

Reviewer 1 (Pierrot)

Reviewer comments: normal font

Author replies: bold font

General Comments:

The article describes in detail a new mathematical method called “Furthest First” to calculate the optimal adjustments to apply to measured parameters on individual cruise and produce an internally consistent data product, the Global Ocean Data Analysis Project version 3 (GLODAPv3) which spans decades of surface and interior biogeochemical observations around the globe.

GLODAP is fundamental to tracking how the ocean functions as the planet's primary climate buffer. By providing a standardized, three-dimensional view of the ocean interior, it allows scientists to measure how much human-induced stress the marine environment is absorbing and how those changes alter global climate feedback loops. It helps quantifying the ocean carbon sink, assess ocean acidification and ground-truth climate projections. Improving the quality of the product is crucial for science and it validates the purpose of this article . It correctly mentions that it does not pretend to improve the accuracy of the product but simply the internal consistency, which is all this exercise can hope for, while reducing the possibility of regional or other biases and preserving as much as possible the potential trends present in the data.

The reviewed article is very well-structured, providing a clear and logical progression that enhances its overall readability. It effectively begins by identifying the critical limitations and unresolved issues of the previous methodology, establishing a strong justification for the study. Building on this foundation, the authors clearly explain how their newly proposed method directly addresses and resolves these historical shortcomings, specifying that a major advantage is its iterative approach to determining adjustments, which optimizes data refinement. The methodology itself is described with excellent detail, ensuring the approach is transparent and reproducible. Furthermore, the authors effectively demonstrate that the new method is particularly well-adapted to the flexibility required for such an exercise. They clearly explain how it leaves essential room for field oceanographers to weigh in, and limit adjustments made to specific cruises based on scientific criteria.

The clear description of the methodology effectively demonstrates why this approach is perfectly tailored to the problem at hand. Importantly, the authors provide a clear rationale for why the mathematical results are entirely sound from a biogeochemical perspective.

The proposed methodology is sound, and its validation via simulated data clearly demonstrates its superiority over the previous approach. This work holds notable scientific significance because it improves a data product of wide importance to the community. Structurally, the manuscript is excellent, featuring concise language that demonstrates the authors' expertise. The availability of the open-source code ensures

robust reproducibility and allows the method to be seamlessly applied to future datasets, maximizing its scientific utility.

Thank you for your very positive assessment of the manuscript and constructive feedback.

Specific comments:

I only have a couple comments about sections I found were not very clear to me.

Starting on line 44, the authors state that “...while GLODAP cruises are well-connected within the major ocean basins, they are relatively poorly connected between basins.”. Could the authors explain what they mean by “connected”? I’m guessing they can only be connected by crossovers with trans-basins cruises?

Yes, we mean connected by crossovers. We revised the sentence to be clearer (added words are underlined): “A network analysis revealed that the most likely cause is that while GLODAP cruises are well-connected by crossovers within the major ocean basins, they are relatively poorly connected by crossovers between cruises in different basins.”

If that’s the case, I am not clear why this would mean the “...differences between basins probably reflect random uncertainties in cruise pair offsets in the connecting cruises, which do not average out to zero because of the scarcity of connections, rather than true regional biases that should be removed with adjustments.”

Consider two separate clusters of cruises (A and B) that are each internally consistent (i.e., they have been adjusted such that within each cluster the offsets have been minimised). Now imagine one cruise being added (C) that has one crossover with one cruise in A and one crossover with one cruise in B. Let crossover A-C = +2 and crossover B-C = -2. If clusters A and B are each internally consistent, then the optimal solution that satisfies the complete network A-B-C is to adjust the whole of cluster A down by 4 relative to the whole of cluster B (or B up by 4, or some intermediate). But as this between-cluster offset is based on only two crossovers, it may well be an artifact of random uncertainties rather than a true bias between the clusters. More crossovers between A and B would help determine whether the offset is real. We think it is likely to be due to random uncertainties in the GLODAP case rather than real biases because we cannot imagine a reason why all cruises in one ocean basin would be biased high relative to another basin; the biases do not correlate with measurements from any particular country or laboratory.

On line 67, the authors state that “...individual cruises are likely to end up with non-zero offsets after adjustment.”. It seems to me the whole procedure aims at minimizing the offsets, not making them zero. Something does not make sense to me here.

The procedure does aim to minimise the average absolute offsets and it is generally possible to find a solution where all are equal to zero. We added the word “average”

to make it clearer that we're talking about the weighted mean cruise offsets rather than individual crossovers: "individual cruises are likely to end up with non-zero average offsets after adjustment."

On line 202, "Supplementary Information" is mentioned but I did not see any...!?!

This phrase was accidentally left in from an earlier draft of the manuscript – we have removed it.

Technical corrections:

Page 2. Line 35: I would specify at this stage that the data used for crossovers is deep data. I know it is mentioned later but I feel that it would help the reader understand early that the adjustments will not minimize offsets between surface data.

We updated the sentence as follows (added words underlined): "The crossover step compares deep (e.g., >1500 m) data..."

Page 6. Equation (2). I don't believe the term $T'_{ij}T$ is defined clearly.

We added after the equation: "where superscript T denotes the transpose of the matrix."

Page 12. Figure 2. The change of scale after the vertical line should be clearly indicated.

We added to the caption: "Note the change in horizontal axis scale at 10,000 iterations, indicated by the vertical black line."

Page 13. Figure 3. These graphics are very nice. Unfortunately, the small nodes are practically invisible, especially when the article is printed in black and white. Would the authors consider adding a black thin border around the nodes to increase their visibility?

Thank you. We tried putting edges on the nodes but they are too small for it to work well, and they cannot be easily made larger without overlapping. The nodes that are difficult to see can still be located by looking at the pattern of the edges (lines between nodes). We think that the current appearance is the best compromise.

All figures: separation of units with "/". I would suggest placing the units within parentheses as "/" has a specific meaning and doesn't read well in this case.

The slash has its usual meaning (i.e., division). This is the way recommended by the IUPAC "Green Book" (Brett et al., 2023) (Section 1.1 on page 1 of the 4th Edition, Abridged Version) to denote units on figure axes and in table headers. In brief, a quantity (e.g. mass = 10 kg) is a value (10) multiplied by a unit (kg), so to obtain the bare value for an axis label we need to divide the quantity by the unit (mass / kg = 10). We have however added parentheses around compound units in the revised

manuscript to remove ambiguity and updated “yr” to “a” to conform fully with the IUPAC recommendation.

References

Brett, C. M. A., Frey, J. G., Hinde, R., Kuroda, Y., Marquardt, R., Pavese, F., Quack, M., Stohner, J., and Thor, A. J. (Eds.): **Quantities, Units and Symbols in Physical Chemistry: 4th Edition, Abridged Version**, Royal Society of Chemistry, Cambridge, UK, <https://doi.org/10.1039/9781839163180>, 2023.

Reviewer 2 (Sabine)

Reviewer comments: normal font

Author replies: bold font

This manuscript provides an important description of how the “corrections” were made to the GLODAPv3 data product. It gives a clear description of what they did and why. They also do a nice job of comparing how this approach differs from previous approaches. It does make me wonder what they do when there is no crossover, or they think the crossover is not valid for some reason (e.g. too far away). They discuss limited crossovers between basins, but does that mean that every other cruise has good crossovers to use? I have a few other nitpicky questions below, but overall thought this was an excellent manuscript worthy of publication.

We thank the reviewer for the positive assessment and constructive feedback.

What to do when crossovers are limited or invalid depends on the specific application. In GLODAP, cruises with no or insufficient valid crossovers are not included in the crossover and inversion analysis. For more details, please see the dataset description paper (Lange et al., 2026).

Lines 92:94 – The authors state that for some variables crossover differences are multiplicative rather than additive. Is there somewhere that states which variables were treated this way and why they are handled differently than the additive variables?

This is described in an earlier paper (Lauvset and Tanhua, 2015), which we have now cited in the appropriate part of the revised manuscript (Section 2.1). For things like this that are specific to the GLODAP application, rather than general features of the method, we provide only a brief overview of the GLODAP approach here as an example; the same variables might be better treated differently in a different dataset or application. This manuscript is intended to give a more generalised overview of the method, which can be applied in different ways.

Line 100 – I am concerned that the detailed explanation is cited as an in prep manuscript. This means that the reader cannot actually see it. Will this manuscript be published soon?

The data paper was submitted shortly after this one and it is available as a preprint (Lange et al., 2026). We tried to coordinate submission as much as possible but in the end it was necessary for one of the papers to cite the other before it was actually available. We have updated the citation to refer to the preprint now. However, these details are only specific to the GLODAP example and not an integral part of the FF inversion method being described here.

Figure 2 – Throughout the manuscript, there is a focus on “cruise adjustments”. I assume that means that they are adjusting entire cruises by one value, but I did not see any discussion of some of the possible subtleties in cruise uncertainty. What if a cruise has multiple legs and things change between legs? What if there are two instruments on a cruise and the two different instruments have different offsets? What if three or four carbon parameters are analyzed and there are ways to validate the measurements using different carbon pairs? Are these things considered, or is there an assumption that the PI has already done what they could with this type of additional cruise information?

This is an issue specific to the GLODAP application rather than a general feature of the FF inversion method. However, we agree that this could be an important principle more generally for users of the method to be aware of, so we added a paragraph to Section 2.1:

“In general terms, a ‘cruise’ is a subset of data that was measured and calibrated together such that any systematic bias in the values should be consistent and can be eliminated using a constant correction across the whole subset. Usually this corresponds to an individual oceanographic expedition identified by a common expedition code (expocode). However, in some circumstances an alternative approach might be needed, for example to account for differences between legs of an expedition or offsets between different instruments used to measure the same variable.”

Also, what is with the slash in the units of all the figures?

The slash has its usual meaning (i.e., division). This is the way recommended by the IUPAC “Green Book” (Brett et al., 2023) (Section 1.1 on page 1 of the 4th Edition, Abridged Version) to denote units on figure axes and in table headers. In brief, a quantity (e.g. mass = 10 kg) is a value (10) multiplied by a unit (kg), so to obtain the bare value for an axis label we need to divide the quantity by the unit (mass / kg = 10). We have however added parentheses around compound units in the revised manuscript to remove ambiguity and updated “yr” to “a” to conform fully with the IUPAC recommendation.

References

Brett, C. M. A., Frey, J. G., Hinde, R., Kuroda, Y., Marquardt, R., Pavese, F., Quack, M., Stohner, J., and Thor, A. J. (Eds.): Quantities, Units and Symbols in Physical

Chemistry: 4th Edition, Abridged Version, Royal Society of Chemistry, Cambridge, UK, <https://doi.org/10.1039/9781839163180>, 2023.

Lange, N., Lauvset, S. K., Carter, B. R., Humphreys, M. P., Woosley, R. J., Olsen, A., Bittig, H. C., Kozyr, A., Álvarez, M., Azetsu-Scott, K., Becker, S., Brown, P. J., Cotrim da Cunha, L., Dias, L., Hoppema, M., Ishii, M., Jeansson, E., Murata, A., Müller, J. D., Pérez, F. F., Schirnack, C., Steinfeldt, R., Ulfssbo, A., Velo, A., and Tanhua, T.: The Global Ocean Data Analysis Project version 3 (GLODAPv3) – an internally consistent biogeochemical data product for the world ocean, *Earth Syst. Sci. Data Discuss.*, 1–45, <https://doi.org/10.5194/essd-2026-496>, 2026.

Lauvset, S. K. and Tanhua, T.: A toolbox for secondary quality control on ocean chemistry and hydrographic data, *Limnology and Oceanography: Methods*, <https://doi.org/10.1002/lom3.10050>, 2015.