

Biogeosciences Discuss., referee comment RC1
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Comment on bg-2021-78

Adrienne Sutton (Referee)

Referee comment on "An Empirical MLR for Estimating Surface Layer DIC and a Comparative Assessment to Other Gap-filling Techniques for Ocean Carbon Time Series" by Jesse M. Vance et al., Biogeosciences Discuss.,
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Vance et al. present an analysis of different statistical and empirical methods for filling gaps in ocean carbon time series. Gaps in ocean carbon time series are common, and they can become an issue when assessing variability and calculating long-term trends, for example, especially if using certain statistical techniques that require regular, uniform data sets with characterized variability. They find that the empirical methods of replacing missing values with monthly climatological mean (mean imputation), multivariate linear regression (MLR), and weighted moving average and multiple imputation by chained equation (MICE) outperform the statistical methods. Given the various drivers of ocean carbon variability, it is not surprising that the climatological and empirical methods performed better than the statistical approaches. However, it is my understanding this had not been assessed prior to this study, and it is an important paper that can support efforts to harmonize trend and variability analyses across global time series.

However, the following three major issues should be addressed before publication:

1) For the error propagation described in section 2.6, what is the reasoning for using CO₂ flux? Using CO₂ flux introduces several other potential biases and errors to the assessment:

- uncertainty in air pCO₂,
- major bias and errors of NCEP winds (see: <https://doi.org/10.5194/bg-15-1701-2018>, <https://doi.org/10.1029/2018GB006047>, <https://doi.org/10.1002/2017GL073814>)
- uncertainty in the gas transfer velocity coefficient (resulting in total uncertainty in CO₂ flux of ~20%), and
- uncertainty (~5%) introduced in the calculation of sw pCO₂ from DIC and TA.

How will those biases and errors complicate your assessment of gap filling error propagation? The relative uncertainty for CO₂ flux at BATS is reported in line 361 as 3.5%. What does this uncertainty take into account? Not items 1 – 4 above, as this value

would be much higher. These issues should be addressed in the error propagation, or another parameter should be used for this assessment.

2) Data used in this study need to be cited properly, which is incredibly important to the programs supporting these time series measurements. Those data should be cited in the methods and/or funders noted in the acknowledgements, depending on what each time series program recommends, not recorded as web addresses in the notes of Table 2. For the moorings, if you are accessing original data files via NCEI, those citations can be found at https://doi.org/10.3334/cdiac/otg.tsm_papa_145w_50n for Papa and https://doi.org/10.3334/cdiac/otg.tsm_keo_145e_32n for KEO. If you are accessing the mooring data from the synthesis product, the citation can be found at <https://doi.org/10.7289/V5DB8043>. I am not as familiar with the citation requirements of all the ship-based time series, but with a quick search I found this data citation request for HOTS, for example: <https://hahana.soest.hawaii.edu/hot/dataaccess.html>

3) Finally, it may be out of the scope to include additional analyses in this paper, but it would be worthwhile discussing future work that can build off these results. For example, what satellite-based products are best suited for the MLR approach? Are there any that can span open ocean and coastal environments, so gap filling methods can be applied consistently across all global ocean and coastal time series? Also, it would be useful to study whether there are discrepancies in calculated trends when using these different gap filling methods (at least the most successful methods) or no gap filling methods at all. Both of these analyses seem like they could have been included in this paper, but I could also understand if those are the next assessments planned using the most promising empirical gap filling methods resulting from this work.

Minor issues:

Line 31: Use the most recent version of the Global Carbon Budget:
<https://doi.org/10.5194/essd-12-3269-2020>

Line 89: Define DT.

Line 89: State the sites that did not measure DIC directly as in line 87 for discrete sampling sites.

Line 90: What measured parameters are being used to calculate DIC from the moored data? Measured pCO₂ and pH? The measured pCO₂ and pH pair has several issues, most importantly in this application is the issue brought up below for line 118, in that data return from pH sensors tend to be poor and data gaps will usually fall at the same time each year. Data return from the pCO₂ systems are much better, and you will avoid much of the repeated seasonal gaps if you used established salinity-alkalinity relationships (in the Fassbender references) for those open ocean locations paired with measured pCO₂ as discussed in <https://doi.org/10.5194/bg-13-5065-2016>. This will increase N Years in Table 3 for Papa and KEO.

Lines 96-99: It would be useful to present more information (figure or some statistics like mean diff and standard deviation) about how MODIS and VIIRS compare at this particular site so it is more clear why VIIRS was chosen.

Line 118: "Missing at random" is not a good assumption for many of the moored time series, especially the open ocean sites which tend to be serviced around the same time every year. Sensor failures are more likely late in the deployment, which can be around the same time every year just before servicing. That should be acknowledged here.

Line 202: BATS is a different latitude than Mauna Loa, and therefore, has different annual

mean and seasonality of air xCO₂. xCO₂ air from same latitude of BATS should be used from one of these products:

https://www.esrl.noaa.gov/gmd/ccgg/obspack/our_products.php

<https://www.esrl.noaa.gov/gmd/ccgg/carbontracker/>

Line 344: What about: <https://doi.org/10.1002/lom3.10232> and <https://doi.org/10.3389/fmars.2017.00128>?

Line 358: You should note that the studies cited here do not use ocean DIC time series. Include information on what types of time series these are (soil flux and respiration, etc).

Lines 406-408: Since trends were not considered in this paper, this statement may be a bit premature?

Line 655: What is the note with the "*" referring to?

Figure 10: Why aren't the models listed above the top panel? And spline should maybe be presented on the far right or left since it has a diff y axis for the 6 month gap?

Figure 12: Consistent with earlier comments about error propagation for CO₂ flux, these results showing higher uncertainty at higher outgassing and uptake values are consistent with increased uncertainty at higher wind speeds. This makes it difficult to understand what is a gap filling uncertainty vs uncertainty in other parameters that impact flux.