238 "TF presented the highest mean concentration for the whole study (0.77 _ 0.76 _mol L-1)." I notice that given the mean PO₄ of 0.28 this mean NO₃ is much less than what is expected from Redfield, is this typical for the area?

AC: Low N/P relationships are typical for this study area (Anfuso et al., 2010). This information has been added in the text: Line 273-275: "The mean N/P ratio in surface waters for the whole study was 3.5 ± 2.0 , similar to that estimated by Anfuso et al. (2010) in the northeast continental shelf of the Gulf of Cádiz, which indicates a relative phosphate deficit with respect to the Redfield ratio (Redfield et al., 1963)".

-Lines 283-291, please state the uncertainty of the implied pCO₂ growth. Please elaborate why you believe the excess pCO₂ growth (over the atmospheric growth) is caused by continental input.

AC: The uncertainty value has been added in the text (Line 309). The pCO₂ growth caused by continental inputs was also found by other authors and this point is included in the text. Line 311-314: "This suggests a possible increase of the anthropogenic nutrient and C inputs from land (Mackenzie et al., 2004) since the direction and magnitude of estuarine and continental shelf CO₂ exchange with the atmosphere is highly dependent on the terrestrial organic budget and nutrient supplies to the coastal ocean (Borges and Abril, 2011; Cai, 2011)".

-Lines 300-305, can the reason for difference pCO₂ over different depth ranges be due to different TA/DIC ratios in the FW influenced areas and those offshore?

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AC: Thank you for your comment. This is a very interesting question. However, at the moment, we do not have available this information needed to answer it.

-Line 321, in which form is the CO₂ input?

AC: The form of CO₂ input is inorganic carbon. This sentence has been edited in the text (Line 331-334).

-Lines 333-334, How pCO₂ increase can be computed from only F? or do you make more assumptions?

AC: More assumptions are necessary: mean depth of the water column (23 m) and the fact that it is well-mixed; a pH = 8; in the conditions of mean temperature and salinity in the Gulf of Cádiz (18.8 °C and 36.19, respectively) and using the K1 and K2 acidity constants proposed by Lueker et al. (2000) in the total pH scale (information indicated in the text: Line 341-346).

-Lines 335-342, you mention that upwelling systems can be influencing the distribution of pCO₂ in the Gulf of Cadiz. BUT do you have any evidence for such influence in your data? If not why do you mention it here?

AC: There is some evidence in our data for the Trafalgar transect. This point is included in the text: Line 351- 354: "In our database experimental evidence of the upwelling was found only in the TF transect. A local decrease of the mean values of SST (17.4 °C) and pCO₂ (399.1 μ atm) was observed in this coastal area of TF, with respect to the deeper areas (18.8 °C and 405.1 μ atm, respectively) for the whole period". In addition, in Fig. 10 it can also observed that the areas near to the Trafalgar section show lower values of CO₂ flux during summer and winter.

-Figures: Figure 1: show important currents and places mentioned in the text. Figures 2, 3, 5, 6, and 7. Clarify in the caption whether both underway and discrete data are used.

AC: Fig. 1 has been improved and the figure captions have been clarified.

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References:

Anfuso, E., Ponce, R., Castro, C. G., and Forja, J. M.: Coupling between the thermo-haline, chemical and biological fields during summer 2006 in the northeast continental shelf of the Gulf of Cádiz (SW Iberian Peninsula), 47–56, *Sci. Mar.*, [https://doi:10.3989/scimar.2010.74s1047](https://doi.org/10.3989/scimar.2010.74s1047), 2010.

Please also note the supplement to this comment:

<https://www.ocean-sci-discuss.net/os-2019-6/os-2019-6-AC3-supplement.zip>

Interactive comment on *Ocean Sci. Discuss.*, <https://doi.org/10.5194/os-2019-6>, 2019.

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