Report #1 by Referee #2 Patrick Rafter

A brief comment to say that I think that, based on the Aims & scope of ESSD, I think this work clears the bar for publication. However, I also think the other reviewer—clearly an expert in machine learning and statistics and probably other things—is providing priceless advice for producing a well-above average final product. I furthermore strongly approve the authors' willingness to improve their dataset.

Overall, it seems that my work here is done! Not that the work of reviewing is completed, but that the comments and requests are well above my expertise. And I am *thoroughly* enjoying the comments and responses because I am learning a lot. I'd like to thank the other reviewer and authors for providing this education.

R: We sincerely thank you for your valuable time, careful review, and generous recognition of our work. We are extremely grateful for your confirmation that our work aligns with the Aims & Scope of ESSD and meets the journal's bar for publication, which is a great encouragement to our team.

We agree with your high evaluation of the expert advice from the other reviewers, and we commit to comprehensively and rigorously addressing all of their comments to further elevate the quality of our manuscript and dataset. We also highly appreciate your approval of our commitment to improving the dataset, and we have completed all related optimizations in strict accordance with the reviewers' guidance, to ensure the dataset meets the highest standards of ESSD.

We are deeply grateful that you have found value in the review exchange, and we have likewise learned a great deal from insightful feedbacks from all three reviewers throughout this process. Thank you again for your outstanding support and professional contribution to our work. We will deliver a thoroughly revised manuscript that fully addresses all reviewers' comments, and we welcome any additional feedback you may have.

Report #2 by Anonymous referee #1

I feel the authors have done a great job of addressing my concerns. My only remaining concern is that some of the material in the response to reviews feels important for understanding the utility of this new data product, and, upon a quick read, I wasn't positive that all of that material had made it into the manuscript.

We sincerely thank you for your consistent, highly professional, and invaluable guidance throughout the multiple rounds of review. Your feedback has been critical to improving the transparency, reusability, and rigor of our work.

To directly address your concern, we have systematically integrated all technical details, validation results, and utility descriptions essential for readers to understand and reuse our data product into the revised manuscript. All these additions are clearly highlighted in the tracked revision version of the manuscript for easy verification.

Below is our point-by-point response to your specific recommendations:

I might urge the following measures:

1. Confirm that the 3D product (now on Zenodo) is adequately described in the paper and potentially the abstract.

R: We have completed a comprehensive update to describe the 3D data product in the main manuscript (at the end of Section 3.5 Reconstruction of $\delta^{13}C_{DIC}$), the abstract, and the Data Availability section, to ensure full transparency, traceability, and accessibility of the product for all readers. All revisions are clearly highlighted in the tracked revision version of the manuscript for easy verification.

Corresponding Revision Details

Abstract Update: We have added a clear description of the 3D data product and modified the relevant description to the end of the abstract (Line 24-30): "*Additionally, the validated GPR framework was applied to the GLODAPv2 1°×1° global interior ocean mapped climatology (Lauvset et al., 2016), producing a climatological gridded 3D $\delta^{13}C_{DIC}$ dataset for the Atlantic Ocean. These reconstructed $\delta^{13}C_{DIC}$ datasets provide new opportunities to resolve regional carbon cycle dynamics, validate Earth system models, refine estimates of oceanic carbon uptake on at least decadal timescales, and extend climate reanalysis records. The reconstructed $\delta^{13}C_{DIC}$ data, quality-controlled observational data from 51 cruises, and gridded $\delta^{13}C_{DIC}$ product are available at https://doi.org/10.5281/zenodo.18481145 (Gao et al., 2025).*"

Main Manuscript Update: We have added a detailed paragraph describing the 3D product at the end of Section 3.5 Reconstruction of $\delta^{13}C_{DIC}$ (Lines 438-445) to the main text: "Additionally, a spatially continuous 3D (1°×1° horizontal resolution, 33 standard depth layers) climatological $\delta^{13}C_{DIC}$ dataset for the Atlantic Ocean was generated using the validated GPR framework. This product was built on gridded environmental predictors (temperature, salinity, oxygen (used to calculate AOU), nitrate, silicate, and DIC) from the GLODAPv2 1°×1° global interior ocean mapped climatology (Lauvset et al., 2016) and monthly mean atmospheric xCO_2 spanning 1972–2013. The resulting product aligned with the coordinate system and structural conventions of the GLODAPv2 gridded framework, ensuring full interoperability with mainstream ocean biogeochemistry research workflows. It is specifically designed to address the critical limitations of discrete site-level $\delta^{13}C_{DIC}$ observations for basin-scale spatial analyses. This gridded product is

archived alongside our other datasets in the Zenodo repository (https://doi.org/10.5281/zenodo.18481145, Gao et al., 2025)."

We also modified Section **5 Data availability** (Lines 606–613) to explicitly detail all three datasets in the Zenodo archive, including the 3D gridded product: "*All products described in this work are publicly archived in the Zenodo data repository under DOI: https://doi.org/10.5281/zenodo.18481145 (Gao et al., 2025). This archive contains three complementary, community-standard compliant datasets: (1) a GPR-reconstructed $\delta^{13}C_{DIC}$ dataset based on the GLODAPv2.2023 Atlantic Ocean subset, with full interoperability with standard GLODAPv2 Atlantic Ocean subset workflows; (2) a comprehensive quality-controlled compilation of $\delta^{13}C_{DIC}$ observational data from 51 Atlantic cruises, supporting method reproducibility and independent validation; and (3) the 1°×1° climatological gridded 3D $\delta^{13}C_{DIC}$ dataset aligned with the GLODAPv2.2016b mapped climatology (Lauvset et al., 2016), for spatially continuous basin-scale analyses.*"

2. Consider moving the Appendix to a supplement with several sections and making appropriate references throughout the document (so people can quickly find the relevant sections).

R: We sincerely appreciate this valuable recommendation, which greatly improves the readability and navigability of our manuscript. However, the Earth System Science Data submission guidelines specify that technical and theoretical developments supplementary to the main text should be formally included as numbered appendices within the manuscript. Supplementary material (Supplement) is reserved exclusively for content that cannot reasonably be included in the main text or appendices (e.g., very large images, code, videos).

To fully meet both the journal's requirements and your recommendation, we have completed the following revisions: We have split the original single, lengthy Appendix into several sections (Appendix A1 to Appendix A4), each with a clear, focused section title, enabling readers to quickly locate the relevant technical details without disruption to the narrative logic.

We have added targeted, subsection-level in-text citations to the reorganized Appendix throughout Section 3.4 Additional validation using data extracted from a numerical model environment of the main manuscript, exactly where each corresponding technical detail is mentioned. Representative citations include: 1) A citation to Appendix A1 when introducing the grid-based subsampling validation framework, with additional specific citations to Appendix A1.2 (model configuration) and Appendix A1.3 (validation results and figures). 2)A citation to Appendix A2 when describing the observation-constrained sparse validation, with specific citations to Appendix A2.1 (experimental design) and Appendix A2.3 (results and figures). 3) A dedicated citation to Appendix A3 when referencing the supplementary full Atlantic domain generalization test. All citations are placed directly adjacent to the relevant content, allowing readers to immediately access the full technical details with a single cross-reference, fully meeting your requirement that readers can quickly find the relevant sections.

Specifically, the original Figure R3 is now presented as Figure A5 in Appendix A3. We have also added a corresponding in-text citation for Figure A5 in Section 3.4 of the main manuscript, ensuring this supplementary validation result is fully visible and accessible to all readers.

This adjustment achieves the goals of your recommendation, ensures full transparency and accessibility of all technical details for readers, and is compliant with the journal's formatting and

content guidelines.

3. Consider also adding figures R3 and R4 to the supplement and referencing them in the text. They are helpful for my thinking at least.

R: Thanks for your suggestions. Consistent with the structural revisions to the Appendix described in our response to Comment 2, we have integrated the original Figure R3 into the Appendix.

After careful evaluation, we have not included Figure R4 in the final manuscript for two reasons: first, its focus on eMLR-based downstream anthropogenic carbon analysis falls outside the core scope of this ESSD data manuscript, which centers on the development, validation, and release of the Atlantic $\delta^{13}C_{DIC}$ dataset; second, this analysis is only part of our preliminary ongoing work. We feel a full, publication-ready research requires additional multi-transect validation, rigorous uncertainty propagation analysis, and intercomparison with existing anthropogenic carbon products, all of which are ongoing and will be presented in a dedicated follow-up study.

To directly address your concern, we have added rigorous guidance on the appropriate use of the dataset in the Challenges and Limitations section of the main manuscript (Lines 559–566: "*The application of reconstructed data to estimate the Suess effect using extended Multilinear Regression (eMLR) methods in repeated hydrographic transects requires careful, case-specific consideration. Our preliminary analysis confirms that sample density significantly affects the anthropogenic $\delta^{13}C_{DIC}$ changes estimated via the eMLR method. Results derived from the sparse downsampling $\delta^{13}C_{DIC}$ data deviate from those obtained using full observational datasets, while the anthropogenic $\delta^{13}C_{DIC}$ changes calculated from our reconstructed high-density $\delta^{13}C_{DIC}$ data show strong consistency with the full-observation benchmark. However, the magnitude of decadal-scale Suess effect (~ 0.2 ‰) is comparable to the overall uncertainty of the reconstructed $\delta^{13}C_{DIC}$ values (0.11 ‰). Thus, further rigorous and comprehensive assessment of these uncertainties is critical to ensure the reliability of decadal-scale isotopic trend estimates derived from eMLR analyses, and to avoid biased or erroneous conclusions.*"). This content forms a complete logical closure with our preliminary verification results, clearly communicating the dataset's capabilities and appropriate usage boundaries to all readers.

That said, I feel the content of the manuscript is now publishable pending editorial review.

Thanks for your hard work.

We thank the reviewer for the constructive and extremely valuable comments and suggestions, which help us in improving our manuscript significantly. It is so appreciated. From the above replies and the revised manuscript, we hope we have thoroughly and carefully addressed all the comments one by one. Again, thank you for your encouragement.