Copernicus Marine Service

QUALITY INFORMATION DOCUMENT

In Situ TAC Objective Analysis products INSITU_GLO_PHY_TS_OA_NRT_013_002

Issue: 1.3

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CHANGE RECORD

Issue	Date	§	Description of Change	Author	Checked By
1.0	18/01/2017	all	Creation of the document	T. Szekely	L. Petit de la Villéon
1.1	13/03/2020	All	New Version of the ISAS software and of the climatology first guess	D. Dobler	L. Petit de la Villéon
1.2	25/11/2022	All	Dataset name change Document template change	T. Szekely	S.Tarot
1.3	28/08/2023	All	Dataset Update	T. Szekely	S. Tarot

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I EXECUTIVE SUMMARY

I.1 Products covered by this document

The document describes the quality of the global gridded temperature and salinity fields based on the near real time temperature and salinity product INSITU_GLO_PHYBGCWAV_DISCRETE_MYNRT_013_030.

The details of the product INSITU_GLO_PHY_TS_OA_MY_013_002 are given in **Table 1**.

Product Specification name	INSITU_GLO_PHY_TS_OA_MY_013_002
Short description	Objective analysis of monthly export from Coriolis database
Variables	Temperature (TEMP), salinity gridded field (PSAL), percentage of the variance (PCTVAR) and parameter error
Geographical coverage	Global (-77°N to 89.9°N, -180°E to 179.5°E)
Spatial resolution	0.5° in longitude and varying in latitude with 0.5° at equator and 0.1° at 77°S / 0.2° at 89.9°N (see *Figure 1*)
Vertical levels	There are 152 vertical levels, starting at 0 meters, then every 5 meters from 3 meters up to 100 meters, every 10 meters from 110 meters to 800 meters, and every 20 meters from 820 meters to 2000 meters in depth.
Temporal resolution	Monthly fields, centred on the 15th day of each month Covering 2015 to present
Target delivery time	Monthly
Update frequency	As Needed
Data source	Temperature and salinity profiles from INSITU_GLO_PHYBGCWAV_DISCRETE_MYNRT_013_030

***Table 1**: Short description of the product INSITU_GLO_PHY_TS_OA_NRT_013_002*

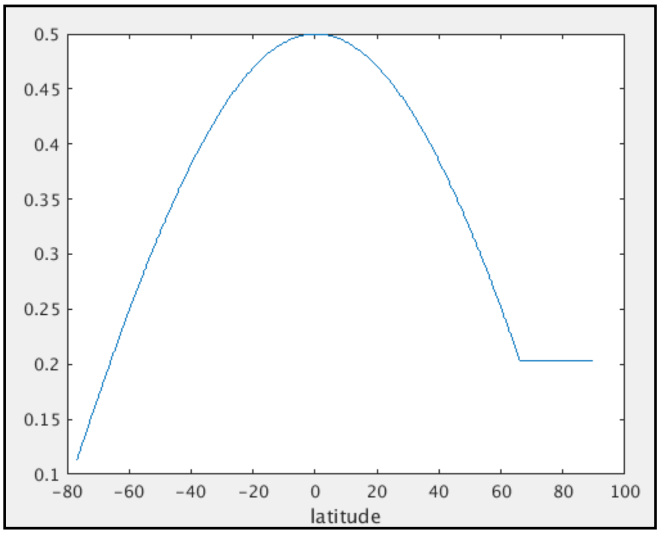

***Figure 1**: Latitude resolution of the product (in degrees) as a function of latitude.*

I.2 Summary of the results

This product is based on the objective analysis (i.e., the interpolation of sparse in-situ observations on a regular grid) of the temperature and salinity measurements taken from the global near real time dataset from the Coriolis Database (INSITU_GLO_PHYBGCWAV_DISCRETE_MYNRT_013_030 product) and linearly interpolated on 152 vertical levels between 0 and 2000 dbar. The objective analysis is performed using the In Situ Analysis System (ISAS) tool, based on the work by Gaillard et al. (2015) and developed by N. Kolodziejczyk and A. Prigent. This tool is based on the method developed by Bretherton et al. (1976). The method interpolates the temperature and salinity profiles in 3 dimensional fields, taking into account the correlation between nearby profiles, the bathymetry and the variability of the Rossby radius.

The accuracy of the method depends on the spatial resolution of the initial temperature and salinity sampling. Consequently, the results of the gridded fields are very close to the first guess in the poorly sampled zone.

To avoid misinterpretations of the gridded temperature and salinity fields, the product includes parameter error fields that consider the coverage. The error fields are a composite of estimated ocean variability in the sparsely sampled zones and measurement errors in the well sampled zones. Consequently, the estimated parameter error at a given point can vary from a few degrees Celsius or PSU in the early period to a few tenths of a degree Celsius or PSU after the full deployment of the ARGO program in 2008.

I.3 Estimated Accuracy Numbers

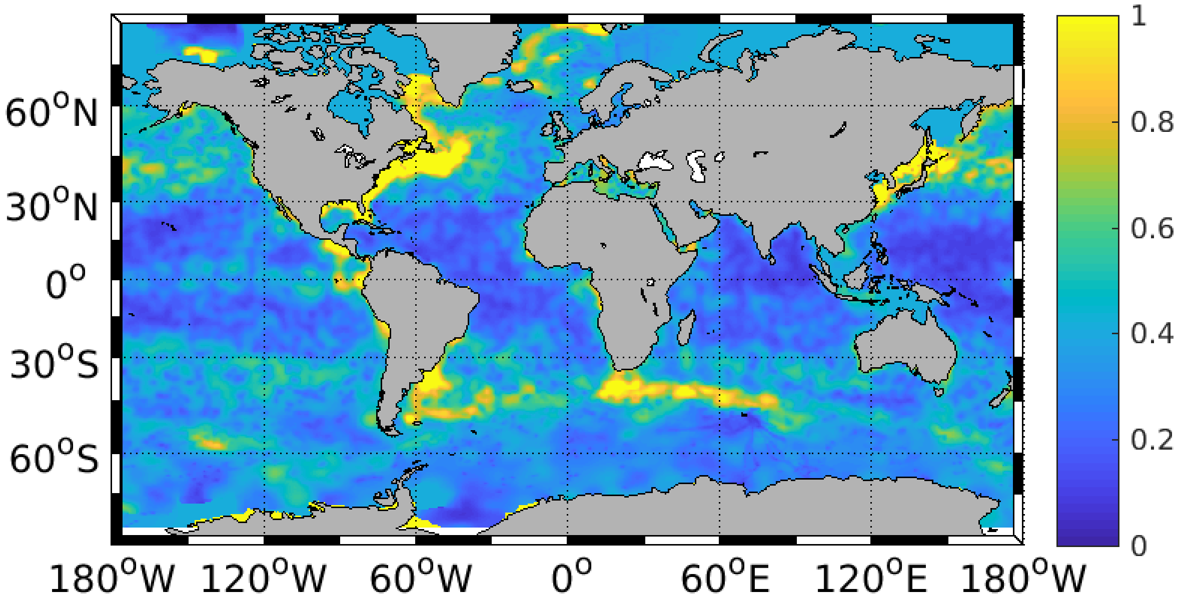

Figure 2: *Ocean surface temperature error (unit: °C) for January 2015 for the INSITU_GLO_PHY_TS_OA_NRT_013_002 product.*

Figure 2 gives an overview of the surface temperature error field for the NRT product for January 2015. The parameter error depends both on the local variability and the availability of data. For instance, the low parameter error along transects south of the Kerguelen islands (49°S, 69°E) are associated with sea mammal borne measurements.

The PCTVAR (percentage of the product parameter variance associated to the in-situ measurements) parameter is distributed along with the analysed field (TEMP of PSAL) and the error parameter. The value of PCTVAR is close to 100 when there are no measurements within 1 correlation length of the grid point, and close to 0 when there are plenty of in-situ measurements in the vicinity of the grid point.

Figure 3 shows the time evolution for different depths of the percentage of surface field with a PCTVAR lower than 80 % for temperature and salinity fields. It shows that the PCTVAR value is higher before the deployment of the ARGO program and quickly decreases in the early ARGO years. Consequently, the user should keep in mind that the accuracy of the global objective analysis solution is better during the ARGO era.

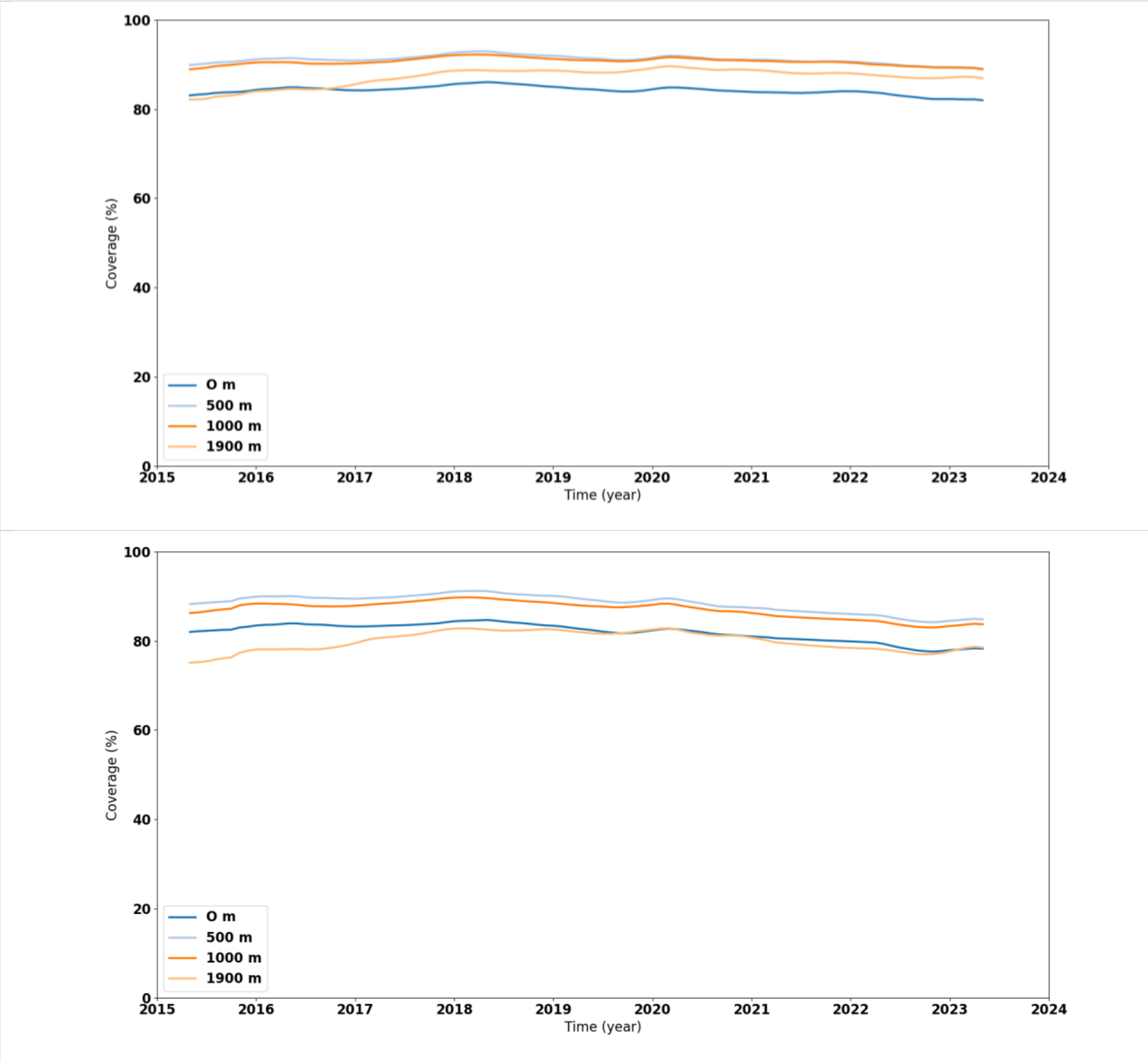

***Figure 3** Percentage of surface field with PCTVAR< 80 % for NRT temperature (top) and salinity (bottom) fields depending on the depth.*

II PRODUCTION SYSTEM DESCRIPTION

Production centres name: Ifremer

Poduction system name: Global ocean In-Situ temperature and salinity, delayed time mode validated, objective analysis (INSITU_GLO_PHY_TS_OA_NRT_013_002)

Description

The INSITU_GLO_PHY_TS_OA_NRT_013_002 product provides an objective analysis of temperature and salinity profiles distributed within it. This analysis was generated using version 8 of the ISAS tool (Gaillard et al., 2015). The temperature and salinity measurements are interpolated onto a regular grid using the optimal interpolation technique introduced by Bretherton et al. in 1976. To conform to this approach, the ISAS tool initially calculates temperature and salinity anomalies relative to a climatology. These anomalies are then mapped onto the regular grid, and the result is combined with the reference climatology to create the final dataset.

In the equations developed by Bretherton et al. in 1976, interpolation errors tend to be lower when the mean of the anomalies is minimized. Therefore, it is crucial to utilize climatologies that closely align with the observed data. Given the context of increasing ocean heat content, using a set of climatologies is essential to minimize interpolation errors. The choice of climatology (first-guess) for the objective analysis varies depending on the year of analysis. The specific list of climatologies and their corresponding analysis years is provided below.

The interpolated profiles are mostly ARGO floats (Wong et al, 2020), conductivity temperature depth profiles (CTD), XBTs, mechanical bathythermographs measurements and sea mammal measurements (Treasure et al, 2017).

II.1 ISAS Calculation method

This product is composed of temperature and salinity measurements collected from different sources by the Coriolis data center[2]. Most of the data concerned by the objective analysis are ARGO profiles, XBTs, CTDs, MBTs and sea mammals borne measurements. However, sole the profiles having both temperature and salinity are included to work with consistent fields of temperature and salinity. TAO/PIRATA/RAMA moorings are now included. Given the better QC and coverage with Argo, XCTD are now discarded.

First, the temperature and the salinity profiles are linearly interpolated to fit the ISAS grid vertical sampling (see table 1 for a vertical sampling scheme description). The extrapolated points with a low confidence level are flagged after Quality Checks (QC). The second set of QC warnings is triggered for profiles that deviate from the first guess by more than six standard deviations of the temperature or salinity first guess field. This step aims to exclude profiles with significant data-climatology anomalies in low-variability zones while retaining them in high-variability zones.

[2] https://www.coriolis.eu.org

The objective analysis parameters are summarized in eq (1), named correlation function:

$$C(dx, dy, dt) = \sum_{i=1}^{2} \sigma_{Li}^2 \exp\left(\frac{dx^2}{2L_{ix}^2} + \frac{dy^2}{2L_{iy}^2} + \frac{dt^2}{2L_{it}^2}\right) \quad (1)$$

With dx,dy,dt the distance between a profile and a grid point, $\sigma_{L1} = 1\ \sigma_{ocean}$ and $\sigma_{L2} = 2\ \sigma_{ocean}$.

The correlation scales are L_{1x} = 300 km, L_{2x} = Rossby radius, L_{1y} = 300 km, L_{2y} = Rossby radius and

$T_{1,2}$ = 21 days.

The objective analysis parameters are summarized in table 2 (See Gaillard et al., 2015 for details). The objective analysis is performed on measurement anomalies relative to a reference field, the first guess, at the 15th day of each month.

The first guesses are based on the ISAS 2017 monthly climatology and the ISAS version 7.0 is used. The whole dataset (2015 to 2020) has been reprocessed with this configuration.

Data with high spatial and/or temporal resolution are often subject to averaging to prevent an artificial bias toward specific measurements. This operation becomes necessary because the equation developed by Bretherton et al., 1976, assumes that all analyzed observations are independent. Consequently, when both high-frequency and low-frequency profilers fall within the correlation scales (as described in equation 1), they may carry similar weights in the equation (1). As a result, the solution may be unduly influenced by the high-resolution profiles rather than the sparser ones. To mitigate this issue, mooring data is averaged using a 9-day criterion, while other datasets, such as sea mammal-borne profiles and ice-tethered profiles, are averaged using a 5-day/5 km criterion. The criterion thresholds have been chosen to optimize the product data sampling and the product stability.

Lastly, the temperature and salinity grids are reconstructed by summing the objective analysis of the anomalies and the first guess field, following the method of Gaillard et al. (2015).

This method produces monthly gridded field of temperature and salinity and the associated PCTVAR fields. The PCTVAR fields are a gridded quantity varying between 0 and 100 and are related to the influence of the observations on the interpolated field. A PCTVAR value that tends toward 0 can be considered uncorrelated with the first guess. On the contrary, a PCTVAR of 100 is associated to a final value equal to the first guess (such as at high latitudes where few observations are available, (see **Figure 4**). Consequently, the user should keep in mind that the global objective analysis solution accuracy is better in the deep ocean zones and north of 60°S. Note also that small differences can occur between temperature and salinity PCTVAR since drifting Argo salinity profiles can be discarded by quality process.

Figure 4 shows an example of analyzed field map at surface for salinity (left) and temperature (right) and the corresponding PCTVAR values.

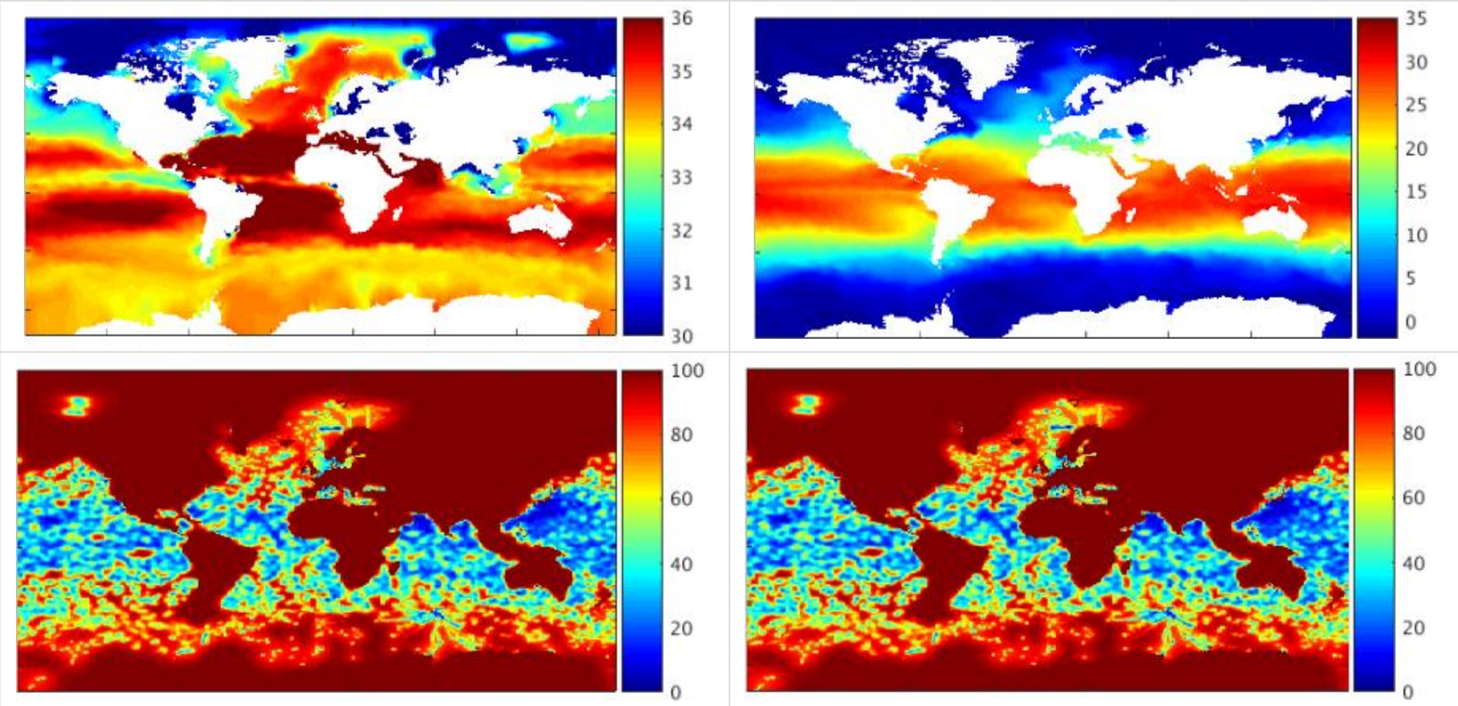

***Figure 4**: Surface salinity analysed field (top left, unit : PSU) and associated PCTVAR (bottom left, unitless) and surface temperature analysed field (top right, unit: °C) and associated PCTVAR (bottom right, unitless), for November 2015.*

II.2 Correction of the ARGO fast salinity drift

Since 2016, many of the ARGO profiles are affected by a drift of the salinity sensor (hereafter Fast Salty Drift, or FSD). According to the ARGO global data center, this problem may appear on up to 25% of the ARGO floats, leading to a positive drift of the salinity in ARGO based gridded products after 2016.

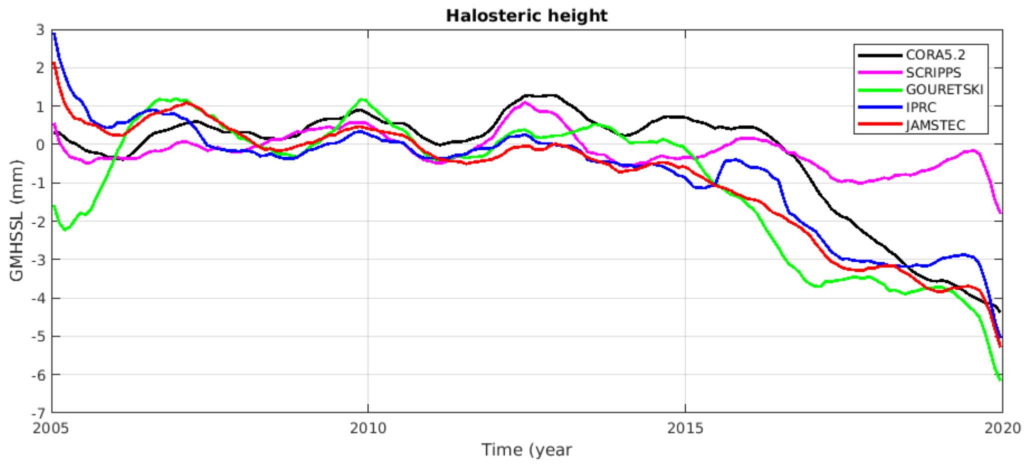

***Figure 5**: Halosteric height anomaly (HAS) for CORA 5.2 (December 2020 version) and gridded products from SCRIPPS[3], IPRC[4], JAMSTEC[5] and Gouretsky[6].*

Figure 5 shows that all OA tested products except for those of SCRIPPS have a Halosteric height anomaly (HAS) drift beginning in 2015-2016, from -4 mm (CORA) to -6 mm (Gouretski) drift in 2020. The SCRIPPS product differs from the others since it is the only product where ARGO real time profiles are adjusted to a climatology before the objective analysis.

The CORA product appears to have a limited drift compared to other products. In fact, the validation process of CORA data flags a fraction of the drifting floats, and the CORA OA production framework is synchronized to the ARGO delayed time mode validation and adjustment process, in order to integrate a maximum of ARGO delayed time mode adjusted profiles.

Furthermore, an adjustment method (described in Rommeich et al., 2009) is employed to correct the ARGO profiles, addressing drifting profiles that may go unnoticed within the ARGO framework. This algorithm aligns with the one utilized in the SCRIPPS product.

For each ARGO real time profile, the algorithm calculates the anomaly between the measurements and a climatology based on the OA products between 2005 and 2015. If the mean anomaly is lower than 0.25 PSU, the profile is adjusted by the value of the anomaly, otherwise the profile is flagged as bad in the objective analysis and excluded from the calculation.

[3] https://sio-argo.ucsd.edu/RG_Climatology.html
[4] http://apdrc.soest.hawaii.edu/datadoc/argo_iprc_gridded.php
[5] http://apdrc.soest.hawaii.edu/datadoc/argo_iprc_gridded.php
[6] Gouretsk refers to EN4 objective analysis with Gouretski and Cheng, 2020 XBT correction scheme.
Data access : https://hadleyserver.metoffice.gov.uk/en4/download.html

Figure 6 shows that the adjustment method eliminates almost all of the drift. The correction statistics are then analysed to flag the remaining FSD profiles in CORA. The adjustment is not applied before 2016 because the differences between the OA and OA adjusted curves before 2016 are caused by the anomaly period calculation and the ARGO global DAC listing removal. The list of rejected profiles with the higher adjustment values is quality controlled, and flagged when necessary.

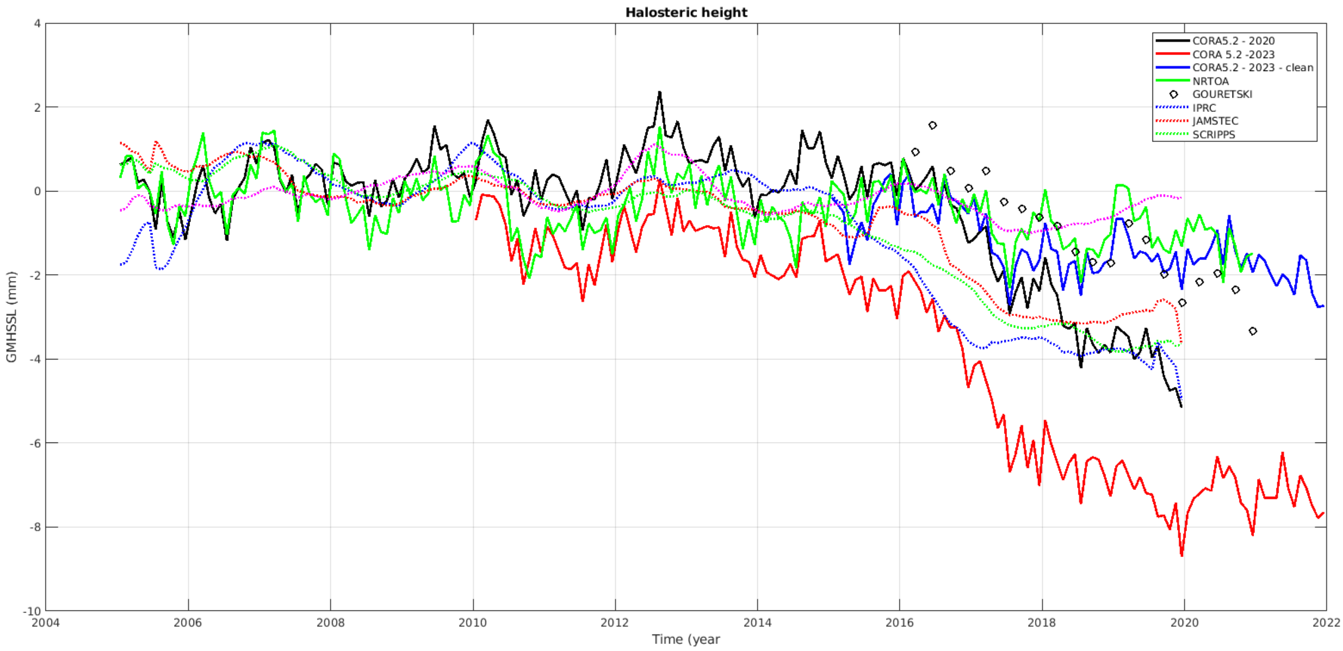

***Figure 6**: Halosteric height anomaly (HSA) for INSITU_GLO_PHY_TS_OA_NRT_013_002 and INSITU_GLO_PHY_TS_OA_MY_013_052 (December 2023 version, labelled "CORA 5.2 – clean" and "NRTOA" in the figure) and gridded products from SCRIPPS (pink), IPRC (blue), JAMSTEC (yellow) and Gouretsky. (green). Unit: mm*

III VALIDATION FRAMEWORK

The dataset has been validated by comparison with the previously used ISAS release and configuration (release 6.2 and first guess ISAS11). The main differences between 6.2 and 7.0 releases are:

- Correction in the computation of super-observations
- Treatment of platform as a whole.
- Tuning of alert system configuration
- Optimal Analysis configuration variance parameters.

The following diagnostics have been performed:

- Comparison of salinity fields and temperature fields
- Comparison of global heat content results
- Comparison of global salt content results.

These diagnostics have been performed between several test cases:

- Old 6.2 release/ISAS11 first-guess
- 7.0 release/ISAS13 first-guess
- LOPS ISAS15 Argo only product (Kolodziejczyk et al., 2017)
- CORA 5.2 product (Szekely et al., 2019).

In the Following section, some validation results will be presented. A comparison of monthly fields of the former and the latest version of the objective analysis (section IV.1), and a validation of the global ocean heat content in the objective analysis fields (section IV.2). A presentation of the global mean halosteric anomaly of the product have already been presented on section II.2.

IV VALIDATION RESULTS

IV.1 Comparison of salinity fields and temperature fields

Given that the ISAS15 dataset concludes at the end of 2015, the comparison of these datasets has been conducted for a specific month within this timeframe. For instance, the differences for November 2015 are shown in Figures 7 and 8. Notably, there are localized disparities, which can be attributed to various factors. Firstly, the dataset quality exhibits improvements when the new configuration was implemented, particularly due to the increased availability of 2015 delayed mode data in the 2020 run compared to the January 2016 run with the old configuration. Secondly, configuration adjustments also play a role in these differences. Lastly, variations in data inputs contribute to these distinctions, which are predominantly observed in northern area and coastal zones.

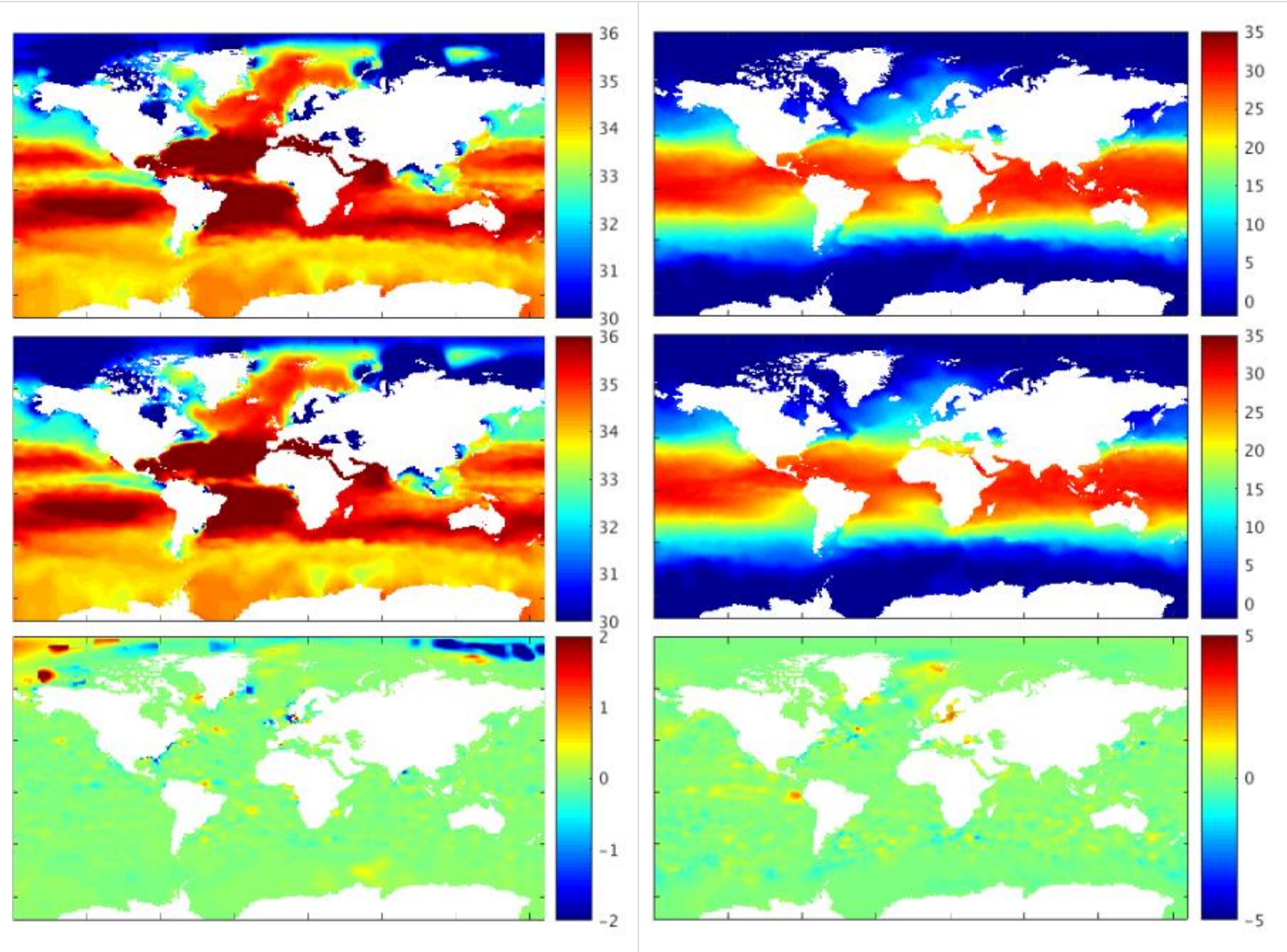

Figure 7*: Differences for surface November 2015 analysed fields of salinity (left panel) and temperature (right panel) between 7.0 configuration (top panels) and old 6.2 configuration (middle panels). The anomaly (New configuration minus old configuration) is shown on bottom panels for salinity (left) and temperature (right). Unit: PSU*

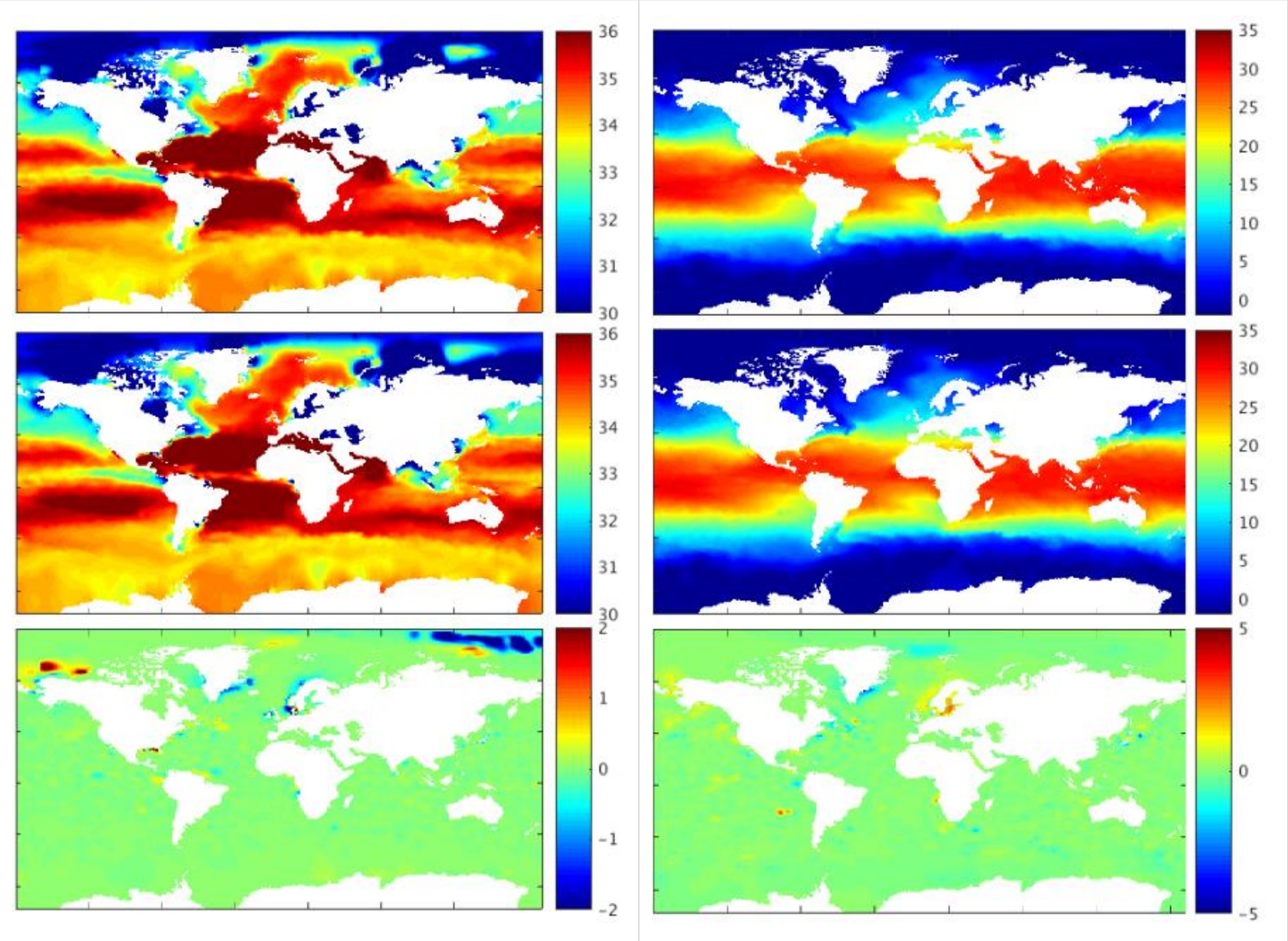

Figure 8: Differences for November 2015 surface analysed fields of salinity (left panel) and temperature (right panel) between 7.0 configuration (top panels) and ISAS15 Argo only configuration (middle panels).. The anomaly (New configuration minus old configuration) is shown on bottom panels for salinity (left) and temperature (right). Unit: PSU

IV.2 Global Ocean Heat Content anomaly comparison

The validation process began before the whole time series was reprocessed with the new 8.0 configuration. Nominally, to compute the Global Ocean Heat Content Anomaly (GOHCA), the mean of a chosen time period (in years) is removed. Given the fact that we had no access to this mean at the beginning of the validation process, a proxy has been chosen: the climatological first guess ISAS13 (Gaillard, 2015), which is also the ISAS15 dataset first guess and is calculated for the same time period as the CORA5.2 dataset first guess. When comparison is done with the old 6.2 configuration, the ISAS11 first guess is used. shows the evolution for the 3 products used in the comparison, the multi-product from Meyssignac et al. (2019) and the points for the first years of the new configuration. The overall anomaly scales are coherent between products. The global heat rate is especially coherent between 2013 and 2015. The ISAS15 trend follows closely the Meyssignac et al.(2019) trend between 2010 and 2015. The new NRT product follows the trend of CORA and previous NRT 6.2 analysed fields.

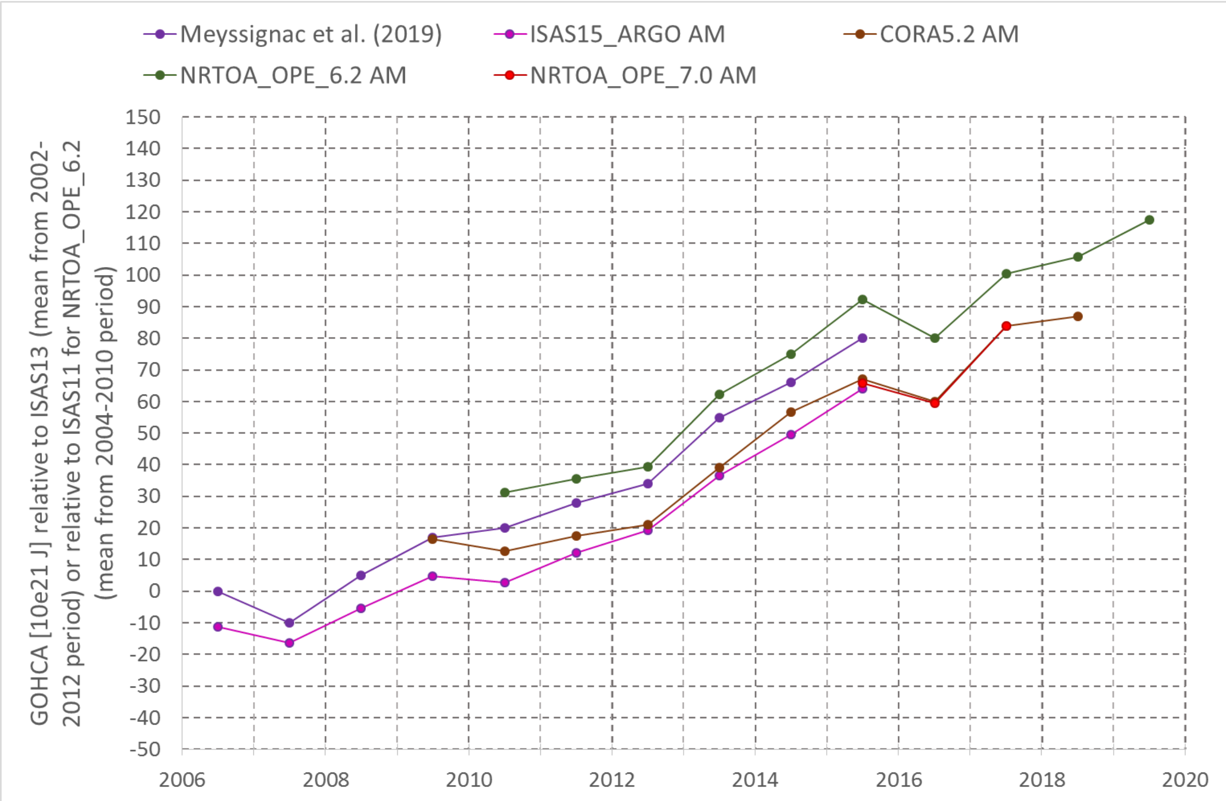

Figure 9: Evolution of the annual mean of the anomaly of the global ocean heat content (GOHCA) for the objective analysis with the 7.0 configuration (red curve), the former 6.2 configuration (green curve), the ISAS15 product (pink curve), the CORA 5.2 product (brown curve) and the multi-product mean from Meyssignac et al. (2019) (purple curve). The integral has been done on 0-2000 dbar.

The seasonal variability has also been compared between the various products for the year 2015. The maps obtained in the 0 to 300 dbar layer are presented in . The main structures are similar in shape, location and amplitude in the various compared products.

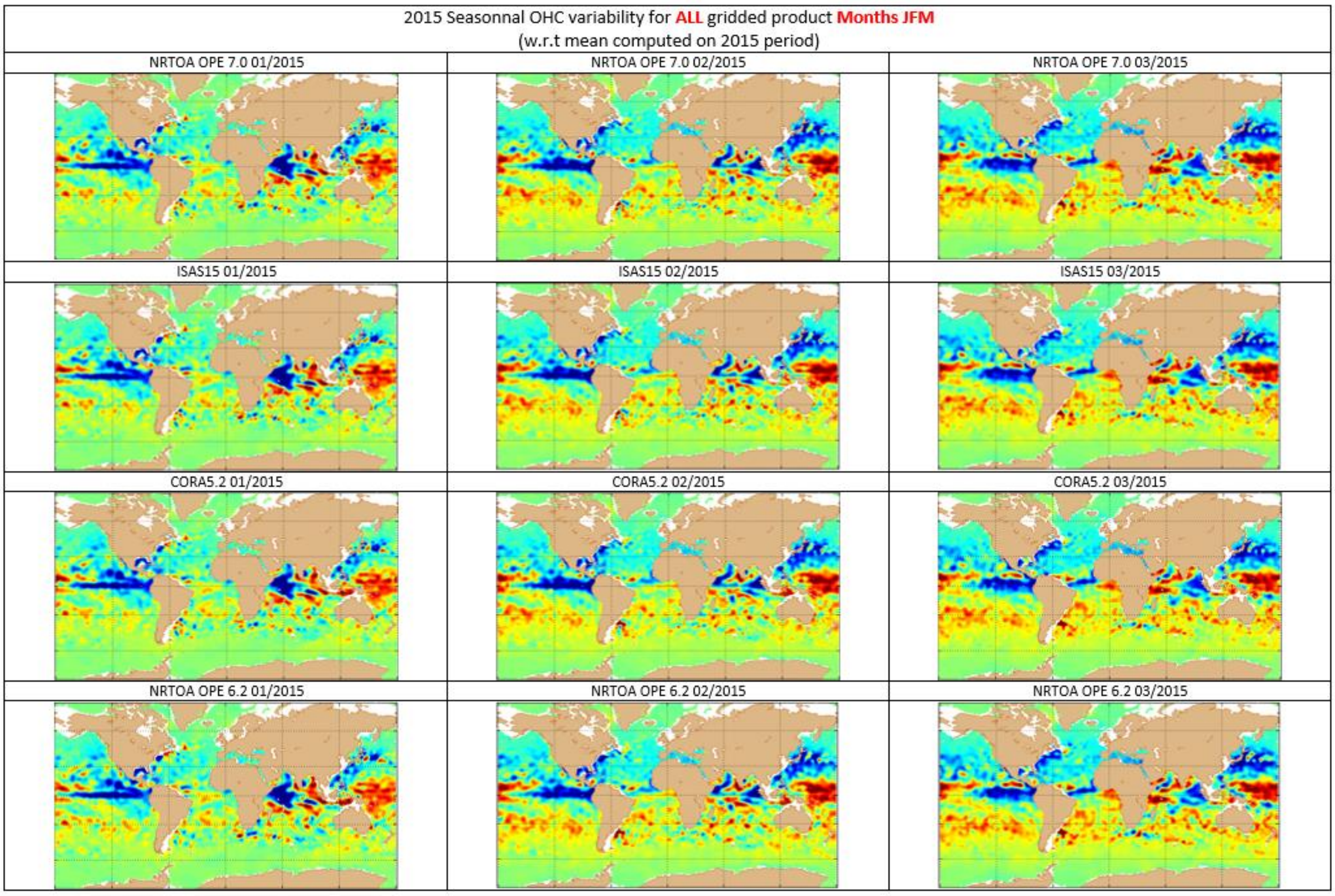

***Figure 10:** Seasonal variability (with respect to 2015 mean) of the ocean heat content anomaly in the 0 to 300 dbar layer.*

V SYSTEM NOTICIABLE EVENTS, OUTAGES OR CHANGES

Date	Change	Effects on the product
November 2023 release	Update of the objective analysis parameters and reference fields	Better accuracy of the ocean heat content estimation on the low data coverage zones (see section IV)

VI QUALITY CHANGES SINCE PREVIOUS VERSION

Date	Change	Effects on the product
November 2023 release	Update of the objective analysis parameters and reference fields	Better accuracy of the ocean heat content estimation on the low data coverage zones (see section IV)

VII REFERENCES

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