Author Comment (AC4)

Reply to Community Comment (CC1) -Damián Leonardo Arévalo-Martínez

Manuscript: essd-2026-109

Title: A Comprehensive Global Aquatic N_2O Emission Database (GANED): Unravelling N_2O Emission Patterns from Different Water Bodies

Response to: Community Comment CC1

Original comment date: 09th June 2026

Dear Damian L. Arévalo-Martínez & Hermann W. Bange:

We sincerely thank you for the detailed and constructive assessment of our manuscript. Your comments identify important limitations in the scope of the database, the representation of marine observations, the transparency of the harmonization procedures, and the interpretation of the resulting patterns. We will address these concerns through substantial revision to the manuscript, a comprehensive quality-control check, and an updated data files. This Author Comment (AC4) response is submitted by the contact author on behalf of all co-authors, who have reviewed and approved the revisions to be made described below. A complete point-by-point account of the implemented changes, together with the revised manuscript, updated dataset, reproducible code, and data-change log, will be provided at formal resubmission following the ESSD final-response and finalize workflow.

We agree with the central concern that the current version of GANED underrepresents the breadth of available marine N_2O observations and that the term comprehensive overstates the present scope of the compilation. We will therefore revise the title and objectives, provide a direct comparison with established marine, inland-water, and freshwater databases, and clearly distinguish the current data release from planned future expansion. GANED will be presented as a harmonized cross-realm observational framework that complements, rather than replaces or competes with, established domain-specific resources. Major external marine resources, including MEMENTO, PANGAEA, and GO-SHIP, will be identified as priority sources for integration in a subsequent revision following provenance verification, permission and licensing checks, unit harmonization, and rigorous de-duplication.

CC1 Main Comments:

While the relevance of a continued improvement on our understanding of the cycling and emission of N_2O across ecosystems and over different time scales is clear, the observational basis, line of argumentation and methodological approach of this manuscript are insufficient to substantiate the claims regarding the global distribution and fluxes of N_2O; in particular, for the marine realm.

Response: We acknowledge this overarching assessment and agree that the marine component of GANED is substantially underrepresented relative to the available observational evidence. In the revised manuscript and database, we will take concrete steps to address this, as detailed below.

Comment 1

The major issue is that in their compilation the authors excluded an overwhelmingly large amount of data on N_2O concentrations which are indeed available. This is especially evident when comparing the data coverage of marine systems on Fig. 4 and published work by e.g. Yang et al. (2020) and Resplandy et al. (2024). The data coverage of the global ocean is restricted to a handful of data points, which clearly does not reflect the state of the art. Since a few of the manuscripts cited by the authors (e.g. Resplandy et al., 2024) explicitly refer to large databases such as MEMENTO, it is surprising that the authors opted for not using them. Other examples of databases which are openly available and have been used for work on N_2O, such as GO-SHIP and PANGAEA, were also not considered.

Response: We fully accept this and this is fundamental and valid point out. We also acknowledge that the exclusion of these databases was not adequately explained. This created a systematic bias against marine observations, where N_2O is frequently reported alongside only a subset of the physicochemical parameters we compiled for inland, freshwater and handful data points of marine systems. We will integrate marine N_2O concentration and flux records from MEMENTO, GO-SHIP, and PANGAEA databases into GANED, assigning appropriate *'Source-IDs'* and *'Site-IDs'* consistent with our relational structure together with the marine and coastal syntheses identified in the comment. Relevant inland-water and freshwater compilations, including the sources specifically identified by the reviewer, will also be assessed systematically. Where records lack some ancillary variables, these will be marked as 'NA' rather than excluding the observation entirely, thereby relaxing the inclusion criterion that previously functioned as an effective limitation to marine data.

We will cite MEMENTO (Bange et al., 2009), the GO-SHIP program, PANGAEA, and related data synthesis efforts by (e.g., Yang et al., 2020; Resplandy et al., 2024; Bange et al., 2024) explicitly in the revised manuscript and acknowledge the researchers who have built and maintained these resources. The revised submission will also include a source inclusion and exclusion ledger and a database-specific flow diagram. All figures specifically Fig. 4 and all statistical summaries will be updated to reflect the expanded marine coverage.

Comment 2

Although the data scarcity is particularly evident for open and coastal seas, even for inland aquatic ecosystems, recent work (see e.g. Zheng et al., 2022) does provide a compilation of observations which was disregarded in this manuscript. With regards to anthropogenically-driven emissions, which is a topic explicitly addressed by the authors, there is recent work by e.g. Tang et al. (2024) who provides solid data on the contribution of such settings where natural and human-impacted areas are adjacent.

Response: We acknowledge this. While we did extract data from many of the same primary studies, we may did not systematically cross-reference our compilation against that synthesis (suggested) to ensure completeness. Therefore, we will cross-reference GANED against Zheng et al. (2022) and incorporate any additional observations not already present. We will also review and incorporate data from Tang et al. (2024) and other recent compilations identified by the reviewer. Where overlap exists, we will document this rather than duplicating records.

Comment 3

In the absence of a reasonable explanation for the omission of data from both inland and marine aquatic systems, it is unsettling to read that a 'comprehensive' emission data base (as stated in the title) is presented, and that 'A formal validation against an independent global reference product is currently not possible due to the lack of a globally consistent benchmark dataset...' This, especially since the authors themselves cite the work by Tian et al. (2024), in which the current figures for different systems are included.

Response: This is a valid comment. The statement about the lack of a benchmark dataset was inaccurate given the existence of MEMENTO and similar like GO-SHIP program, PANGAEA for marine systems. We will revise the title. The word “Comprehensive” will be removed or replaced

with “Harmonized” from the title and from all claims in the Abstract, Discussion, and Conclusions. We will conduct a formal plausibility assessment by comparing GANED data against suggested databases for overlapping marine sites, against the global N_2O budget figures reported in Tian et al. (2024), and against other existing compilations (e.g., Wilson et al., 2018; 2020; Petrescu et al., 2021). The revised manuscript will describe the database as a versioned and provenance-preserving integration framework, not as a complete global inventory. We will report the degree of overlap and any systematic differences. We will also acknowledge incompleteness clearly throughout the manuscript, replacing language that implies exhaustive coverage with honest assessments of what the database covers and what it misses.

Comment 4

The manuscript devotes limited attention to marine systems, calls oceans and coastal waters major contributors in one section, and later describes the ocean as a minor source or sink. The explanation based on the limited extent of oxygen-minimum zones is not supported.

Response: We thank reviewer to correctly identifying this inconsistency in our manuscript. The apparent contradiction arises from two different perspectives: (i) the global budget context, where oceans are indeed the largest contributors to total aquatic N_2O emissions (primarily from oxygen-minimum zones (OMZs) and upwelling regions), and (ii) the per-unit-area perspective from GANED’s limited marine observations, where most sampled sites show low or near-zero fluxes because the database, as submitted, captures very few measurements within the key OMZs and upwelling zones. This is an artifact of our data coverage, not a real finding.

1. We will revise the discussion to explicitly separate per-area flux patterns (which are a property of the observation-level data) from total emission contributions (which require upscaling with area weighting). We will be clear that the low per-area fluxes in our current marine data do not contradict the well-established finding that oceans are the largest total source due to their vast surface area and the disproportionate contribution of OMZs.
2. We will add a dedicated subsection on marine N_2O dynamics grounded in existing literature (including Codispoti, 2010; Capone and Hutchins, 2013; Bange et al., 2024; Resplandy et al., 2024), discussing the role of oxygen minimum zones, equatorial and coastal upwelling systems, and the distribution of marine N_2O sources and sinks.

Any statements depicting oceans as a "minor sink" will be removed or corrected to reflect the well-established understanding that oceans are net sources of N_2O, with localized sink behavior in undersaturated regions being a minor component.

Comment 5

Yao et al. (2020) is used to support a global estimate although it addresses streams and rivers, Tian et al. (2024) is represented incompletely, and Rees et al. (2022) is cited in an inappropriate oxygen-minimum-zone context.

Response: We accept these corrections. We will conduct a systematic review of all citations in the revised manuscript to ensure each reference is used in a manner consistent with its actual scope and findings. Yao et al. (2020) will be cited only in the context of streams and rivers. Tian et al. (2024) will be described consistently as a global N_2O budget that includes both top-down and bottom-up components. Rees et al. (2022) will be used only in the Arctic and polar-ocean context and will not be cited as evidence for oxygen-minimum-zone processes. A complete citation rechecking will be conducted across the Introduction, Results, Discussion, and Conclusions. Each citation will be checked against the scope and conclusions of the original source, and broad generalizations will not be supported by studies restricted to a single aquatic domain. Numerical values, significant figures, units, and notation will also be standardized throughout the manuscript, tables, figures, and Supplement.

Objectives and Novelty:

(1) construct a harmonized database for data acquisition and observation.
(2) characterize the distributional patterns of N_2O concentrations and fluxes across various aquatic ecosystems.
(3) identify existing data gaps and propose future research directions to advance the understanding of N_2O dynamics in aquatic ecosystems.

Comment 6

With regards to (1) it can be argued that while such a database for inland and marine waters does not exist, individual products are readily available and steps towards harmonization are in place (see e.g. Wilson et al., 2018; Wilson et al., 2020; Petrescu et al., 2021).

Response: Objective (1): Rather than claiming to be the first harmonized database, we will position GANED as an attempt to integrate N_2O observations across freshwater and marine systems within a single relational framework, explicitly building on and linking to existing products rather than claiming to replace them.

Comment 7

With regards to objective (2), there are plenty of manuscripts... which address this point... the global vertical and zonal distribution is rather well known."

Response: Objective (2): We agree that the distributional patterns of N_2O are already reasonably well characterized, especially for marine systems. The added value of GANED lies in enabling cross-system comparisons using a common framework and in identifying inconsistencies between concentration and flux observations across aquatic types. We will revise to frame this more modestly and cite the existing distributional characterizations (Aho et al., 2023; Bange et al., 2024; Rosentreter et al., 2021).

Comment 8

As for objective (3)... the identification of gaps from this study lacks the robustness needed to substantiate such claims."

Response: Objective (3): We agree that our gap identification, particularly for marine systems, lacked robustness due to insufficient data coverage. With the integration of MEMENTO, GO-SHIP, and PANGAEA data, our gap analysis will be substantially improved. We will also explicitly compare our coverage against existing syntheses to identify residual gaps more rigorously

Methodological Issues:

Comment 9

The data compilation includes master and doctoral theses, as well as 'selected reports', which according to the journal's rules... are not allowed.

Response: We thank the reviewer for pointing this out. We will remove citations of theses and reports from the reference list in the revised manuscript. The data points sourced from these publications will be retained in the database (with the original source information), but in the

manuscript text, we will only cite peer-reviewed publications with DOIs or preprints with DOIs. We will add a note in the Data Source dataset documentation indicating that some records were sourced from academic theses and that the corresponding peer-reviewed publications (where they exist) are cited in the manuscript. We will make every effort to identify the peer-reviewed counterparts of thesis-derived data.

Comment 10

In section 2.1 (specifically l.120–124), the authors describe the procedure followed to search for data in bibliographic databases and repositories. After trying to mimicry that approach with some of the key words listed in the manuscript, the results show that the relevant literature (and databases) which are missing in the study, do appear. Under this scenario, it is unclear why these were not used for this manuscript.

Response: This is a fair observation. Our search focused on peer-reviewed articles reporting site-level N_2O observations and may not have captured database repositories (MEMENTO, PANGAEA) that do not appear as individual journal articles in WoS/Scopus searches. Our initial approach was designed for extracting observations from individual studies rather than harvesting structured databases. This was a significant limitation of our search strategy. We will expand our data acquisition to include systematic searching of data repositories and will report this process explicitly in the revised manuscript.

Comment 11

Based on that description, it is unclear if one, several or all of the criteria have to be met in order for the dataset to be included.

Response: We acknowledge this ambiguity. In practice, all four criteria (Line: 124-128) were intended to be met. We will revise the inclusion criteria as follows: criteria (1) and (2) remain mandatory (direct N_2O measurements with geospatial coordinates); criteria no. (3) is retained (peer-reviewed or DOI-accessible sources); criteria no.(4) is relaxed to recommended but not mandatory, observations without all ancillary variables will be included with *'NA'* values for missing parameters. This revision is directly responsible for enabling the integration of MEMENTO and other suggested marine datasets.

Comment 12

In line. 143-144, the authors indicate that the proposed database "builds upon analogous compilations in aquatic GHG research". However, it is unclear which are those compilations.

Response: We will explicitly cite the analogous compilations, including GRiMeDB (Stanley et al., 2022) for methane (CH_4), the global carbon dioxide (CO_2) database from the Global Carbon Project, and MEMENTO (Bange et al., 2009) for marine N_2O. The relational structure of GANED was adapted from these precedents.

Comment 13

It is unclear what exactly does this mean (average values, gridding procedure, etc.)... variability across gradients in e.g. salinity and oxygen are typically hotspots for N_2O production. Because of this, this assumption bears a serious risk of masking some of the natural variability.

Response: This is a critical and valid concern. The averaging of multiple depths at a single site was applied in a limited number of specific cases (primarily the Pearl River basin and Guangdong Province streams), where samples were collected from multiple points within a single cross-section and data were reported as mean values. For vertical profiles in stratified systems (lakes, reservoirs, marine waters), we agree that averaging across depths masks the critical redox-driven variability that often produces N_2O maxima at oxycline interfaces.

We will revise the database to retain depth-resolved records wherever original data allow. For marine datasets from MEMENTO and GO-SHIP, vertical profiles will be preserved with depth as an additional metadata field. We will add a *"Depth_m"* field to the concentration and flux datasets and will include a flag (*"Aggregated-Depth": Yes/No*) indicating whether a record represents a depth-integrated or depth-specific measurement. The specific averaging rules applied and the number of affected records will be reported in the revised manuscript.

Comment 14

A discussion on the compatibility of those methods (e.g. chambers vs. estimating air-sea gradients) is not provided. Also, although recalculation of gas transfer coefficients (k) based on previous syntheses are mentioned, neither the exact procedure nor the corresponding citations were included.

Response: We agree this is a significant revision. This is essential for users to interpret and filter flux data appropriately. In the revision, the *'Fluxes table'* will include explicit metadata describing the origin and calculation of each flux estimate. For records derived using concentration-gradient approaches, we will revisit the original studies and add the following fields: *'Flux_Origin'* (chamber-static, chamber-floating, conc-gradient-k_{600}, conc-gradient-direct-*k*, both-methods, or NR), *'k-value'* (reported gas transfer velocity in md^{-1}); *'k_method'* the parameterization applied (e.g., Wanninkhof 2014, Raymond 2012);'C_{eq}*_method'* (Method used to calculate equilibrium N_2O concentration (e.g., Weiss-1980; Weitz, 2019);'Solubility_formula'; Temp_used_conversion' (°C), 'Wind_used_for_k' (in situ, regional station, ERA5, or not reported), and 'Atm_N_2O_used' (the atmospheric N_2O concentration assumed in the source study). When the original publication does not provide the required information, the field will be coded as 'NR/NA'. A new Section 2.3.3, entitled *'Flux Provenance and Methodological Comparability'*, will describe the calculation assumptions, measurement principles, and limitations associated with each flux origin. Regarding the suggested comparative analysis of chamber-based vs. concentration-gradient fluxes: we will explore this using the subset of studies that report both methods at the same sites. We acknowledge such studies may be scarce, but even a qualitative comparison would be informative.

Comment 15

line.257–260: Based on the current description, it is unclear how including isotopic data helps increasing the measurement accuracy and comprehensiveness of the proposed database. One could generally agree in that having isotopic evidence provides more insights into processes than what could be gained by evaluating concentrations alone. However, having the data on a compilation per se does not result in that effect

Response: We agree. The reviewer is correct that simply including isotopic data in the database does not automatically improve measurement accuracy. The statement that isotopic data increase measurement accuracy will be removed. Isotopic composition, including $\delta^{15}N$, $\delta^{18}O$, and site preference (where available), will be described only as ancillary process-diagnostic information that may support source attribution and pathway interpretation. Isotopic observations will not be used to validate or increase the accuracy of concentration or flux measurements unless an original study explicitly reports an independent validation procedure. Their availability, analytical method, and linkage to the corresponding N_2O observation will be documented separately.

Comment 16

The procedures followed as part of the quality assurance are superficially (and not quantitatively) mentioned, which makes it challenging to judge on the credibility of the approach.

Response: We will substantially expand the quality assurance section with quantitative details: the exact number of records flagged at each QC step, the specific outlier thresholds applied per aquatic type, the cross-verification procedure, and the handling of extreme values. The revised workflow will preserve the original reported values and units, the conversion equation, the person and date of verification, and a correction or exclusion note. Automated checks will cover coordinate ranges, units, physically implausible values, duplicate records, referential integrity, date consistency, and method-specific required fields. Suspected outliers will be flagged, not deleted, and will be excluded only when verification against the original source demonstrates a transcription, unit, or attribution error.

Closing response:

We appreciate that the issues raised extend beyond citation completeness and identify fundamental limitations in the current scientific scope, data coverage, methodological transparency, and interpretation of the manuscript. Accordingly, the revised submission will be treated as a substantial reconstruction of both the database and the associated analyses. We will revise the scope and claims of GANED, expand and harmonize the underlying data sources, strengthen quality-control and provenance documentation, and reassess all statistical analyses after database rebuilding. The current global marine conclusions, driver interpretations, temporal assessments, and predictive statements will be demonstrably supported by the expanded dataset, rigorous quality assessment, and comprehensive re-analysis

We thank the reviewers for identifying these problems and for providing a clear pathway toward a more rigorous, transparent, and reusable data product. A complete point-by-point description of the changes will accompany the revised manuscript upon resubmission.

On behalf of all co-authors,