Reviewer #1 Evaluations:

General comments

This study updates the ULB-SOM-FFN-coastalv1 pCO2 data product, enhancing its capability to detect the long-term trends spanning from 1982 to 2020 (> 30 years) on a global scale. The authors achieved this objective by using additional environmental predictor (pCO2air) and new pCO2 observations from SOCAT v2022 for training and validation. The average bias between the pCO2 product and SOCAT observations are all close to 0 µatm in different decades (Figure 3), which means that this new version is suitable for investigating decadal trends in coastal pCO2 and CO2 fluxes on a global scale. To the best of my knowledge, this is the first coastal pCO2 product that tries to resolve long-term pCO2 trends. I tried to be picky to find out some potential mistakes, yet it's worth acknowledging that the author's calculations appear to be robust. At least my ability might not be sufficient to identify any big mistakes that might exist.

Author's response: We would like to express our gratitude to Zelun Wu for his examination of our study and the recognition of the interest of our work. We are also grateful for his constructive suggestions to improve the quality of our manuscript. We have considered all Zelun Wu's remarks and provide in the following sections detailed responses to each comment (in blue). Changes to the original manuscript were made using Word's "track changes" option, and the line numbers indicated in our responses refer to the revised version of the manuscript.

Please also note that we updated the ULB-SOM-FFN-coastalv2 pCO_2 and FCO_2 products to address a small issue related to the sea-ice product, which was identified while working on these revisions. All figures, tables, and numbers in the text were thus updated to account for this correction but our results are only marginally modified, and our discussion and conclusions thus remain unchanged.

On behalf of the co-authors,

Alizée Roobaert

Nevertheless, as a data user, I would be very grateful if the author could clarify some of my concerns in the article so that I can use this data correctly in the future.

R1C1: My primary concern revolves around the lack of clarity in defining the term "long-term trend". This study focuses on assessing the "long-term trend" or specifically, the "decadal trend". The term "long-term" is a relative definition, and the term "decadal trend" means the linear or nonlinear tendency of a time series longer than 10 years. Given that Figure 4 and Section 3.2 employ a "30-year" constraint for comparison, It is interesting to ask whether the updated version can be used to identify the linear trends of the 10~30 years time scale.

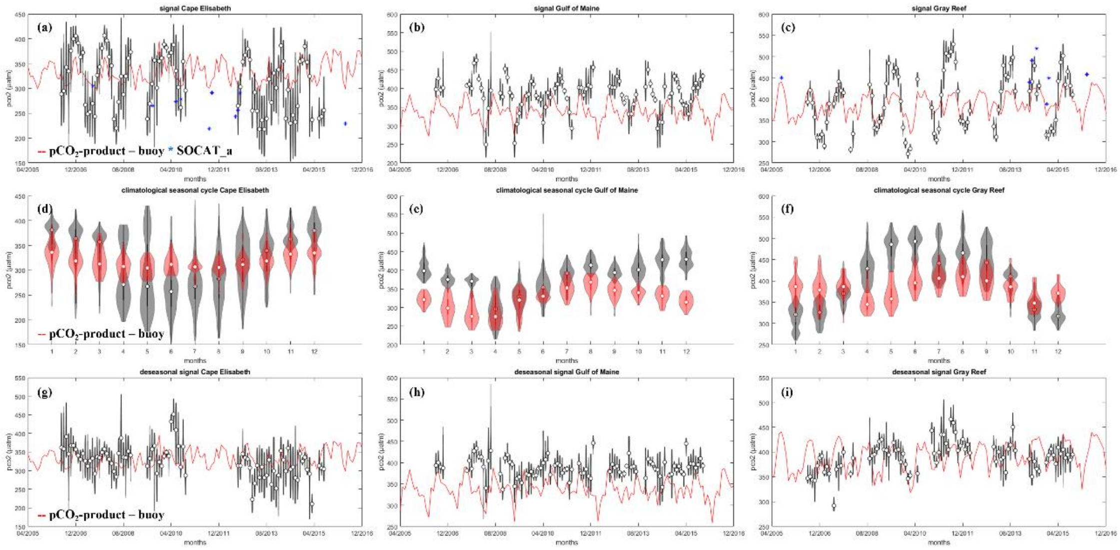
If the answer is yes, it is suggested to compare the pCO2 product with the buoy data, as mooring data are more continuous than SOCAT observations. Sutton et al. (2019) have comprehensively summarized these time series, with several buoys deployed in coastal areas and with continuous measurements longer than 10 years, including NDBC Buoy 46041 in Cape Elizabeth, NDBC Buoy 41008 in Gray's Reef, and Coastal Western Gulf of Maine Mooring in the Gulf of Maine. All three of these buoys have records since 2006, rendering them suitable for supplementary comparison, as proposed in Figure 4.

If the answer is no, i.e., the current version doesn't validate for trends < 30 years, I recommend clearly clarifying the definition of "trend" or "long-term" in the title, abstract, and conclusions, to ensure that the data can be used correctly in future studies.

Ref: *Sutton, et al., 2019. Autonomous seawater pCO2 and pH time series from 40 surface buoys and the emergence of anthropogenic trends. Earth Syst. Sci. Data 11, 421–439. https://doi.org/10.5194/essd-11-421-2019*

R1R1: We concur with this point which was raised by both reviewers in R1C1 and R2C1 and we agree that temporal scales investigated in our studies need to be better defined in the text. In our study, we consider the "long-term trend" or the "multidecadal trend" as a linear trend that spans at least over a period exceeding 10 years. In our study, long-term trends are calculated over the entire 1982 to 2020 period, resulting in a 39-year time series. The term "decadal trend" describes a linear trend derived from a time series spanning 10 years exactly, while the "interannual variability" refers to year-to-year fluctuations and is not derived from a linear trend analysis. We thus modified the text in several places with more precise definitions of the different temporal explored (see also R2C1).

The good evaluation of the reconstructed pCO_2 product against SOCAT (SOCAT_a and SOCAT_b) performed in this study lends confidence in our ability to properly capture the temporal evolution of coastal pCO_2 with the newly reconstructed pCO_2-product at the different timescales described above. We however agree with R1C1 that to complement the spatiotemporal evaluation against SOCAT, a comparison of the newly reconstructed pCO_2-product against pCO_2 times series of measurements sampled using buoys located in coastal areas provides a better picture and independent test of the performance of our data product. We thus followed R1 suggestion and compared the reconstructed pCO_2 times series against the 3 buoys with measurements longer than 10 years located in Cape Elizabeth (NDBC Buoy 46041), in Gray's Reef (NDBC Buoy 41008) and in the Gulf of Maine (Coastal Western Gulf of Maine mooring, Sutton et al., 2019). The three pCO_2 time series for each buoy location mentioned above are presented in FIG_R1C1.



FIG_R1C1: Comparison between the reconstructed coastal pCO_2-product (red) against times series from 3 coastal buoys (black) namely in Cape Elizabeth (NDBC Buoy 46041), in Gray's Reef (NDBC Buoy 41008) and in the Gulf of Maine (Coastal Western Gulf of Maine mooring, Sutton et al., 2019). (a-c) Monthly time series, (d-f) climatological mean seasonal cycles, (g-i) linear trends from deseasonalized data. The violins for the buoys represent the intra variability on the pCO_2 measurements. The violins in panels (d) to (g) for the reconstructed pCO_2 represent the pCO_2 variability of the month x around its monthly climatological pCO_2 mean.

Although smaller amplitude variabilities are generally observed, results show that the reconstructed pCO_2 times series follow those of the observational data with values that are mainly between the buoys errors (FIG_R1C1a-c). We speculate that the smaller amplitude stems from the coarser 0.25° x 0.25° degree grid resolution of our method compared to the point nature of the buoy data. Landschützer et al. (2016) drew a similar conclusion when they compared their open ocean pCO_2 data with open ocean at HOT and BATS and is further corroborated by the much smaller variabilities obtained when raw SOCAT data are averaged at the grid cell level (Fig. 4 of the Ms). The exception is the Gulf of Maine where a general underestimation of pCO_2 is observed compared to the buoy observations. The reconstructed pCO_2 product also reproduces the observed climatological seasonal cycles (including a relatively good timing of the seasonal maxima and minima) for the 3 buoys as shown in FIG_R1C1d-f. Absolute average biases values of 14, 4, 45 µatm and RMSE values of 50, 53 and 61µatm are calculated between the pCO_2-product and the observations for Cape Elisabeth, Gray's Reef and in the Gulf of Maine, respectively. These statistical error values are larger than those calculated when the comparison is performed against SOCAT, whether on a global or regional scale. This is not surprising since the reconstructed pCO_2 product is for a global application and is quite challenging to compare to specific coastal buoys that present high temporal and spatial variability such as shown by the violin in FIG_R1C1.

The good evaluation of the reconstructed pCO_2 against both SOCAT_a, SOCAT_b as well as against buoys data gives confidence to identify the linear trends of both the pCO_2 and FCO_2 over different temporal scales. This study, however, only presents an overview of the long-term variations of the coastal FCO_2 (Sect. 3.2) but does not discuss coastal pCO_2 and FCO_2 variabilities on decadal and interannual timescales.

We modified the text in the Ms to include the comparison against the buoys data:

Lines 387-411: 'Finally, the reconstructed pCO_2 times series are compared against 3 buoys with measurements longer than 10 years located in Cape Elizabeth (NDBC Buoy 46041), in Gray's Reef (NDBC Buoy 41008) and in the Gulf of Maine (Coastal Western Gulf of Maine mooring, Sutton et al., 2019). The three pCO_2 time series for each buoy location mentioned above are presented in Fig. S3. Although smaller amplitude variabilities are generally observed, results show that the reconstructed pCO_2 times series follow those of the observational data with values that are mainly between the buoys errors (Fig. S3a-c). We speculate that the smaller amplitude stems from the coarser 0.25° grid resolution of our method compared to the point nature of the buoy data. Landschützer et al. (2016) drew a similar conclusion when they compared their open ocean pCO_2 data with open ocean at HOT and BATS and is further corroborated by the much smaller variabilities obtained when raw SOCAT data are averaged at the grid cell level (Fig. 4). The exception is the Gulf of Maine where a general underestimation of pCO_2 is observed compared to the buoy observations. The reconstructed pCO_2 product also reproduces the observed climatological seasonal cycles (including a relatively good timing of the seasonal maxima and minima) for the 3 buoys as shown in Fig. S3d-f. Absolute average biases values of 14, 4, 45 µatm and RMSE values of 50, 53 and 61 µatm are calculated between the pCO_2-product and the observations for Cape Elisabeth, Gray's Reef and in the Gulf of Maine, respectively. These statistical error values are larger than those calculated when the comparison is performed against SOCAT, whether on a global or regional scale. This is not surprising since the reconstructed pCO_2 product is for a global application and is quite challenging to compare to specific coastal buoys that present high temporal and spatial variability such as shown by the violin in Fig. S3.

The good evaluation of the reconstructed pCO_2 against both SOCAT_a, SOCAT_b as well as against buoys data gives confidence to identify the linear trends of both the pCO_2 and FCO_2 over different temporal scales. ~~The overall good agreement in terms of biases and RMSEs lends confidence to our ability to unravel the long-term temporal coastal pCO_2 evolution with the newly reconstructed pCO_2-product .~~ For example, our results show that for all the 8 studied regions represented in Fig. 4, an ~~-~~increase in pCO_2 over time comprised between 12~~0~~ and 20 µatm $decade^{-1}$ is calculated for the long-term trend with our pCO_2 product, a range in good agreement with the 12-18 µatm $decade^{-1}$ obtained with SOCAT_b. Although New Zealand shows the largest bias between SOCAT_b and the pCO_2-product, they both agree that this region displays the fastest trend in terms of pCO_2 rise (18 µatm $decade^{-1}$ and 20 µatm $decade^{-1}$ for SOCAT_b and the pCO_2-product, respectively).'

Some other comments:

R1C2: Line 41, "The exchange of carbon dioxide (CO2) … depends on … (ΔpCO2)", Quantification of fluxes also relies on gas transfer velocity and the solubility of CO2. Suggestion: "… mainly depends on … on the global average".

R1R2: We agree with R1C2 and we modified the text accordingly.

R1C3: Line 180, "fCO2to pCO2 using the equation of Takahashi et al. (2012, page 6)".

I guess you are using this equation?

pCO2 = fCO2 x [1.00436 – 4.669 x 10-5 x SST (°C)]

It is acceptable to utilize this empirical equation since it will only result in small numerical differences compared to the results computed using CO2SYS. But it is hard to get the 2012 edition now, I recommend referencing a more recent version, such as the 2017 edition, as it will be easier for readers to access the specific equation.

R1R3: We indeed use the equation pCO_2= fCO2 x [1.00436 – 4.669 x 10-5 x SST (°C)] and we agree that a more recent reference is more suitable when referring to this equation. We therefore cite the Takahashi (2018) edition in the updated manuscript (Takahashi et al., 2019).

R1C4: Line 183: "In this study, the coastal domain (total surface) … ".

The 200m isobath has been commonly accepted as the shelf break criterion. An alternative approach is to consider a broader domain characterized by a distance to the coast of less than 200 nautical miles (approximately 370 km or 400 km). A 300 km definition for the wide shelf could also be employed. In the results section, the authors use the term "narrow coastal domain" without providing a distinct definition. I suggest explicitly clarifying this definition in the method section.

R1R4: We agree with R1C4 that a clarification regarding the definition of the two coastal domains used in this study is needed in the method section. We thus changed the text accordingly:

Lines 187-195: 'this study, the coastal domain ('wide coastal ocean' with a total surface area of 76 million km², Laruelle et al., 2017) excludes the Black Sea, estuaries as well as inland water bodies and its outer limit is defined as whichever point is furthest from the shoreline between the 1000 m isobath and a fixed 300 km distance (roughly the outer edge of territorial waters), following the coarse SOCAT definition of the coastal oceanic domain. At the end of this entire procedure, a total of ~ 14 million and ~ 4 million discrete coastal data have been allocated to SOCAT_a and SOCAT_b, respectively. A more common delineation of the coastal ocean is also used in this study when discussing the air-sea CO_2 exchange (Sect. 3.1) using the shelf break as the outer limit of the coastal domain ('narrow coastal ocean', 28 million km²). The depth of the shelf break is calculated using a high-resolution global bathymetric database and estimated by calculating the slope of the sea floor. The isobath for which the increase in slope is the maximum over the 0–1000m interval, yet still inferior to 2 % define the outer limit of the shelf break (Laruelle et al., 2013).'

R1C5: Line 187: "a total of ~ 14 million and ~ 4 million coastal data", discrete samples or grids?

R1R5: We agree with R1C5 that a clarification was needed and modified the text accordingly:

Lines 191-192: 'At the end of this entire procedure, a total of ~ 14 million and ~ 4 million discrete coastal data have been allocated to SOCAT_a and SOCAT_b, respectively.'

R1C6: Line 193: "global atmospheric reanalysis ERA-interim wind product (Dee et al., 2011)", ERA-interim is the 3-gen reanalysis data offered by ECMWF, encompassing the period from 1979 to 2019. Given that this work covers the years 1982 to 2020, I'm curious about how you obtained the wind speed data for the final year of your analysis. Furthermore, why not use the latest version ERA5?

R1R6: We thank the reviewer for this comment since it provides us the opportunity to correct an oversight in our manuscript because we indeed used ERA5 and not ERA-interim for the wind product. Unfortunately, the old references (here and in the next comment) were copied from the original Laruelle et al. (2017) approach, whereas for this study we actually updated the wind product for our calculation but forgot to update references in the text. We now updated the text and Table 1 by changing ERA-interim with ERA5 and refer to Hersbach et al. (2020) instead of Dee et al. (2011).

Lines 200-202: 'For U_{10}, we use the monthly mean of the 0.25° resolution product of the European Center for Medium-Range Weather Forecasts (ECMWF) ERA5 ~~global atmospheric reanalysis ERA-interim~~ wind product (~~Dee et al., 2011~~Hersbach et al., 2020), which has a native temporal resolution of 6 hours.'

R1C7: Line 198, "using the NCEP reanalysis total pressure at sea level (Kalnay et al., 1996).", While I believe that the choice of pressure data products has a minimal impact on pCO2air calculations, I'm curious why not use the newer NCEP2 version. Additionally, since this work employed the wind speed from ERA-Interim, why not use pressure data from ERA5 or ERA-Interim, which could offer enhanced spatial resolution to align with the wind speed data. Could you elaborate on the reasons behind these choices?

R1R7: We thank the reviewer for this comment since we again referred to the wrong product for atmospheric pCO_2. In this study, we use the atmospheric pCO_2 from the SeaFlux product (Fay et al., 2021) which is calculated from the dry air mixing ratio of atmospheric CO_2 (xCO_2) derived from the ESRL surface marine boundary layer CO_2 product (Duglokencky et al., 2019) multiplied by the ERA5 sea level pressure (Herbach et al., 2020) with a vapor correction according to Dickson et al. (2007).

We thus modified the text and now refer to ERA5.

Lines 204-210: 'The atmospheric pCO_2 is from the SeaFlux product (Fay et al., 2021) which is calculated from the dry air mixing ratio of CO_2 (xCO_2) provided by the ~~NOAA Marine Boundary Layer reference~~ESRL surface marine boundary layer CO_2 product (https://www.esrl.noaa.gov/gmd/ccgg/mbl/data.php, Duglockencky et al., 2019~~https://www.esrl.noaa.gov/gmd/ccgg/mbl/~~) with a vapor correction according to ~~assuming 100 % humidity at the air-sea interface (following calculation specified in~~ Dickson et al. ~~,(~~2007), ~~and~~ using the ~~NCEP reanalysis total pressure at sea level (Kalnay et al., 1996)~~ERA5 sea level pressure (Herbach et al., 2020) and applying the method of Landschützer et al. (2014) and Fay et al. (2021).'

R1C8: Line 199: "due to the proximity to the continent of the coastal ocean, the latter might be more exposed to anthropogenic sources of CO2", I can't understand what "the latter" means, "coastal ocean"?

R1R8: We agree with R1C8 that the text was not clear, and we modified it as follows.

Lines 210-213: 'It should be noted that, due to the proximity to the continent ~~of the coastal ocean~~, the coastal ocean ~~the latter~~ might be more exposed to anthropogenic sources of CO_2 and thus might be exposed to higher atmospheric pCO_2 compared with the global oceanic average.'

R1C9: Line 212-214: "by computing (1) … (2) …", The final interpolated values use those options in the order of rank (i.e., using an "if... elseif" while programming), or take the average of all options?

R1R9: We agree with R1C9 that the text was not clear and modified it as follows.

Lines 223-225: 'the interpolation is performed by computing in the order of rank (1) the mean of the next neighboring cells of the month x, (2) the mean value of the month x+1 and month x-1 of the same cell, (3) …'

R1C10: Line 231: "Ho et al., (2011)", I'm interested to know if there is a specific reason for not utilizing the Wanninkhof 2014 method.

R1R10: We decided to use the empirical equation of Ho et al. (2011) because this particular equation is calibrated using an extensive collection of data sampled at different locations and is thus applicable at global scale for the coastal domain. Furthermore, we would like to note that both Ho et al. (2011) and Wanninkhof et al. (2014) are very similar and thus lead to the same results (due to the use of the same gas exchange coefficient). We nevertheless acknowledge that over the last decades many appropriate gas transfer formulations have been developed and published and that the choice remains subjective.

R1C11: Line 241, Equation 2. I have this question as well while reading Robaert et al., 2019. Notably, the uncertainty of CO2 solubility appears to be absent from the equation. While it may be plausible to argue that this uncertainty is minimal (0.2%, as suggested by Weiss, 1974), it remains essential to keep this term in the equation.

R1R11: We agree with R1C11 that all potential sources of uncertainties on the FCO_2 calculation should be discussed in the MS. Since we consider that the uncertainty of the solubility term (K_0) is very negligible such as suggested by Weiss (1974) compared to those from the wind speed product, sea-ice or k choice we didn't evaluate the influence of using different combination of SST and SSS products on the K_0 calculation and thus on the FCO_2 calculation. We however do not want to create the impression that we omit uncertainty terms, thus we added a sentence to discuss the uncertainty of the K_0 term:

Lines 259-264: 'We also include the effect of the choice of sea-ice product on the FCO_2 uncertainty (σ_{ice}) which was not included in the original calculations of Landschützer et al. (2014, 2018) but has been identified as a potential source of uncertainty in global coastal reconstructions (e.g., Resplandy et al., in rev.). All of these four sources of uncertainty are expressed in Pg C yr^{-1}. We do not include the uncertainty associated with the solubility term (K_0) in our uncertainty assessment since this contribution is minimal as suggested by Weiss et al. (1974, 0.2%).'

R1C12: Line 249-252, "σ_{wind} is calculated …", The wind speed data products cover different time periods, and please specify the time period for which the standard deviation is calculated.

R1R12: We agree with R1C12 and modified the text accordingly:

Lines 262-268: 'All of these four sources of uncertainty are expressed in Pg C yr^{-1}. We do not include the uncertainty associated with the solubility term (K_0) in our uncertaint~~yies calculation~~assessment since this ~~latter~~contribution is minimal as suggested by Weiss et al. (1974, 0.2%). σ_{wind} is calculated following the strategy described in Roobaert et al. (2018) which consists of using the standard deviation of global FCO_2 fields calculated with 3 different wind products: the ERA~~-interim~~5 (~~Dee et al., 2011~~Hersbach et al., 2020), the Cross-Calibrated Multi-Platform Ocean Wind Vector 3.0 (Atlas et al., 2011) and the NCEP/NCAR reanalysis 1 (Kalnay et al., 1996). Since these wind products cover different time periods, σ_{wind} is calculated for the overlap period (1991-2011) between products.'

R1C13: Line 275: "θmap is calculated as the RMSE …" RMSE of the training set (SOCAT_a vs. predicted) or independent validation set (SOCAT_b vs. predicted)?

R1R13: The RMSE is calculated against the training dataset. We modified the text according:

Lines 291-292: 'θ_{map} is calculated as the root mean squared deviation between the reconstructed pCO_2 and the gridded pCO_2 observation from the training dataset (SOCAT_a).'

R1C14: Line 297: "and a r² of 0.7 are calculated", We all know that R2 is the coefficient of determination, but please use the full name the first time it is mentioned in the manuscript.

R1R14: We agree with R1C14, and we modified the text accordingly.

R1C15: Line 338: "This dataset consists of a pool of 404,206 gridded cells that are uniformly distributed between both hemispheres (SOCAT_b, Fig. S1) and presents a good correspondence with SOCAT_a (93 % of the residuals between SOCAT_b and SOCAT_a are < 5 µatm and with a global RMSE value of 6 µatm, Fig. S2)." I tried to comprehend this sentence, but I failed. In my understanding, SOCAT_a and SOCAT_b are independent, they are non-repetitive random samples of the original data set; thus, I can't understand why they would "correspond." And what are the residuals between SOCAT_b and SOCAT_a mean?

R1R15: We apologize for the confusion. The reviewer is correct that both datasets are independent. What we tried to say here was that observations are homogeneously distributed, which is an essential criterion for the network training. Furthermore, we also noticed that - for both independent datasets - reconstruction errors and RMSE are very similar, thus our reconstruction performs equally well and is not biased towards one dataset, which would be a sign of overfitting.

For clarity, we now rephrased this to 'This dataset consists of a pool of 404,206 gridded cells that are uniformly distributed between both hemispheres (SOCAT_b, Fig. S1)., an essential criterion for training the network ~~and presents a good correspondence with SOCAT_a (93 % of the residuals between SOCAT_b and SOCAT_a are < 5 µatm and with a global RMSE value of 6 µatm, Fig. S2)~~.'

R1C16: Line 381: The title of subsection "Spatial and seasonal dynamics", I think it is more appropriate to use "variations" than "dynamics" in the subtitle, as the discussion in this section pertains specifically to variations rather than dynamics.

R1R16: We modified the text accordingly.

R1C17: Line 388-389: "Using the shelf break as the outer limit of the coastal domain ('narrow coastal ocean', 28 million km²)", This marks the initial instance of employing the term "narrow coastal ocean" in the manuscript. Please clarify how you define the "shelf break", 200m?

R1R17: The 'narrow coastal domain' used in this study is based on the coastal definition of Laruelle et al. (2013). The outer limit is defined as the shelf break which is estimated by calculating the slope of the sea floor. The isobath for which the increase in slope is the maximum over the 0–1000 m interval, yet still inferior to 2 % is defined as the outer limit of the shelf by Laruelle et al. We clarified the definition of the 'narrow coastal domain' as suggested by R1C17 but also R1C4 in the method section of this study.

Lines 187-196: 'this study, the coastal domain ('wide coastal ocean' with a total surface area of 76 million km², Laruelle et al., 2017) excludes the Black Sea, estuaries as well as inland water bodies and its outer limit is defined as whichever point is furthest from the shoreline between the 1000 m isobath and a fixed 300 km distance (roughly the outer edge of territorial waters), following the coarse SOCAT definition of the coastal oceanic domain. At the end of this entire procedure, a total of ~ 14 million and ~ 4 million discrete coastal data have been allocated to SOCAT_a and SOCAT_b, respectively. A more common delineation of the coastal ocean is also used in this study when discussing the air-sea CO_2 exchange (Sect. 3.1) using the shelf break as the outer limit of the coastal domain ('narrow coastal ocean', 28 million km²). The depth of the shelf break is calculated using a high-resolution global bathymetric database and estimated by calculating the slope of the sea floor. The isobath for which the increase in slope is the maximum over the 0–1000m interval, yet still inferior to 2 % define the outer limit of the shelf break (Laruelle et al., 2013).'

R1C18: Line 387-393: The digits numbers are not consistent in the flux section. For example, "0.4 Pg C per year (with an uncertainty of ± 0.03 Pg C yr-1)", or "-0.2 ± 0.01 Pg C yr -1". I suggested using two digits number to keep consistent.

R1R18: We now use two digits numbers to keep the consistency of our formulation throughout the manuscript (the updated values are 0.40 Pg C yr^{-1} and 0.18 Pg C yr^{-1}, instead of 0.3 Pg C yr^{-1} and 0.2 Pg C yr^{-1} respectively).

R1C19: Line 440: "(0.1 Pg Cyr -1decade -1and 0.03 Pg C yr -1decade -1", What are the uncertainties and p-values? (i.e., Δa in y = (a ± Δa)x + b)

R1R19: Following R1C19, uncertainties have been added to the estimations. Our updated coastal trend of -0.06 Pg C yr^{-1} $decade^{-1}$ has a p-value < 0.05 on a Mann-Kendall statistical test and an uncertainty (Δa) of 0.0009 Pg C yr^{-1} $decade^{-1}$. A p-value < 0.05 and an uncertainty (Δa) 0.0005 Pg C yr^{-1} $decade^{-1}$ are calculated for our updated trend shelf values of -0.02 Pg C yr^{-1} $decade^{-1}$, respectively. These numbers have been included in the Ms.

Lines 479-484: 'The overall intensification of the coastal sink that we observe in this study (0.061 Pg Cyr^{-1} $decade^{-1}$ (± 0.0009 Pg C yr^{-1} $decade^{-1}$ with a p-value < 0.05) and 0.023 Pg C yr^{-1} $decade^{-1}$ (± 0.0005 Pg C yr^{-1} $decade^{-1}$ with a p-value < 0.05) for the wide and narrow coastal domain, respectively) supports the only two available observational coastal studies performed at the global scale (i.e., Laruelle et al., 2018; Wang et al, 2017) which were however significantly limited by the small fraction of the coastal ocean domain investigated (e.g., 6 % in Laruelle et al., 2018) and both predict an increase in efficiency of the global coastal CO_2 sink over the last three decades.'

R1C20: Line 455: "increase of the global coastal CO2 sink is to be found in the high latitudes of the northern hemisphere,", According to the product, yes. But there are still uncertainties for this conclusion, as the largest errors are observed in the high latitudes of the northern hemisphere (Figure 2c), notably within the Arctic Ocean.

R1R20: We agree with R1C20 and added a sentence to discuss this particular point.

Lines 489-504: 'The significant strengthening of this global coastal sink that we observe in this study, which has approximately doubled between 1982 and 2020 (wide coastal domain) results from a general tendency towards an increase of the coastal CO_2 sinks intensities (e.g., in the high latitude of the Northern Hemisphere, Fig. 6a) combined with decreases in intensity of several CO_2 sources such as along upwelling currents (e.g., in the Arabian sea). However, since a large fraction of the global CO_2 uptake results from coastal regions > 40° of the Northern Hemisphere and since these CO_2 sinks regions present strong negative rates of change in FCO_2 (Fig. 6a), our result suggests that the primary driver of this twofold increase of the global coastal CO_2 sink is to be found in the high latitudes of the northern hemisphere, which contribute disproportionately to the global-scale coastal FCO_2 trend. Further studies should however be carried out to support this conclusion, given the paucity of observational pCO_2 data in those high latitude regions that translate into high uncertainties in our pCO_2 product, as for example in the Arctic Ocean. However, tTaking also the large heterogeneity in decadal the long-term FCO_2 trends, a quantitative analysis of the respective contributions of different coastal systems to the global strengthening of the coastal CO_2 sink should also be performed in the future, using a regionalized approach. Moreover, changes in wind speed and sea-ice coverage have likely not been constant over time and further analysis of their influence on the rate change of FCO_2 should be analyzed for each decade individually to better understand the interplay between these different drivers. Overall, our results highlight the complex nature of the coastal FCO_2 dynamics and emphasizes the need for further investigation and understanding of the specific factors influencing the FCO_2 trends in different coastal regions.'

R1C21: Line 507: "latest release of the SOCAT", Please include the version information, such as "the latest release of SOCAT (v2022)," to provide further context.

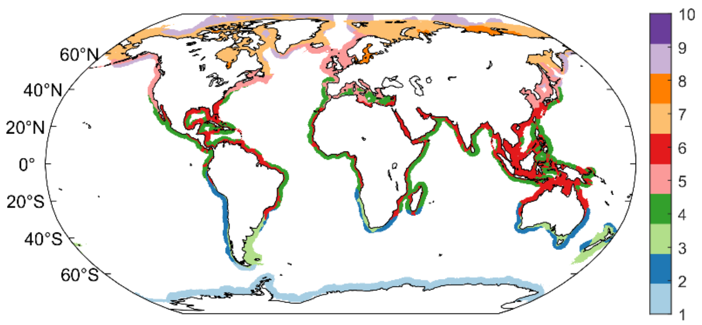
R1R21: We modified the text accordingly:

Lines 549-552: 'In this study, we presented a new coastal pCO_2-product for the 1982-2020 period using ~ 18 million direct coastal observations from the SOCATv2022 database (Bakker et al., 2022) latest release of the SOCAT database combined with an updated version of the coastal 2-step SOM and FFN method used by Laruelle et al. (2017).'

Figures and Tables:

R1C22: Figure 1. The color scale is hard for me to recognize, especially the P9 and P10. The font size of the latitude and width of the color bar can be smaller (like in Figure 2).

R1R22: Figure 1 has been updated (see Fig_R1C22 below) with suggestions from R1C22.



Fig_R1C22. New Fig. 1.

R1C23: Table 2. Row 4, column 1: Sea-ice coverage (ice, no unit) ◊ Sea-ice coverage (dimensionless) Row 5, column 5: MBL is using the zonal average or meridional average xCO2air? MBL doesn't provide 3-d gridded data; the resolution is 0.05 sin latitude. Also, because the SOM and FNN steps use different input variables, I suggest adding one more column or other ways to mention which variables are used in which step.

R1R23: Table 1 has been updated with suggestions from R1C23 (see Table_R1C23). The referee is correct that the MBL product does not provide 3D data. To derive the 3D atmospheric CO_2 within SeaFlux (Fay et al., 2021), the authors interpolate the data first from the original 0.05 sin latitude to 1° latitude and then use the same latitude value for each degree longitude to get the final 3D gridded atmospheric xCO_2 dry molar fraction. Multiplying this 3D field with the 3D ERA pressure fields and applying the Dickson et al. (2007) water vapor correction, the final pCO_2_wet can be calculated. We nevertheless believe the original reference to the MBL product should remain, however, we further added: '… applying the method of Landschützer et al. (2014) and Fay et al. (2021)'.

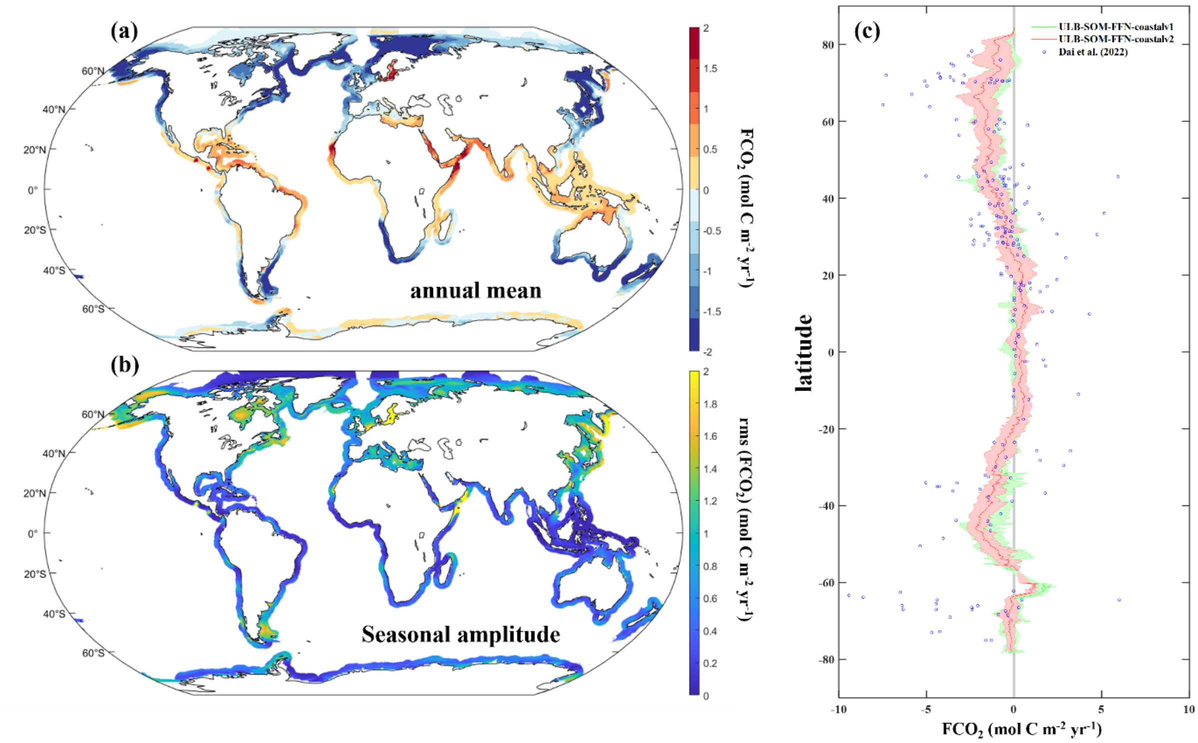
Lines 204-210: 'The atmospheric pCO_2 is from the SeaFlux product (Fay et al., 2021) which is calculated from the dry air mixing ratio of CO_2 (xCO_2) provided by the ~~NOAA Marine Boundary Layer reference~~ESRL surface marine boundary layer CO_2 product (https://www.esrl.noaa.gov/gmd/ccgg/mbl/data.php, Duglockencky et al., 2019~~https://www.esrl.noaa.gov/gmd/ccgg/mbl/~~) with a vapor correction according to ~~assuming 100 % humidity at the air-sea interface (following calculation specified in~~ Dickson et al. ~~,~~ (2007), ~~and~~ using the ~~NCEP reanalysis total pressure at sea level (Kalnay et al., 1996)~~ERA5 sea level pressure (Herbach et al., 2020) and applying the method of Landschützer et al. (2014) and Fay et al. (2021).'

Table_R1C23. New Table 1.

environmental drivers	used for SOM	used for FFN	period	resolution	manipulation	name and/or references
Sea Surface Temperature (SST, in °C)	X	X	1982-2020	0.25°, daily	monthly mean	NOAA OI SSTv2 (Reynold et al., 2007)
Sea Surface Salinity (SSS, in PSU)	X	X	1982-2020	0.25°, daily	monthly mean	EN4.2 SSS (Good et al., 2013)
Wind speed at 10 meters above sea level (U_{10}, in m s^{-1})	X	X	1982-2020	0.25°, 6 hours	monthly first moment	ERA5 (Hersbach et al., 2020)
Sea-ice coverage (ice, dimensionless)	X (rate change)	X (rate change)	1982-2020	0.25°, daily	monthly mean rate changed in sea-ice coverage	Reynolds et al. (2007)
Atmospheric pCO_2 (in µatm)		X	1982-2020	1°, monthly	aggregated to 0.25°	SeaFlux product (Fay et al., 2021) with xCO_2 derived from the ESRL surface MBL CO_2 product (Duglokencky et al., 2019), ERA5 sea level pressure (Herbach et al., 2020) and with a vapor correction (Dickson et al., 2007) and the method of Landschützer et al. (2014) and Fay et al. (2021)
Chlorophyll a (Chl-a, in mg m^{-3})		X	1998-2020	4km, monthly	aggregated to 0.25°, extended the period and filled cells with no data	E.U. Copernicus Marine Service Information (https://doi.org/10.48670/moi-00281)
Bathymetry (in m)	X	X	-	2 min	aggregated to 0.25°	ETOPO2 US Department of Commerce (2006)

R1C24: Figure 5. Please adjust the colorbars and latitude font size in (a) and (b) like Figure 2 or Figure 4(a) to provide more information.

R1R24: Figure 5 has been updated following the reviewer's suggestion (see Fig_R1C24).



Fig_R1C24. Updated Fig. 5

Some grammatical mistakes:

R1C25: Line 43: “the number of … have considerably”, should be “has” I think

R1R25: We agree with R1C25 and modified the text accordingly.

R1C26: Line 104: benchmark should be plural

R1R26: We agree with R1C26 and modified the text accordingly.

R1C27: Line 124: “in a first step”, should be “in the first step”

R1R27: We agree with R1C27 and modified the text accordingly.

R1C28: Line 143: “P9 represent”, should be “represents”

R1R28: We agree with R1C28 and modified the text accordingly.

R1C29: Line 367: “Largest RMSE” should be “The largest RMSE”

R1R29: We agree with R1C29 and modified the text accordingly.

R1C30: Line 376: “CO2 exchanges” should be “CO2 exchange”

R1R30: We agree with R1C30 and modified the text accordingly.

R1C31: Line 383: “both hemisphere” should be “hemispheres”, “a CO2 sinks” should be “CO2 sinks”

R1R31: We agree with R1C31 and modified the text accordingly.

R1C32: Line 426: typo, “through”

R1R32: We agree with R1C32 and modified the text accordingly.

R1C33: Line 441: "at global scale" should be "at a/the global scale"

R1R33: We agree with R1C33 and modified the text accordingly.

R1C34: Line 461: "our results … and emphasizes" should be "emphasize"

R1R34: We agree with R1C34 and modified the text accordingly.

R1C35: Line 510: "However, these investigation .." should be "investigations"

R1R35: We agree with R1C35 and modified the text accordingly.

R1C36: Line 532: "to calculated" should be "to calculate"

R1R36: We agree with R1C36 and modified the text accordingly.

REFERENCES

Dickson, A. G., Sabine, C. L., & Christian, J. R. (2007). Guide to best practices for ocean CO2 measurements. PICES Special Publication 3, 3(8), 191. https://doi.org/10.1159/000331784

Dlugokencky, E. J., Thoning, K. W., Lang, P. M., and Tans, P. P.: NOAA Greenhouse Gas Reference from Atmospheric Carbon Dioxide Dry Air Mole Fractions from the NOAA ESRL Carbon Cycle CooperativeGlobal Air Sampling Network, 2019 (data available at: https://www.esrl.noaa.gov/gmd/ccgg/mbl/data.php).

Fay, A. R., Gregor, L., Landschützer, P., McKinley, G. A., Gruber, N., Gehlen, M., Iida, Y., Laruelle, G. G., Rödenbeck, C., Roobaert, A., & Zeng, J. (2021). SeaFlux: Harmonization of air-sea CO2 fluxes from surface pCO2 data products using a standardized approach. In Earth System Science Data (Vol. 13, Issue 10, pp. 4693–4710). https://doi.org/10.5194/essd-13-4693-2021

Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., Nicolas, J., Peubey, C., Radu, R., Schepers, D., Simmons, A., Soci, C., Abdalla, S., Abellan, X., Balsamo, G., Bechtold, P., Biavati, G., Bidlot, J., Bonavita, M., De Chiara, G., Dahlgren, P., Dee, D., Diamantakis, M., Dragani, R., Flemming, J., Forbes, R., Fuentes, M., Geer, A., Haimberger, L., Healy, S., Hogan, R.J., Hólm, E., Janisková, M., Keeley, S., Laloyaux, P., Lopez, P., Lupu, C., Radnoti, G., de Rosnay, P., Rozum, I., Vamborg, F., Villaume, S., and Thépaut, J.: The ERA5 global reanalysis, Q. J. Roy. Meteor. Soc. 146, 1999–2049, https://doi.org/10.1002/qj.3803, 2020 (data available at:https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels-monthlymeans?tab=overview)

Ho, D. T., Wanninkhof, R., Schlosser, P., Ullman, D. S., Hebert, D., & Sullivan, K. F. (2011). Toward a universal relationship between wind speed and gas exchange: Gas transfer velocities measured with 3He/SF6 during the Southern Ocean Gas Exchange Experiment. Journal of Geophysical Research: Oceans, 116(7), C00F04. https://doi.org/10.1029/2010JC006854

Landschützer, P., Gruber, N., Bakker, D. C. E., & Schuster, U. (2014). Recent variability of the global ocean carbon sink. Global Biogeochemical Cycles, 28, 927–949. https://doi.org/10.1002/2014GB004853

Landschützer, P., Gruber, N., & Bakker, D. C. E. (2016). Decadal variations and trends of the global ocean carbon sink. Global Biogeochemical Cycles, 30, 1396–1417. https://doi.org/10.1002/2015GB005359

Laruelle, G. G., Dürr, H. H., Lauerwald, R., Hartmann, J., Slomp, C. P., Goossens, N., and Regnier, P. A. G. (2013): Global multi-scale segmentation of continental and coastal waters from the watersheds to the continental margins, Hydrol. Earth Syst. Sci., 17, 2029–2051, https://doi.org/10.5194/hess-17-2029-2013.

Laruelle, G. G., Landschützer, P., Gruber, N., Tison, J. L., Delille, B., & Regnier, P. (2017). Global high-resolution monthly pCO2 climatology for the coastal ocean derived from neural network interpolation. Biogeosciences, 14(19), 4545–4561. https://doi.org/10.5194/bg-14-4545-2017

Sutton, et al., 2019. Autonomous seawater pCO2 and pH time series from 40 surface buoys and the emergence of anthropogenic trends. Earth Syst. Sci. Data 11, 421–439. https://doi.org/10.5194/essd-11-421-2019

Takahashi, T., Sutherland, S. C., & Kozyr, A. (2019). Global ocean surface water partial pressure of CO2 database: Measurements performed during 1957–2018 (version 2018). NOAA/NCEI/OCADS NDP-088 (V2018) Rep., 25 pp., https://www. ncei. noaa. gov/access/ocean-carbon-data-system/oceans/LDEO_Underway_Database/NDP-088_V2018. pdf.

Wanninkhof, R. (2014). Relationship between wind speed and gas exchange over the ocean revisited. Limnology and Oceanography: Methods, 12(C5), 351–362. https://doi.org/10.1029/92JC00188

Weiss, R. F. (1974). Carbon dioxide in water and seawater: the solubility of a non-ideal gas. Marine Chemistry, 2(3), 203–215. https://doi.org/10.1016/0304-4203(74)90015-2