AGU Advances

Peer Review History of

External Forcing Explains Recent Decadal Variability of the Ocean Carbon Sink

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Peer Review Comments on 2019AV000149

Reviewer #1

External forcing explains recent decadal variability of the ocean carbon sink
McKinley et al., 2020

The ocean is a major player in the global carbon cycle, responsible for the uptake of o.o. 25% of the total anthropogenic CO2 emissions since preindustrial times. Date-based products as well as hind-cast models suggest considerable interannual-to-decadel variations of marine CO2 uptake, which are not very well understood, partly related to intrinsic uncertainty of both techniques. The authors take a new approach here by comparing the ensemble means of hind-cast models and data-based products with results from a simple externally forced 1D surface ocean model. Doing so they are able to quantify the externally forced component of CO2-uptake variability. They show that, when confronting (forcing) the 1D-model with the time history of atmospheric pCO2 and the SST variability associated with two major volcanic eruptions, the model shows variations of marine CO2 uptake which are highly correlated with those of the ensemble means of hind-case models, as well as, data-based products. In particularly adding the globally averaged volcano-associated SST variability (affecting CO2-solubility in the box model) contributes to a considerable increase in the correlation of de-trended air sea CO2 fluxes. To my understanding, this study makes a strong case for the role of externally forced variability to the interannual-to-decadel variability of marine CO2-uptake, to be considered explicitly in future studies of the controls of marine CO2 uptake and its projections.

The paper is well written and is an important contribution to the field of marine CO2-uptake variability, and given the public discussion on climate change, also relevant to a wider audience. I suggest publication after minor (technical) revisions.

Minor issues:

Abstract/Plain Language Summary: The authors relate the oceans uptake of CO2 only to the fossil fuel carbon emissions, which gives a 39% share (integrated uptake / cumulative emissions). The ocean however, does not differentiate between CO2 from fossil fuel emissions vs. the net flux associated with land use change (e.g. deforestation) or cement production and other human sources. Also the CO2 in the atmosphere (a major external driver considered in this manuscript to impact on marine CO2 uptake) is not only changing due to fossil fuel burning. Typically the literature on marine CO2 uptake gives number o.o. 25% of the total anthropogenic CO2 emissions. I don't see the justification for the 39% number.

Introduction:
paragraph 1 (the ms has no page / line numbers!): Uncertainty contributes to imbalance in the annual global budget for Cant. Could you be a little more explicit about the quantitative contribution to the mentioned 10%? I thought that most of the related uncertainty resides on land and not in the ocean.

Methods: very sound!

1D-model, abiotic formulation.
The mean biological pump component size (265 mmol/m3) taken from the textbook SG06 is based on their eq 8.4.1 which applies global mean surface PO4 as PO4ref. But this is not correct, as has been shown e.g. in Ito et al., 2005 and Marinov et la. 2008 (GBC). The more correct PO4ref would be PO4preformed. Since PO4-preformed >> PO4-surface, using PO4preformed gives order of factor two lower value for the soft-tissue pump component. You may want to compute this from AOU from WOA data. Further, I wonder how you do you treat alkalinity for the abiotic (no soft-tissue, no CaCO3 counter pump) formulation. (This should not affect the major results you show, though.)

dz=500m: Due the results (correlations, main story) depend on the choice of the box depth?

Results:
no further comments!

Conclusions/follow up
It is interesting to see that the 1-D box model proposes such a simple perspective on marine CO2-uptake variability. Very early after Pinatubo, Keeling sen observed what at that time had been referred to as the Pinatubo atmospheric carbon anomaly (eg Sarmiento 1993; Nature, 365, 697). Given the discussion in that paper, I wonder whether the 1D-model perspective would also survive a more in depth analysis including 13C and oxygen uptake. The authors may want to elude on this briefly in the paper.

Data/code: I assume that the code, which is currently shared privatly will become fully public on figshare after publication. Data sources are given. I note, that the code/data for the DeVries model seem to be only partially available, and partly only on request. But this is not critical for this publication, I think.

Reviewer #2

I find this article to be well organized, well written, and convincing. I also think the main point could be articulated somewhat more clearly. Specifically, much of the article focuses on arguing that forcing rather than internal variability controls variations in the ocean carbon sink. However, the 2019 DeVries et al. paper doesn't use the term "internal variability", just climate variability. For clarity (i.e., to help the community follow your logic even more easily), I think it would be useful for the authors to more explicitly state that the influence of 1990s climate variability on the ocean (i.e., Figure 4A of DeVries et al.) is in fact the result of the ocean's recovery from Pinatubo cooling, and thus a response to external forcing. The smaller climate variability of the 2000s may be more reflective of the overall importance of climate variability on the ocean carbon sink for these two decades - with external forcing being the dominant control over this period. This article also helps to explain why there is global coherence in the ocean carbon uptake rate being greater in the 2000s than 1990s, which could be emphasized.

Something the authors may want to consider is that there may be ocean responses to climate variability and climate change that are not presently being expressed. Therefore, it could be worth acknowledging in the text that marine carbon cycle processes (e.g., stratification and its effects on the functionality of ocean ecosystems - e.g., Kwon et al., 2009) could be altered by climate change and variability in the future, which may then compete with external forcing to affect the ocean carbon sink. At present, this article could have the unintended side effect of deemphasizing the importance of many processes that are poorly understood and poorly represented in models. Acknowledging the short time period over which the analysis was conducted is advised to avoid unintended misinterpretations by people both inside and outside of the climate community.