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Interactive comment on "Dynamics of air–sea CO_2 fluxes in the North-West European Shelf based on Voluntary Observing Ship (VOS) and satellite observations" *by* P. Marrec et al.

P. Marrec et al.

pmarrec@sb-roscoff.fr

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Dear Anonymous Referee #1,

We very much appreciate your quick and constructive comments, which will allow us to improve the overall quality of our manuscript. We will, in a first time, give you detailed answers for each of your comments below, then we will include them in our revised manuscript, once we have received the second interactive comment from the Anonymous Referee #2.

Anonymous Referee #1 Comment (AC): I hope that the authors upload this data to either (or preferably both) of these databases, as it is a useful dataset for the community.

Author Reply (AR): Be assured that we will upload this dataset to both SOCAT and LDEO databases.

AC: I would expect more profiles to be available in the CS regions, have the authors looked for research cruises or glider based observations of MLD in the CS region? More in-situ comparisons (outside of E1 station) against the modelled MLD would be welcome, as this is a complex region for MLD approximation.

AR:We considered your remark and made 2 figures (Figures 1a and 1b attached to this reply) to compare the observed MLD in the Celtic Sea and at E1 fixed station with Armor-3D L4 Analysis observation products provided by the Copernicus Marine Environment Monitoring Service (ex-MyOcean, http://marine.copernicus.eu/), which are combined products from satellite observations (Sea Level Anomalies, Mean Dynamic Topography and Sea Surface Temperature) and in-situ (Temperature and Salinity profiles) on a $\frac{1}{4}$ degree regular grid in our study area, and modelled MLD computed from the MARS3D model. These figures clearly show the robust approximation of MLD by the model, particularly concerning the start and the end of stratification, despite a small overestimation of the modelled MLD compared to the observed MLD from the Armor-3D L4 Analysis products. We are willing to publish these figures as supplement material if necessary.

AC: I would recommend using a finer scaled wind product, such as those available from the ASCAT sensor (KNMI have a 25 km coastal product that may be of interest.) Or alternatively, a modelled wind speed from ECMWF or equivalent.

AR: We recognized that the use of NCEP 2.5 degree products is coarse for this small study area. We now have access to ASCAT 25km coastal wind speed with the KMNI. In the revised version of our manuscript we will used this wind products for the computation of the k parametrization (for MLR computation and for flux calculation).

AC: Additionally, I am confused as to whether a correction has been made to account for the variability of monthly wind speed data. The air-sea gas exchange parametrisa-

tion used requires either high resolution data, or the intrinsic variability of monthly data to be accounted for.

AR: It is true that no correction has been made to account for the variability of monthly wind speed data. We will consider and discuss the intrinsic variability of monthly wind speed data in the revised version of the manuscript using the formulation given by Wanninkhof et al. (2002) and we will apply it as done by Jiang et al. (2008).

AC: There is very little data in the CL, NCS and IS, and an abundance of data in SCS and WEC. As the Ferry box measurements are also based in this region rich in SOCAT data, I am not convinced by the extrapolation of the MLR outside of the SCS and WEC, nor am I convinced that the low stated RMSE of the synthetic pCO2 data derived from the MLR fully describes the errors that occur from extrapolating so far north (into CL, NCS and IS).

AR: We acknowledge the referee #1 for suggesting the use of pCO2 data from the LDEO database. Thanks to this suggestion we now have access to new pCO2 data, particularly in IS and nCS, which consolidate our assumptions for the pCO2 by MLR. These new in-situ pCO2 data are represented by yellow dots on the updated Figure 8 of the manuscript (Figure 2 attached to this reply. We also chose to include pCO2 data from SOCAT and LDEO databases in CL waters. It should be noted that most of these CL data are located at the boundary of this area, meaning that they are not always entirely representative of this permanently well-mixed system. These new results enhance our extrapolation in these poorly studied areas and therefore support the main purpose of this study, which is to have access for the first time to pCO2 estimates in this area where only few pCO2 data are currently available. Figure 8 will be updated as such in our revised manuscript, Figure 4 and Table 2 in the manuscript will also be updated to include these new sources of in-situ pCO2 data.

AC: The issues of the sharp boundaries between systems regions in figures 9,11 and 12 are also problematic, perhaps another reviewer has come up with a solution for

this? For example, I am surprised in the strength of the gradient between the nWEC and sWEC, in figure 11 between August and October.

AR: The sharp boundaries between permanently well-mixed and seasonally stratified can appear as surprising, especially between August and October. However, these sharp boundaries are a fact that we observed every years between sWEC and nWEC waters. To support this we made 2 new figures (Figure 3a and 3b attached to the reply) showing a comparison between in-situ pCO2 data acquired during 2 crossing performed in August and September 2014 between Roscoff and Cork (Ireland)(from a newly exploited Voluntary Observing Ship, the ferry Pont-Aven) and mean pCO2 data along the ferry tracks calculated from our MLR from 2003 to 2013. We did not have access yet to the requested satellite and modeled products in 2014, which explained the choice of using monthly mean pCO2 estimates instead of newly computed pCO2 estimates from remotely sensed and modelled data. These two figures and the new in-situ pCO2 data between Roscoff and Cork clearly show the presence of these sharp boundaries and we hope that these new data sufficiently support and illustrate this phenomenon. Again we are willing to had these figures to a supplement material upon referee and editor request.

AC:At present, I would like to see this a) lack of data in the CL,NCS and IS; b) sharp boundary problem; resolved before conclusions on the total air-sea fluxes are stated. For this reason, I will not go into further discussion on the conclusions. If no more in-situ data can be found for the CL, NCS and IS, then I'd either like to see additional arguments put forward as to the validity of extrapolating the technique this far North, or the removal of these regions from the study.

AR: We thank Referee #1 for his constructive comments,which allowed use to improve the quality of our manuscript. We hope that our detailed response above will clarify these issues thus allowing him to go further into the discussion on the conclusion.

References:

Wanninkhof,R., Doney, S. C., Takahashi, T. and McGillis, W. R.: The Effect of Using Time-Averaged Winds on Regional Air-Sea CO2 Fluxes, in Gas Transfer At Water Surfaces, AGU Monogr. Ser., vol. 127, edited by M. A. Donelan et al., pp. 351–356, AGU, Washington, D. C., 2002.

Jiang, L.-Q., Cai, W.-J., Wanninkhof, R., Wang, Y., Hüger, H.: Air–sea CO2 fluxes on the US South Atlantic Bight: spatial and seasonal variability. J.Geophys. Res., 113, C07019, doi:10.1029/2007JC004366, 2008.

Figure Captions:

Figure 1 : Mixed layer depth (MLD, in m) at fixed station E1 off Plymouth (50.03°N, 4.37°W, depth 75m, A) and in the Celtic Sea (50°N, 8°W, depth 120m, B). Red dots and lines represent the modeled MLD from the MARS3D model, blue dots and lines represent the observed MLD from the Armor-3D L4 Analysis observation products provided by the Copernicus Marine Environment Monitoring Service and white dots and black lines represent the MLD calculated from temperature and salinity profiles made at fixed station E1.

Figure 2: Time series of monthly pCO2,MLR (μatm, in black) averaged over IS, nCS, sCS, nWEC, sWEC and CL provinces from 2003 to 2013. Monthly mean corresponding to SOCAT data (red dots) and LDEO data (yellow dots) are show for comparison. The blue lines represent the atmospheric pCO2.

Figure 3: Comparison of in-situ pCO2 data (red dots, in μatm) computed from dissolved inorganic carbon (DIC) and total alkalinity (TA) discrete measurements performed on board a newly exploited VOS line between Roscoff (France) and Cork (Ireland) in August 2014 and in September 2014 with mean pCO2 data along the ferry tracks calculated from our MLR from 2003 to 2013 (blue dots, in μatm). The map shows the sampling location during each crossing (August in blue and September in red). The error bars for in-situ pCO2 data represent the uncertainty associated to pCO2 computation from DIC and TA ($\pm$ 5.8 μatm, Zeebe and Wolf-Gladrow (2001)) and the error

bars for pCO2 data from MLR correspond to the uncertainties of 16 μatm and 17 μatm relative to the MLRs developed in permanently well-mixed sWEC and seasonally stratified nWEC, respectively.

Interactive comment on Biogeosciences Discuss., 12, 5641, 2015.

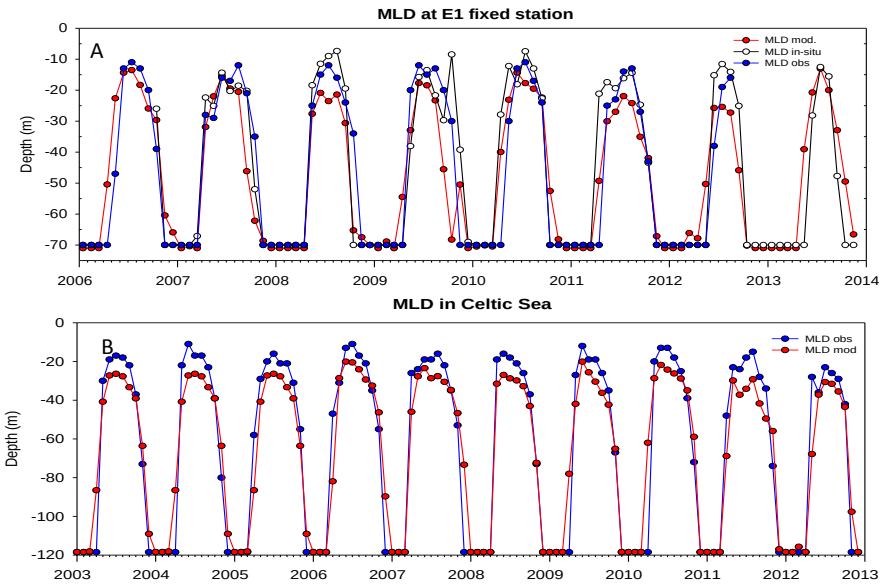

Fig. 1. Figure 1

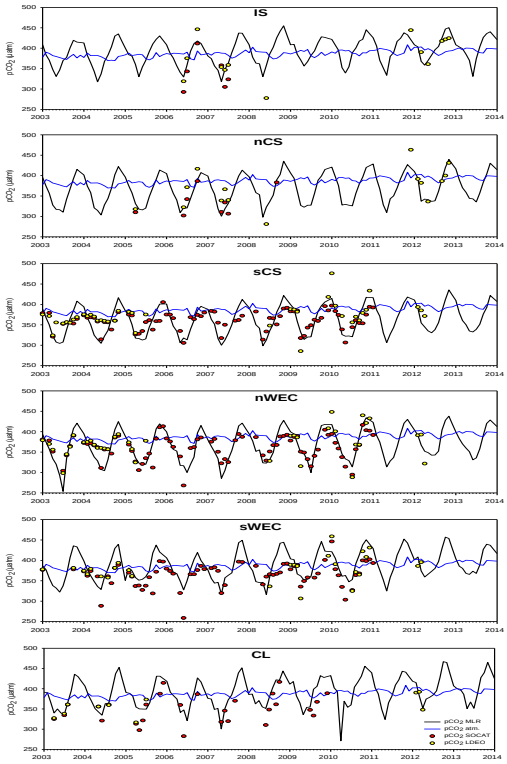

Fig. 2. Figure 2

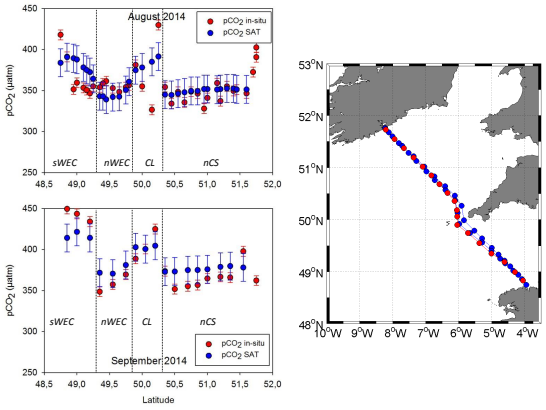

Fig. 3. Figure 3