Response to the reviewers — essd-2026-376

"The consistent in-situ global gridded temperature and salinity dataset, CORA OA 1960–2024"

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We thank both reviewers for their careful reading of the manuscript and for their constructive comments. Together with the Editor's recommendations, they led us to revise the manuscript substantially. Several sections were rewritten, three figures and four tables were added, and the ocean heat content (OHC) analysis was fully recomputed on a common basis.
Reviewer comments are reported as ****RC**** and our answers as ****AC****. All modifications are highlighted in the revised manuscript. Unless stated otherwise, line, figure, table and equation numbers in the RC refer to the original submission, and those in the AC refer to the revised manuscript.

****Renumbering of figures and tables in the revised manuscript:****

Original	**Revised**
Fig. 3	Fig. 7
Fig. 4	Fig. 7
Fig. 5	Fig. 7
Fig. 6	Fig. 8
Table 1	Table 2
Table 3	Table 8

****New material:****
- Fig. 3 (XBT probe types);
- Fig. 5 (data rejected by the climatological filter);
- Fig. 1, new lower panel (fraction of adjusted profiles);
- Table 1 (bias corrections);
- Tables 4–7 (detrended variability and RMS differences for SST and SSS);
- Table 9 (detrended variability of OHC).

Reviewer 1
****RC (main comment):**** **What is presented and discussed is mostly visual and qualitative (except for a table with the trends). I suggest that this could be made more quantitative, and in addition to trends, the authors could provide rms differences between the different time series (for example on*

figure 5 and 6, or even for the OHC), estimates of detrended variability for the different products (at least spatial averages, but why not also examples of spatial maps).
AC: We thank the reviewer for this suggestion and for the positive feedback on the material we posted in our reply (AC1). The revised manuscript now includes:
- the detrended standard deviation of basin-averaged SST and SSS, for each product and each sub-period (1960–1984, 1985–2005, 2006–2020), in Tables 4 and 6;
- the RMS differences between CORA OA and each reference product, for SST and SSS, in Tables 5 and 7;
- for global OHC, the linear trends (Table 8) and the detrended standard deviations (Table 9) for the same three sub-periods.
All tables are discussed in Sects. 4.1–4.3.
The SST and SSS values are those presented in AC1. **The OHC values differ from those in AC1.** Following the Editor's request for comparisons on a consistent basis, the GOHC of CORA OA, NCEI and IAPv4 was recomputed over a common domain (0–2000 m, 60°S–60°N) from the gridded fields, and all series were re-referenced to a common 2005–2020 baseline. GCOS is only available as a global integral, and NCEI only as pentadal means before 2005.
We also added the GOHC of the CORA OA first guess alone (Fig. 9, Tables 8–9). This isolates the influence of the background field on the temporal variability of the product. It shows that CORA OA closely follows the first guess during 1960–1985, departs from it during 1985–2005, and departs strongly from it after 2018, when the first guess is held constant.
With this diagnostic, we now state explicitly that the interannual variability of CORA OA before 1985, and in sparsely sampled regions, is damped towards the WOA23 decadal climatologies and should be regarded as a lower bound. The OHC RMS differences shown in AC1 were not retained; after recomputation, they were largely redundant with the trends and the first-guess diagnostic. Spatial maps of detrended variability are left for future work.

RC: *Bottom of page 3: it would be interesting to know to which extent the data set is MEOP-based, thus qualified/adjusted, and to which extent it is not the case. [...] turtle data in the southwest Indian Ocean [...] presenting large salinity biases.*
AC: Sect. 2.1 now explains that the Copernicus MYNRT dataset underlying CORA combines two kinds of animal-borne profiles:
- adjusted profiles from the MEOP database;
- profiles from other sources (near-real-time versions, independent programmes).
The new Table 1 gives the period and release of the MEOP adjusted profiles (2004–2017, release 2017-11). The new lower panel of Fig. 1 shows the yearly fraction of adjusted animal-borne profiles.
All animal-borne profiles, whatever their origin, go through the same CORA delayed-mode validation. Only measurements flagged good or probably good are used. Residual errors are markedly less frequent among MEOP profiles than among the other near-real-time profiles. The validation relies in particular on the MinMax test and an operator's visual check (Sect. 2.1), which is designed to detect biased sensors such as those described by the reviewer.

RC: *Line 106: a bit strange. Should it be instead of Tclim, Sclim, Tstd and Sstd (otherwise what are Tstd and Sstd?). As there is a combination of two terms, not obvious to the reader what is the proportion of the data that is filtered out in this step. I believe that it should be reported somewhere (maybe a percentage as a function of the depth?).*
AC: The notation of Eqs. 1–2 is now fully defined:
- T_clim and S_clim are the first-guess fields described in Sect. 3.2;
- T_STD and S_STD are the gridded standard deviation fields of the ISAS17 climatology;
- $\alpha = 6$ and $\beta = 2$ m (β carries a length unit, so the equation is dimensionally consistent).

As suggested, we added a figure (Fig. 5) showing the percentage of good and probably good measurements rejected by the filter, as a function of depth and of year. The filter rejects 1.63 % of the temperature data and 2.58 % of the salinity data. Rejections are more frequent below 2000 m, where the standard deviations are very small. For salinity they are also more frequent in the upper 70 m: there, 95 % of the rejected measurements lie within 200 km of the coast, a band that covers only 13 % of the ocean surface.

RC: *114: add 'to a threshold, noted Thres..' I guess later on line 117, the numbers reported are non-dimensional, and thus in units of vertical grid steps?*
AC: Yes. The paragraph has been rewritten (Sect. 3.1, Eq. 3). We now define the ratio r = Δz_obs/Δz_grid, where Δz_obs is the distance between the two observations bracketing a level and Δz_grid is the local grid spacing. r is therefore expressed in units of local vertical grid steps.
The measurement error standard deviation is:
- unchanged for $r \leq 2$;
- multiplied by 4, 9 and 16 for $2 < r \leq 4$, $4 < r \leq 8$ and $8 < r \leq 16$, respectively.
Values with $r > 16$ are discarded.

RC: *Lines 125-129 duplicated in lines 130-133.*
AC: The duplicated paragraph has been removed. Sect. 3.2 has been rewritten.

RC: *Figure 4: there is a change of data density increasing just after 2000m before the early 1990s (also near 800m). Is it linked to the change of grid spacing with depth and the criterium on maximum vertical data spacing. [...] In the figure 4 caption, for the lower panel, it indicates the median of the profiles anomalies, whereas on line 163, this is described as the 'objective analysis profiles'. Is it the same thing and thus after mapping analysis, or before the mapping.*
AC: We agree that this feature (Fig. 6, revised numbering) is linked to the interaction between the grid spacing, which changes with depth, and the vertical interpolation criterion (Eq. 3) applied to the low-resolution bottle casts that dominate the deep data before 1990. We acknowledge in Sect. 3.3.2 that this criterion is somewhat arbitrary, and that it will be revised in future versions of the dataset.
The lower panels show the innovation, computed *before* the mapping. It is the difference between the observations, after vertical interpolation onto the analysis levels, and the first guess at the same locations. The text, the caption of Fig. 6 and the captions of Tables 2–3 have been corrected accordingly.

RC: *179: 'SSS product described in Sammartino et al (2022)'. [...] Why not use the product of N. Kolodziejczyk L4 product (combining satellite salinity with in situ data) or the CCI V4.4 S product [...]*
AC: We added a justification in Sect. 3.4. The Sammartino et al. (2022) SSS L4 product combines in-situ and satellite data, and SST and SSS. This allows it to extend back to 1993. Products based only on satellite salinity (SMOS, Aquarius, SMAP), including the CCI SSS product, start in 2010. Given the 1960–2024 span of CORA OA, we preferred the longer common period. We acknowledge the caveat raised by the reviewer: because the product uses SST, it is not a fully independent salinity reference.

RC: *210: the comment puzzled me. Which data version of the sea mammal data is used. What are the temperature (and pressure) validation steps (if it is MEOP, or if not). There might also be issues of non-randomness of sampling by the sea mammals at time, thus potential biases. [...] There certainly are further issues if the real time data are used.*
AC: The data version and validation are now described in Sect. 2.1 and Table 1.
- **Versions.** The MEOP adjusted profiles come from release 2017-11 (2004–2017). The other animal-borne profiles are near-real-time or independent-programme profiles distributed through the Copernicus MYNRT product (extracted on 3 February 2025).
- **Validation.** All of them go through the CORA delayed-mode validation. It includes the MinMax test on temperature and salinity, with an operator's visual check, and automatic tests on pressure/depth (monotonicity and range).
- **Comparison with other products.** We do not know which quality control the other products apply to animal-borne profiles. Part of the spread among products in the Southern Ocean may therefore come from differences in data validation, and not only from data availability or first guesses. This limitation is now stated explicitly in Sect. 4.1.
We agree that the non-random sampling of animal-borne platforms (along migration routes and foraging areas) may introduce sampling biases.

RC: *237: I don't see from Table 3 a larger spread in the first period than in the last one (when spatially averaged!). The average trend is less in first period, but the spread is comparable. What is really clear is the very small interannual variability of CORA product when basin-averaged.*
AC: We agree that the original wording was misleading, and it has been removed. The OHC trends were recomputed (Table 8). The spread among products is comparable in 1960–1984 (1.8–3.3 ZJ yr^{-1}) and in 2006–2020 (8.9–10.8 ZJ yr^{-1}). The main feature of the early period is the lower CORA OA trend, which is the counterpart of a 30–50 ZJ offset of CORA OA in the 1960s (Sect. 4.3).
As the reviewer points out, the most striking feature is the small interannual variability of CORA OA when basin-averaged. It is now quantified by the detrended standard deviations (Tables 4, 6 and 9) and explained by the relaxation towards the first guess in data-sparse periods.

RC: *On Figure 5, means are not estimated over the same period for the ISAS20 product than for the others [...]. Instead of anomalies, as these are basin-scale averages, why not present instead of anomalies total SST on Figure 5 (as is done on figure 6 for SSS). For the Southern Ocean, I am wondering whether the different products use different defaults for temperature under sea ice, and how is the spatial average done. Is SST in all products, a foundation SST? And how is it estimated if not directly measured?*
AC: In the revised Fig. 7, all series are anomalies relative to their mean over the period common to all products (2002–2020). Differences in temporal coverage therefore no longer cause apparent offsets. Trends are computed over the available period of each product, and are directly comparable only between products with the same coverage, as now stated in the text. We also give the trends restricted to the years before 2023.
We kept anomalies rather than absolute SST. The products define their surface temperature differently:
- the uppermost analysis level for the in-situ gridded products;
- a bulk SST reconstruction for ERSST.
The products therefore have different mean offsets, which would hide their temporal variability on a common axis.

Regarding sea ice, all SST averages, including the Southern Ocean one, are computed between 60°S and 60°N. This excludes the regions covered by sea ice, so the products' different defaults for temperature under sea ice do not affect the comparison. The Southern Ocean average therefore covers 35–60°S. This is now stated in Sect. 4.1 and in the caption of Fig. 7.

RC: *On Fig. 6, IAP presents a strange large negative peak in SSS in 2001, not seen in all the other products, coming from Pacific and Indian Ocean north of 35°S. Any reason? [...] Also, in caption, add that deep ocean is areas with bottom depth > 1500 m.*
AC: Following the reviewer's suggestion, we examined the monthly surface salinity fields of IAPv4 (e.g. January 2001 and January 2003, relative to the January mean of 2004–2010). The negative peak comes from a large-scale, spatially coherent anomaly, stronger than −1 PSU, in the eastern Indian Ocean and the western Pacific Ocean. This pattern is unique to IAPv4 during that period and is absent from the other products. We therefore interpret it as a product-specific artefact in IAPv4 rather than a real oceanographic signal (Sect. 4.2).
The caption of Fig. 8 now specifies that the deep ocean corresponds to areas with a bottom depth greater than 1500 m.

RC: *On most figures, when referring to the Southern Ocean, the panel title reads 'South ocean', which should be changed. On other panels, ocean is not capitalized.*
AC: Corrected in the panel titles and captions (Southern Ocean, Atlantic Ocean, Pacific Ocean, Indian Ocean).

RC: *262: '… has been partly resolved.'*
AC: Corrected.

RC: *Some comparison mentioned at the beginning, such as SSS with the Sammartino et al product, are not really described (they appear on one figure).*
AC: The SSS L4 product is now described and its choice justified in Sect. 3.4. It is included in the discussion of Sect. 4.2 and in the quantitative comparison: detrended variability in Table 6 and RMS differences in Table 7, for 2006–2020.

Reviewer 2
RC: *Vertical interpolation relies on a linear scheme, which could prove problematic across specific regions and depth levels, particularly when dealing with low-resolution profiles. [...] I suggest comparing this technique against interpolation schemes employed by comparable datasets to better highlight its limitations and associated errors.*
AC: We agree that the linear vertical interpolation may be a significant source of uncertainty, especially for low-resolution profiles. We addressed this in four ways.
1. **Full documentation of the scheme.** Sect. 3.1 and Eq. 3 now describe the scheme, which follows the ISAS implementation (Gaillard et al., 2016). The measurement error is inflated as the distance between bracketing observations grows, and values are discarded beyond 16 grid steps.

Interpolated values from sparse profiles are therefore down-weighted in the analysis rather than treated as exact observations.
2. **Diagnostic of its effects.** We identify where and when the scheme affects the product:
   - the step-like data-density structures before 1990 (Fig. 6), linked to bottle casts;
   - the 30–50 ZJ OHC offset of CORA OA in the 1960s, which a basin-scale breakdown shows to be concentrated in the Atlantic, where most early profiles are bottle casts (Sect. 4.3);
   - the reduced number of near-surface data, which partly explains the lower surface variability of CORA OA and ISAS20, both of which use the same scheme (Sect. 4.2).
3. **Comparison with existing methodological studies.** Li et al. (2022) compared vertical interpolation methods and showed that linear interpolation of sparse profiles overestimates GOHC by about 40 ZJ before 1990. This is consistent in sign and magnitude with the early offset we find. Barker and McDougall (2020) and Cheng et al. (2014b) also discuss such schemes. These studies are now used to interpret our results.
4. **Implications.** A dedicated intercomparison would require reprocessing CORA OA with each scheme. The products considered here differ not only in their vertical interpolation but also in their mapping methods, first guesses and data selection, so such a comparison is beyond the scope of this data paper. The conclusions now state that improving the vertical interpolation is the highest priority for the next version of the product.

RC: *More details should be provided regarding the quality control criteria and processing procedures. Additionally, further elaboration is needed on the bias corrections applied to the dataset.*
AC: Sect. 2.1 has been substantially expanded.
- **Data provenance.** Source product, DOI and extraction date.
- **Quality control.** The delayed-mode validation is described:
  - the MinMax test, with reference ranges on 120 km cells derived from the previous CORA version, and an operator's visual check of flagged profiles;
  - automatic pressure/depth tests;
  - the meaning of quality flags 1–4.
  We also state that only data flagged 1 or 2 for both the parameter and the pressure/depth are used. The full list of tests is in the CORA QUID (Szekely et al., 2025).
- **Bias corrections.** A new table (Table 1) summarises the corrections applied to each data type, who applies them, and the references:
  - delayed-mode Argo adjustments;
  - MEOP adjustments of animal-borne profiles;
  - the Cheng et al. (2014) XBT correction;
  - no correction for CTD, bottle and MBT profiles.
- **XBT profiles.** The XBT paragraph has been rewritten. 375 500 XBT profiles (37 %) have an unknown or ambiguous probe type and cannot be corrected, so they are excluded from the analysis. A new figure (Fig. 3) shows the XBT profiles by probe type.

RC: *Ln 8, "The time series spans from 1960 to December of the previous year." [...] contradicting the 1960–2024 interval indicated in your title.*
AC: The sentence now reads: "The dataset is updated annually and covers the period from 1960 to December of the last complete year; the version described here covers 1960–2024."

RC: *Ln 15, remove the word "that".*
AC: Corrected.

RC: *The citation formatting throughout the paper is somewhat disorganized [...] (for instance, lines 18–19).*
AC: Citations have been corrected throughout. Parenthetical citations now appear in parentheses, and narrative citations as "Author (year)".

RC: *Ln 30, periodically updated. Please be more specific about the update frequency.*
AC: The abstract and introduction now specify the update cycle: a full reprocessing every November, extending the series to December of the last complete year, and an interim update covering the first six months of the current year released each June.

RC: *Ln 40-43, INSITU_GLO_PHY_TS_DISCRETE_MY_013_001 and INSITU_GLO_PHYBGCWAV_DISCRETE_MYNRT_013_030. More information is needed for readers who are unfamiliar with these products.*
AC: Sect. 2.1 now describes both products and their relationship: the CORA delayed-mode dataset is derived from the Copernicus near-real-time product. It gives the DOI and the extraction date, and refers to the product documentation for the data sources and the near-real-time validation.

RC: *The caption of Figure 1 is too short.*
AC: The caption has been extended. It describes both panels: the number of profiles by instrument type, and the yearly fraction of adjusted profiles for animal-borne CTDs and profiling floats.

RC: *Ln 87, change "where" to "were".*
AC: Corrected.

RC: *The text font in Figure 2 is too small to read.*
AC: Fig. 2 and 4 regenerated with larger fonts.

RC: *Ln 101, Equation 6 is cited before other Equations. Equations should be cited in order.*
AC: Corrected. Equations are now numbered and cited in order of appearance.

RC: *The entire paragraph explaining the discontinuities introduced by decadal climatologies appears twice verbatim.*
AC: The duplicated paragraph has been removed. We apologise for this oversight.

RC: *Ln 134. What does "yearly climatology" mean? Please explain.*
AC: This term was ambiguous and has been removed. Sect. 3.2 now gives a formal definition of the time-evolving first guess (Eq. 4).
- **Monthly fields.** Each of the seven WOA23 decadal climatologies (1955–1964 to 2015–2022) provides monthly fields. Each is assumed to represent the central year of its period.
- **Interpolation.** The first guess for a given month and year is a linear interpolation between the corresponding monthly fields of the two surrounding climatologies. A worked example is given (January 1973).
- **Particular cases.** The first guess is held constant after mid-2018. Seasonal fields are used below 1500 m.

RC: *Table 1 uses "Celsius degree". Standardizing this to "Degrees Celsius" or simply "°C" is standard practice.*
AC: Corrected. Units are now given as °C in all tables.

RC: *It is not clear to me how the temperature and salinity anomalies are determined and which climatology is used as the baseline.*
AC: Two kinds of anomalies are now clearly distinguished.
1. **Anomalies in the objective analysis.** They are computed relative to the time-evolving first guess derived from the WOA23 decadal climatologies (Sect. 3.2, Eq. 4). The innovation y − Hx_ref is defined in Sect. 3.3 (Eq. 5), and its statistics are shown in Fig. 6 and Tables 2–3.
2. **Anomalies in the inter-product comparisons.** They are computed relative to a common reference period for all products:
   - 2002–2020 for SST;
   - 2005–2020 for OHC and halosteric height.
   This is stated in Sects. 4.1, 4.3 and 4.4 and in the corresponding captions.

RC: *Equation (5) alongside its subsequent explanation remains confusing. Could you please clarify what Rii represents?*
AC: The objective analysis equations have been rewritten with consistent notation (Sect. 3.3, Eqs. 5–8). R is the observation error covariance matrix, assumed diagonal. Its diagonal elements $R_{ii} = \sigma^2_{UR,i} + \sigma^2_{M,i}$ (Eq. 7) are the sum of two variances:
- the variance of the scales not resolved by the analysis (representativeness error);
- the measurement error variance of observation i, possibly inflated by the vertical interpolation (Eq. 3).

RC: *Ln 177, spell out "LOPS/UMR".*
AC: Corrected: "Laboratoire d'Océanographie Physique et Spatiale (LOPS, UMR 6523)".

RC: *The manuscript oscillates between "Argo" and "ARGO".*
AC: Standardised to "Argo" throughout.

RC: *Figure 5, Are the mean SST from different products used the same baseline and comparable?*
AC: In the original version, each product was expressed relative to its own mean over its own period. In the revised Fig. 7, all products are expressed as anomalies relative to their mean over the period common to all of them (2002–2020), as stated in the text and caption. Trends are computed over the available period of each product, which is indicated in the figure legend.

RC: *Ln 233, NODC was merged into NCEI more than 10 years ago. NCEI should be referred, not NODC. Remove "one".*
AC: Corrected. NCEI is used throughout.

RC: *In both Figure 5 and Figure 6, the subplot titles and the captions refer to the "South ocean".*
AC: Corrected to "Southern Ocean" in the panel titles and captions of Figs. 7 and 8.

RC: *Ln 293, "To the contrary, the products based on a near real time processing..." is slightly awkward.*
AC: Replaced by "In contrast, products based on...".

We thank the reviewers again for their time and valuable suggestions.

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