Response to Reviewer 1

This manuscript presents an updated version of the Takahashi surface ocean CO2 climatology. Both this and the associated fluxes that are calculated are very useful for a large scientific community. The update is very welcome. I have a few relatively minor comments below.

Specific comments:

Please provide proper uncertainty assessments for the fluxes. You describe in section 4.2 what sources of uncertainty you include, but you appear to have taken numbers from Wanninhof et al (2013) rather than calculating your own numbers based on the %-uncertainty contributed by each term (from their Table 1). A map showing the uncertainties spatially would be highly useful.

We thank the reviewer for these comments. A complete decomposition of uncertainty analysis, including the mapping of uncertainty, is outside the scope of this paper, which focuses on the method of and release of a ΔfCO2 climatology. We have updated the flux discussion with uncertainty estimates drawn from recent publications and direct the reader to pertinent references which focus more on uncertainty analysis. For our uncertainties associated with spatial and temporal extrapolation of ΔfCO_2, we take estimates directly from T-2009. The updated manuscript now uses 13% uncertainty for error associated with ΔfCO_2 and a value of 0.5 PgC yr^{-1} to account for the uncertainty associated with the time normalization step required for a climatology. Updated analysis presented in Wanninkhof 2014 estimates the uncertainty on gas transfer velocity to be 20%. Finally, Flux analysis presented in Fay & Gregor et al. 2021 estimate uncertainty on the wind reanalysis product to be 0.09 PgC yr^{-1}. Lastly, we maintain the river carbon uncertainty of 0.2 PgC yr^{-1} as presented in Wanninkhof et al. 2013 (Jacobson et al. 2007). These estimates, summed in quadrature, result in a total uncertainty estimate of 0.7 PgC yr^{-1}. This value has been added in the main text and in the Key Points.

Throughout the manuscript several averages are presented. Please provide also a standard deviation for all of them.

We thank the reviewer for this comment. We have added uncertainty (1 standard deviation) estimates to key averages when they are first presented in the text, but left them out in subsequent mention as we feel that it would bog down the reader by adding these values throughout. Specifically, for Section 4 where we discuss regional means, often in the same sentence the amplitude of the seasonal cycle is presented which is an alternative way to visualize the standard deviation of an annual mean value (i.e. a large amplitude seasonal cycle would ultimately have a larger standard deviation for the annual mean). Rather than including these values in the text, we have added a table of mean ΔfCO2 and flux values by biome as suggested by Reviewer 2 (Table 1) and we have included the standard deviation over the 12 months there.

If the reviewer is specifically interested in seeing the standard deviation spatially for the biomes scale means, we again think that including these specific numbers would bog down a reader. Instead, by showing the maps, a reader can quickly assess how variable the values are within a biome.

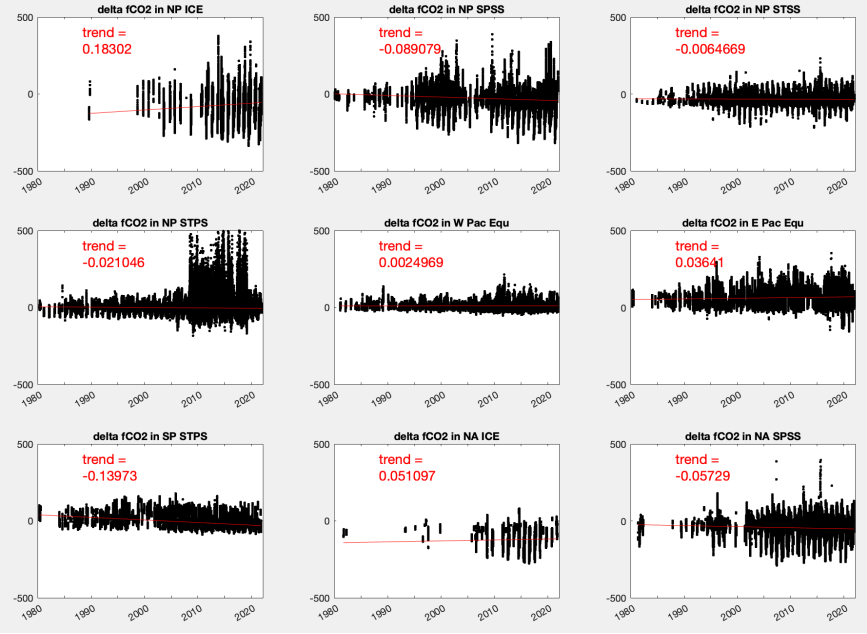
Overall, we strongly agree that showing uncertainties is important in our field, and we have included an expanded discussion of the uncertainty on our flux estimate, however producing specific standard deviation values for every stated mean within this manuscript is not the ideal way to communicate uncertainty.

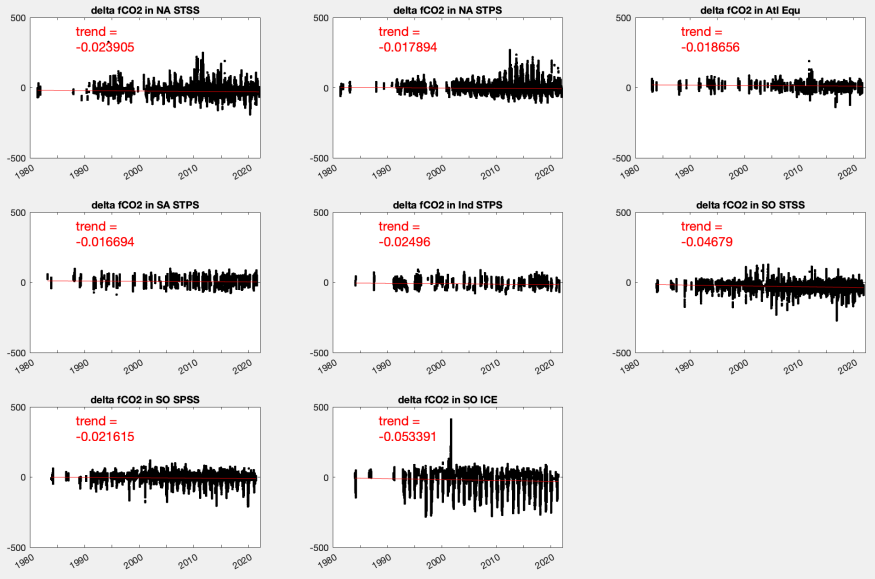
The SOCAT data product was first released in 2011. Thank you for this correction. We have changed the year in the manuscript.

It is very difficult to see the lowest numbers on Figure 1a. Could you make 0 white as in Figure 1b? We thank the reviewer for this comment. The areas with 0 observations are now white, as in Figure 1b. This has improved the figure to make the low values more visible.

Did you test your assumption/hypothesis that there is no trend in \Delta_fCO_2 over the 40 year period? A figure in the supplement showing this would be nice I think.

We thank the reviewer for this question. We did quite an extensive exploration regarding this choice of time normalization, much of which we included in the methods discussion section of the paper. We experimented with using the exact same method as T-2009 which was a trend of 1.5µatm/yr globally as well as a time-varying normalization trend (for example, 1.5µatm/yr prior to 2000 and then 2.0µatm/yr after 2000). None of these versions of the climatology resulted in significantly different global means or seasonal cycle patterns for fCO2 or flux. There were regional differences, but typically that was most prominent in regions with severely limited data (for example the Indian subtropics or the high latitude ice regions). We acknowledge that globally, there is indeed an increasing trend in $dfCO_2$, and therefore a growing ocean carbon sink. However, given the limitations of the available data, no choice is perfect for creating a climatology. We have opted for this method as it is a straightforward method given the available observations in SOCAT (i.e. co-located ocean and atmosphere fCO2 values). Below are time series of all available $dfCO_2$ values that go into our climatology (from SOCATv2022), broken down by biome. Recorded on top of each subplot is a trend in the $dfCO_2$ values from 1980-2021. Globally the trend is -0.07 µatm/yr. The biomes trends vary from -0.09 µatm/yr (in the NP SPSS biome) to 0.18 µatm/yr (in the NP ICE where there is very limited available data before year 2000). None of these trend values are statistically different from zero given 1 sigma confidence intervals. Therefore, we have strong confidence that our assumption is appropriate for the project goal and the available data.





How big is the area of the Arctic Ocean you make land?

It is not so much that we “assign land” to the arctic region as much as we do not produce an estimated ΔfCO2 climatological value for these high latitude regions. This is predominantly due to the lack of available observations to base an estimate on, thus making it very likely a highly uncertain estimate. As stated in the manuscript, just under 10% of the global ocean does not have a value reported in this climatology. Considering ocean areas north of 50N latitude, there are 9.78 *10^6 square km that do not have a reported climatological value in our product.

Line 490: It is unclear which quantity you are referring to here.

We thank the reviewer for this comment. The quantity we are referring to here is the estimated flux for the ocean areas which do not have a reported value in our near-global

climatology. Using the 12-month climatological coastal and high latitude product (Landschützer et al. 2020), we are able to calculate the flux (ocean uptake of carbon) that we are missing by not accounting for these areas. That number is not the same for each month, but varies over the 12 months of the climatology. We have adjusted the text of this sentence to hopefully clarify the meaning. It now reads, “This flux adjustment for missing areas of this climatology varies throughout the seasonal cycle, ranging from -0.43 to -0.31 PgC yr^{-1} during the 12 months of the climatology.”

Line 732-735: This needs revision for clarity. I assumed that the Southern and Northern hemispheres would add up to the global, but it does not (since the tropical area is missing). We thank the reviewer for catching this. In fact, the 3 stated numbers would add up to -1.88 PgC (-1.19+ -1.04 +0.35) which is just slightly more uptake than the mean value we reported in the manuscript. The reason for this is that there are a few areas that do not fall in the defined biomes, but do have an estimated flux value in this climatology, and those regions make up 0.08 PgC/yr of flux. These areas include regions of the Gulf of Mexico as well as areas of the Arabian Sea. To make this conclusion section more clear, we edited the sentences and just split the ocean at +/-30 latitude and quoted the fluxes for those regions. It still communicates the same message- that the southern hemisphere ocean regions are the largest uptake region and the equatorial/tropical region is an area of efflux of carbon. The edited sentence now reads, “Of the major ocean basins, the Southern Hemisphere ocean (south of 30S) is the largest CO_2 sink, taking up 1.22 PgC yr^{-1}, while the Northern Hemisphere ocean (north of 30N) takes up 0.93 PgC yr^{-1}. The equatorial ocean region acts as the only year-round region of carbon efflux to the atmosphere and emits 0.36 PgC to the atmosphere annually.”

I think including the section "LDEO flux" from the supplement in the main text would make sense.

We thank the reviewer for this suggestion. We have experimented with the structuring of this paper in many previous versions and after much deliberation and comments from internal reviewers we have decided to leave all discussion of the results from the LDEO database in the supplementary section in order to reduce confusion with the results discussed here, which are the primary findings and official updated climatology. The information included in the supplementary, discussing the results using the LDEO database, is a tribute to Taro’s impressive work and legacy creating, maintaining, and utilizing that database. Since it is no longer supported or updated, we opted to not include it in the main paper.

I often find the manuscript a bit difficult to read. There are many very long and cumbersome sentences that I struggle to understand. There is also a rather excessive use of semicolons. I know many like semicolons, and I admit to having a particularly strong dislike of them, but they do not aid reading. A semicolon, most often, replaces a word (the word you would need if you used a comma instead). As a non-native reader my brain keeps stopping and trying to identify what the word is. I can't seem to fully grasp what the sentence says without mentally putting that word into it. This makes for slow and frustrating reading. I would therefore urge you to go through the text and

simplify the language and ensure better readability. Many times shorter sentences would do the trick.

We thank the reviewer for this comment and suggestion. We have edited the manuscript throughout to shorten sentences and limit semicolon use. We hope this has improved the readability for all readers.