Atmos. Chem. Phys. Discuss.,
https://doi.org/10.5194/acp-2019-69-RC2, 2019

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Global carbon budgets estimated from atmospheric O_2/N_2 and CO_2 observations in the western Pacific region over a 15-year period" *by* Yasunori Tohjima et al.

Anonymous Referee #2

Received and published: 13 May 2019

Summary: Tohjima et al. here present independent estimates of global carbon sinks using a long-term APO record based on O2/N2 and CO2 measurements over the 2000-2016 period from two stations in Japan and cruise ship measurements from the western Pacific. Using these long-term APO time series, fossil fuel records, global CO2 time series, and correcting for changes in O2 fluxes due to changes in ocean heat content (Z_eff), they calculate the ocean and land sinks of anthropogenic carbon on decadal and pentadal timescales, and find mean values and variability in trends that are relatively in good agreement (within uncertainties) with the GCP reported sinks estimates. Overall, this study is highly relevant and important to the carbon cycle community, providing independent estimates of carbon sinks and thus can help inform observational

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estimates and test models used to infer past and future projections of the global carbon cycle. The paper is well written and structured, though it could benefit from one more round of proofreading for clarity in certain sections (e.g. introduction and conclusion). The paper shows interesting and highly relevant findings that are suitable for publication in the journal of ACP, though I have a few concerns regarding the treatment of uncertainty outlined below that I hope the authors can resolve/clarify. Further, these time-series have great potential to be used as an independent check on specific modeling and ocean observations-based products submitted to the GCP, rather than solely compared to the GCP mean which shows large variations across products. This latter point may be outside the current scope of this work, but could significantly improve the impact of this interesting and relevant study.

Main Issues: The main issues identified in this paper are listed as follow:

1) It's unclear how uncertainty in estimating Z_eff comes into play in the carbon budget estimates, especially given its relevance for the shorter timescales considered. The authors do show trends without Z_eff (figure 8) but it's not evident if this is incorporated in the carbon sinks and trends calculation (i.e. unclear if incorporated in grey shading in figure 8 or error estimates in carbon sinks column in Table 2). Perhaps, the authors could evaluate uncertainty in Z_eff from using the upper/lower bounds with and without Z_eff? Further, it's unclear how correcting for Z_eff in the carbon budgets plays out in the 5 year timescales described (as also discussed in Nevison et al. 2008 and elsewhere). It seems, as referred to by the authors, that the ventilation events of 1999-2001 could impact the pentad trends, and thus similar variability during other years probably could have similar effects on other pentad periods (e.g. 2004-2005 dip in pentad ocean sink seems to co-occur with inter-annual variation that don't seem to be fully suppressed?). Finally, an additional and not insignificant component of Z_eff not included in this study is the atmospheric deposition effect, as detailed in Keeling and Manning 2014, which adds about 0.1 (+/-0.1) Pg C/yr, and which should raise Z_eff from 0.1-0.9 Pg C/yr, to 0.2-1.0 Pg C/yr. Overall, I fell the treatment of Z_eff uncertainty

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within the shorter timescales considered here merits further clarification.

2) I see the need perhaps for a section dedicated to clarifying and detailing the sources, contribution, and methods for calculating carbon budget uncertainty, as it can help clarify the confidence in the pentad trends and conclusions presented here. Table 2, for instance, could incorporate uncertainty due to Z_eff in the carbon sinks column, and in Figure 8 (gray shading). Uncertainty due to undersampling the global signal has also been shown by Nevison et al. (2008) to contribute to uncertainty in estimating budgets on the shorter timescales evaluated here. What is impact of sampling over the western Pacific ($\sim$40S-40N) vs. full global sampling on the carbon sink trends? How does uncertainty in alpha_B in using values of 1.1 vs 1.05 affect the uncertainty in carbon sink budgets? Finally, it's unclear how the contribution of measurement uncertainty, due to span calibration of the gas chromatographic technique and potential longterm drift shared across all cylinders, is incorporated in the uncertainty analysis.

3) The comparison against the GCP could be elaborated on a bit more, as it raises important issues in the field. The authors could elaborate further (through existing or new figure/table) how different estimates reported by GCP compare to the APO method, including hindcast ocean models and ocean observation based products, all of which are readily available in the GCP product as globally integrated fluxes: https://www.icos-cp.eu/GCP/2018. It is interesting that the comparison to the GCP mean showcases similarities in magnitude and in temporal evolution of pentads. The point that the uptake of carbon by the ocean is larger than expected from atmospheric increase alone is very interesting. How do the decadal trends (2000-2016) in this study compare to the pCO2 based air-sea flux timeseries by Landshutzer et al (2016) and Rodenbeck et al (2013), as both of these estimates seem to show larger decadal variability than the ocean models? These items may be beyond the current scope of this study, but could substantially improve the impact of this paper with (hopefully?) relatively minor figure/text additions.

Minor Issues: Minor issues, edits, typos, and technical issues are listed below:

Pg2 L27: “The estimated value for αF is about 1.10$\pm$0.05 (Severinghaus, 1995) and that for αB is about 1.4 (Keeling, 1988).” Should be the other way around: αB is 1.10 and αF is 1.4.

Perhaps add citations for Equations (1), (2), and (3)?

P3 L1, this paragraph could use a brief explanation of APO concept as a tracer for those not familiar with APO, i.e. cancellation of terrestrial influence, etc.

Pg 7 L29, shouldn’t Z_eff be in PgC/yr?

Pg 9 Line 20, the ENSO topic deserves a bit more clarification here. It would be good to preface the ENSO sentence with the findings of Rodenbeck et al 2008, who suggest anomalous outgassing of APO during El Niño, while Tohjima et al 2015 show a suppressed peak instead, and clarify that Eddebbar et al (2017) reconcile this apparent discrepancy through a model-simulated zonal dipole-like ENSO response in the equatorial Pacific, and that enhanced observational zonal coverage in this region is needed to constrain the full basin ENSO response.

Suggested editing notes:

Pg 2 Line 5: remove “still”, and add year by which emissions rose to 10 Pg C/yr?

Pg 2 Line 6: “Paris Agreement . . . aimed to balance the anthropogenic greenhouse gas emissions and natural removals in the second half of this century. . .”, I suggest editing to: “ . . . aimed to reduce anthropogenic greenhouse gas emissions to maintain the increase in global mean surface temperature well below 2°C by 2100, . . .”?

Pg3 L8, suggest deleting “In these days”.

Pg3 L21, “which reduces the ventilation of the seawater.”, suggest instead: “which reduces the ventilation of interior water masses.”

Pg3 L26: replace “huge” with “large”

Pg 14 L 20: Not sure I understand this sentence: “This means that the changing trends of carbon budgets may be evaluated by the at least decadal APO data.” suggest rephrasing and/or elaborating further?

Pg 12 L 32. Replace “stagnant” with “stagnancy”

Pg13 L 1: replace “in spite of’ with “despite”

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