In-Situ TAC OA products
INSITU_GLO_PHY_TS_OA_MY_013_052

Issue: 1.12

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CHANGE RECORD

Issue	Date	§	Description of Change	Author	Checked By
1.0	27/01/2015	all	Creation of the document	T. Szekely	
1.1	06/03/2015	all	Revision after V5 acceptance	T. Szekely	
1.2	May 1 2015	all	Change format to fit CMEMS graphical rules		L. Crosnier
1.3	22/01/2016	all	Updates	T.Szekely	
1.4	March 6 2016	All	Changes after ARV2 report	T. Szekely	L. Petit de la Villéon
1.5	Jan 2017	All	Yearly update	T.Szekely	
1.6	Dec 2017	All	Yearly update	T. Szekely	
1.7	Mar 2018	All	Yearly update	T. Szekely	
1.8	Jan 2019	All	Yearly update	T. Szekely	
1.9	14/09/2020	All	Dataset update	T. Szekely	
1.10	05/07/2021	All	Dataset update, Correction of the fast salinity drift (ARGO)	T. Szekely	
1.11	17/02/2022	All	Dataset update	T. Szekely	S. Tarot
1.12	25/11/2022	All	New template Product, dataset renaming Dataset full reprocessing	T. Szekely	S. Tarot

TABLE OF CONTENTS

I EXECUTIVE SUMMARY

I.1 Products covered by this document

The document describes the Quality of the global gridded temperature and salinity fields released with the delayed mode temperature and salinity products and the associated error bars.

The details of the product CORA: INSITU_GLO_PHY_TS_OA_MY_013_052 are given on table1.

Product Specification Customer name	INSITU_GLO_PHY_TS_OA_MY_013_052
Short description	Objective analysis of the global reprocessing product INSITU_GLO_PHY_TS_DISCRETE_MY_013_001
Variables	Temperature, salinity, temp error bar and salinity error bar
Geographical coverage	Global (-77°N to 90°N, -180°E to 180°E)
Spatial resolution	0.5°, following Mercator projection
Vertical levels	152 vertical levels, (0 m, 3 m, 5 m:5:100 m, 110 m:10:800 m, 820 m:20:2000 m)
Temporal resolution	Monthly fields, centred the 15 of each month. From 1960 to year-1
Target delivery time and update frequency	The whole validation and update process for this product is performed twice a year: around June for temporal extension of six months and at the end of the year (November-December) for temporal extension of six months and also several possible modifications or improvements of the product including full reprocessing.

Table 1: Short description of the product INSITU_GLO_PHY_TS_OA_MY_013_052

I.2 Summary of the results

This product is based on the objective analysis of the temperature and salinity measurements taken from the global reprocessing product CORA (INSITU_GLO_PHY_TS_DISCRETE_MY_013_001), and linearly interpolated among 152 vertical levels. The Objective analysis is performed by the ISAS tool (based on the work by Gaillard et al. (2015) and developed by N. Kolodziejczyk and A. Prigent), 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 contribution of each profile to the temperature or the salinity fields is calculated by computing the innovation of the profiles taken relative to a first guess of the temperature and salinity fields.

The accuracy of the method strongly depends on the spatial resolution of the initial temperature and salinity sampling. As a consequence, the results of the gridded fields might be close from the first guess in the poorly sampled zone, such as the Pacific Ocean or the deep ocean (depth<1000m) before the Argo program.

To avoid misinterpretations of the gridded temperature and salinity fields, error bars fields that take into account the data coverage are produced. The error fields are a composite of estimated ocean variability in the low sampled zones and measurements error in the well sampled zones. As a consequence, the estimated error bars at a given point can vary from a few degree Celsius and PSU in the early period to few tenth of degree after the deployment of the ARGO program.

I.3 Estimated Accuracy Numbers

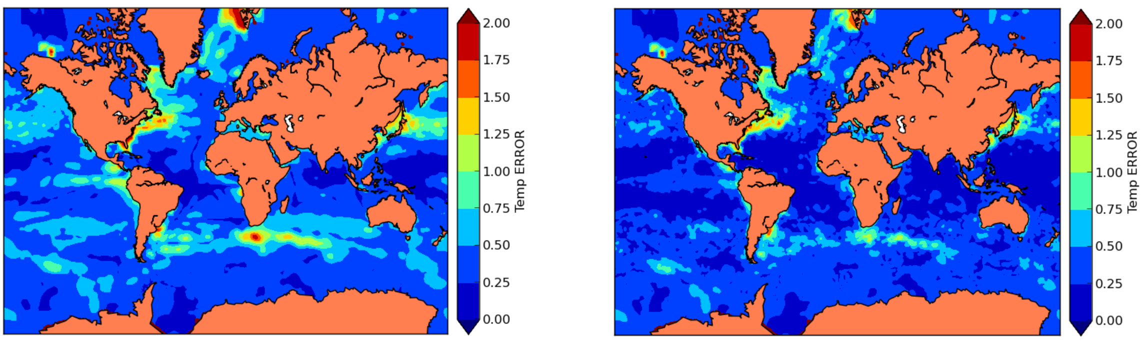

Figure 1: *Ocean surface temperature error bar for January 1993 (left) and January 2016 (right) from the Copernicus INSITU_GLO_PHY_TS_OA_MY_013_052 product.*

Figure 1, left and right gives an overview of the surface temperature error field for January 1993 and January 2016. As expected, the temperature and salinity fields coverage rate increase, associated to the deployment of the ARGO program, tends to increase the accuracy of the analysed field. To the contrary, the product error bar is rather poor in the 1990s due to the low coverage of the ocean data measurements.

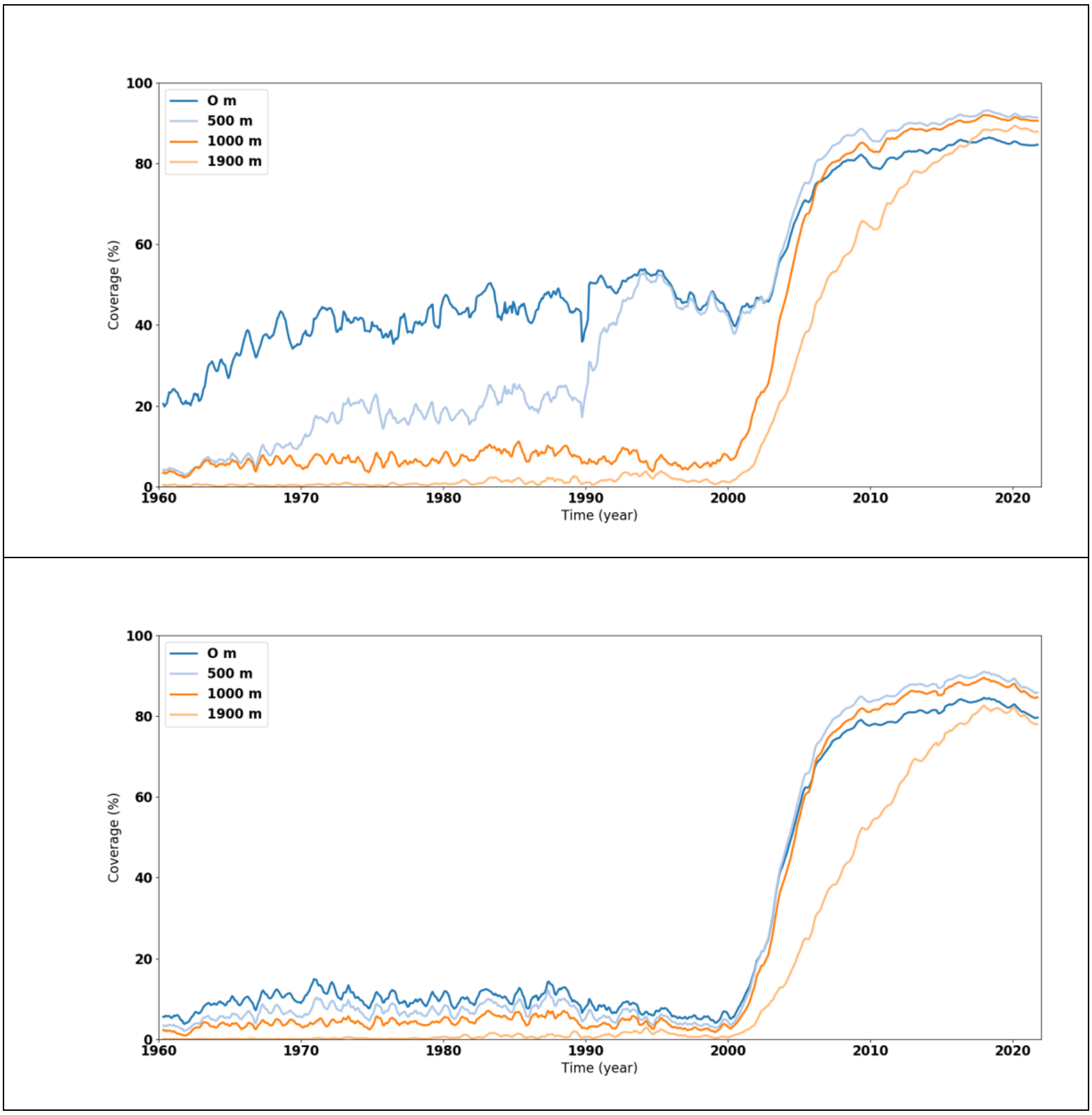

Figure 2: percentage of surface field with PCTVAR<80 % for temperature (top) and salinity (bottom) fields.

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

Figure 2 shows the evolution of the PCTVAR parameter among tome for TEMP and PSAL parameter for various depth. It shows that the PCTVAR value is higher before the deployment of the ARGO program and quickly decreases in the early ARGO years. As a consequence, the user should keep in mind that the global objective analysis solution accuracy is better during the ARGO era. The difference between the TEMP and PSAL fields, mainly depends on the spreading of XBT (unable to measure PSAL and widely used) measurements in the 1990s. The drop in data coverage in 2021 is a consequence of the fast salty drift profiles adjustment and the numerous concerned NRT profiles during this period. This issue should be mitigated in the next versions.

II VALIDATION FRAMEWORK: THE ISAS TOOL CALCULATION

II.1 Calculation method

This product is composed of temperature and salinity measurements collected from different sources by the Coriolis data center. Most of the data concerned by the objective analysis are ARGO profiles, XBTs, CTDs, mooring measurements and drifter measurements. First, the temperature and the salinity profiles are linearly interpolated to fit the ISAS grid vertical sampling (152 vertical levels between 0 and 2000 m depth with a finer resolution at the surface. The extrapolated points with a low confidence level are flagged after quality checks (QC). A second series of QC warning are raised for the profiles that differ from the first guess by more than six standard deviation of the temperature or the salinity first guess field. This step has been set up to keep the profiles with a too strong innovation apart.

Correlation function form	$C(dx, dy, dt) = \sum_{i=1}^{2} \sigma_{Li}^2 \exp\left(\frac{dx^2}{2L_{ix}^2} + \frac{dy^2}{2L_{iy}^2} + \frac{dt^2}{2L_{it}^2}\right)$ Dx,dy,dt gives the distance between a profile and a grid point. $\sigma_{L1} = 1\ \sigma_{ocean}$, $\sigma_{L2} = 2\ \sigma_{ocean}$,
Correlation scales:	L_{1x} = 300km L_{2x} = Rossby radius L_{1y} = 300km L_{2y} = Rossby radius $T_{1,2}$ = 21 days

Table 4: Objective analysis correlation function parameters.

The objective analysis parameters are summarized in table 4 (See Gaillard et al., 2015 for details). The objective analysis is performed on measurements anomalies relative to a reference field, the first guess, at the 15th day of each month.

The first guesses are built on the basis of the monthly climatology developed by the World Ocean Atlas 2013 (www.nodc.noaa.gov/oc5/woa13). The monthly climatologies covering the period 1985-1994,1995-2004 and 2005-2012 are interpolated to provide monthly temperature and salinity fields centered the 15 of each month. This method allows us to provide accurate first guess reproducing the climate tendencies over the covered decades.

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

This method produces monthly gridded field of temperature and salinity and the associated PCTVAR fields. Those fields are a gridded quantity varying between 0 and 100 and are related to the influence of the observations on the solution. A PCTVAR value that tends toward 100 can be considered uncorrelated with the first guess. To the contrary, a PCTVAR of 0 is associated to a final value equal to the first guess.

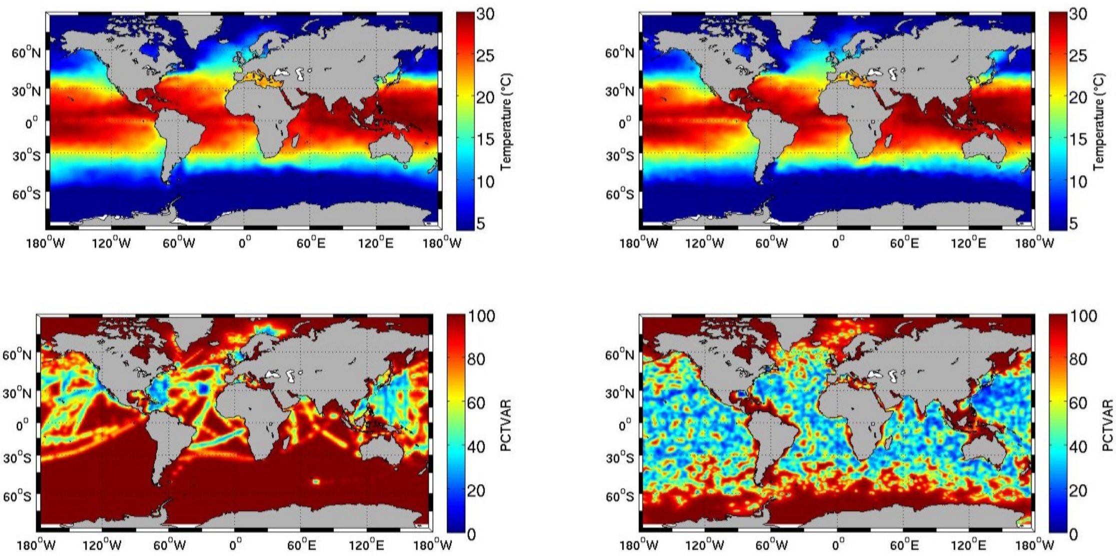

Figure 3: Surface temperature calculated by ISAS (top) and the associated PCTVAR (bot.) for June 1990 (left) and June 2010 (right).

Figure 3 shows the estimation of the surface temperature and the associated PCTVAR value for June 1990 and June 2010. In the PCTVAR figures (bottom), the low values of PCTVAR are associated to measurements taken into account in the objective analysis. On the one hand, it shows the influence of the worldwide development of the ARGO program on the spatial resolution of the ocean sampling of temperature and salinity profiles. On the other hand, the high PCTVAR zones are showing regions where the estimated field is equal to the first guess.

In the objective analysis process, the ocean in-situ measurements are standardized and interpolated on the 152 vertical levels and meta profiles are calculated for instruments sampling with profiles closer than 5 km and 5 days. The processed profiles are distributed together with the associated objective analysis. To the standardised profiles parameter at the interpolated level, the ISAS analysis adds the value of the analysis first guess, the measurement error and the analysis residual. Figure 4 and 5 gives the time variation of the temperature and salinity residual calculated at the location of the in-situ profiles used to perform the analysis. It shows that the mean residual decreases in the early 2000s for temperature and salinity, consecutively with the deployment of the ARGO network. Meanwhile, the temperature residual is enhanced in the subsurface layers corresponding to the thermocline position and the salinity residual is enhanced in the surface layers corresponding to the coastal river plumes. A discontinuity in the temperature residual is visible in the 1990s at 480 m depth, corresponding to the maximum depth of deployment of shallow XBTs. This discontinuity decreases in the early 2000s consecutively to the decreasing weight of the XBT profiles in the global ocean in-situ sampling. The noisy signals below 1000 m visible during the 1990s and early 2000s are caused by the weak sampling of the deep ocean during these years.

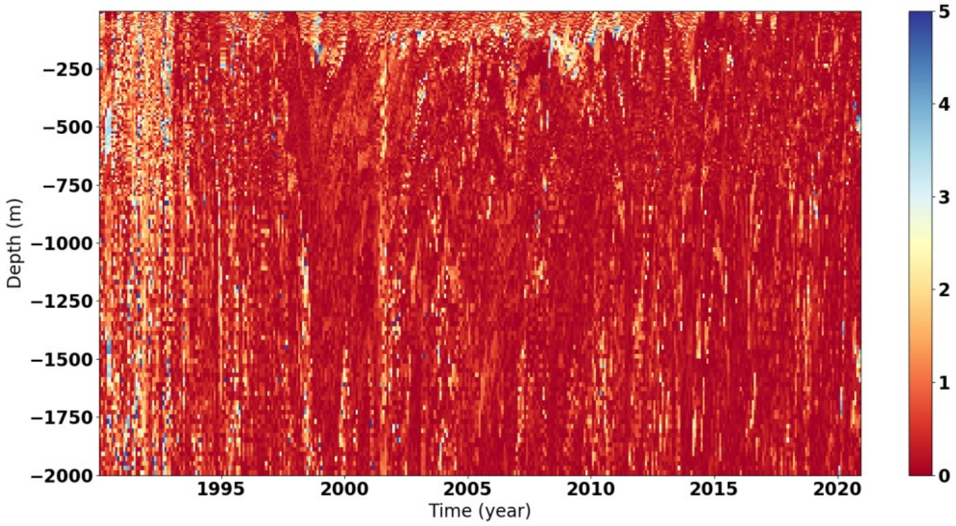

Figure 4: mean salinity residual for the CORA 5.2 objective analysis (Celsius degree)

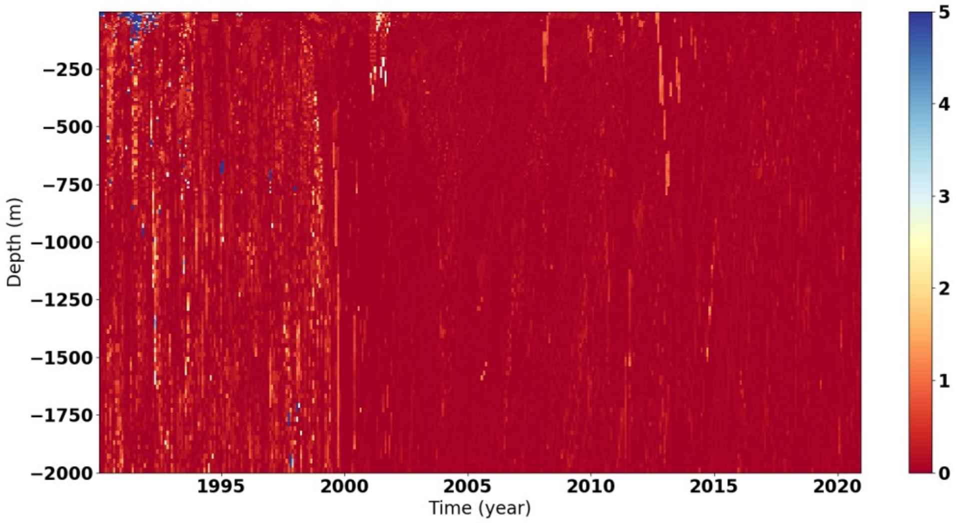

Figure 5: mean temperature residual for the CORA 5.2 objective analysis (units: PSU)

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. According to ARGO global DAC, this problem may appear on up to 25% of the ARGO float, leading to a positive drift of the salinity in ARGO based gridded products after 2016.

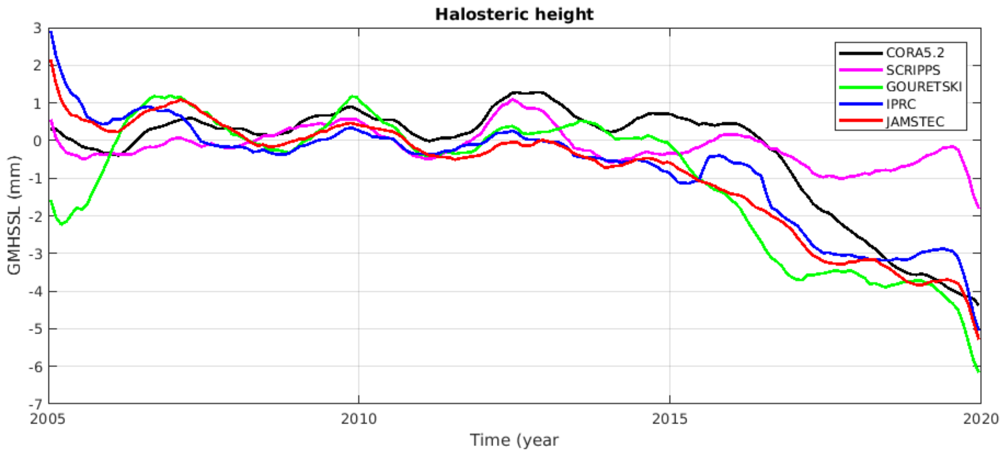

Figure 6: Halosteric height anomaly (HSA) for CORA 5.2 (December 2020 version) and gridded products from SCRIPPS, IPRC and JAMSTEC. The Gouretski label refers to the Metoffice EN4 objective analysis product using Gouretski and Reseghetti (2010) XBT corrections and Gouretski and Cheng (2020) MBT corrections..

Figure 6 shows that all OA tested products but SCRIPPS's have a Halosteric height anomaly (HSA) 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 since the CORA data validation process flags a fraction of the drifting floats and the CORA OA production framework is synchronized to the ARGO DM process in order to integrate a maximum of ARGO delayed time mode adjusted profiles.

To reduce the HSA bias, the CORA analysis has operated the same algorithm as SCRIPPS (Rommeich et al., 2009 method).

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 inferior to 0.25 PSU, the profile is adjusted by the value of the anomaly, else the profile is flagged as bad in the objective analysis and excluded from the calculation.

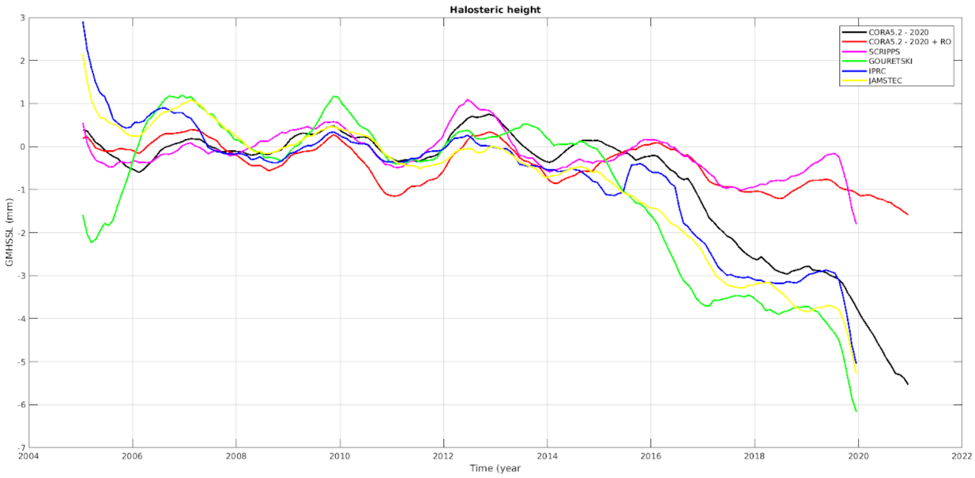

Figure 7: *Halosteric height anomaly (HSA) for CORA 5.2 (December 2021 version) and gridded products from SCRIPPS, IPRC, JAMSTEC . The Gouretski label refers to the Metoffice EN4 objective analysis product using Gouretski and Reseghetti (2010) XBT corrections and Gouretski and Cheng (2020) MBT corrections..*

Figure 7 shows that the adjustment method eliminates almost all the drift. The correction statistics are then analysed to flag the remaining FSD profiles in CORA.

II.3 Estimation of the error bar

An error bar is calculated and distributed with the analysis fields. This error bar takes into account the known ocean variability in the unsampled zones (PCTVAR ~100). It is closer from the ocean measurements variability in the well sampled zones (PCTVAR ~0).

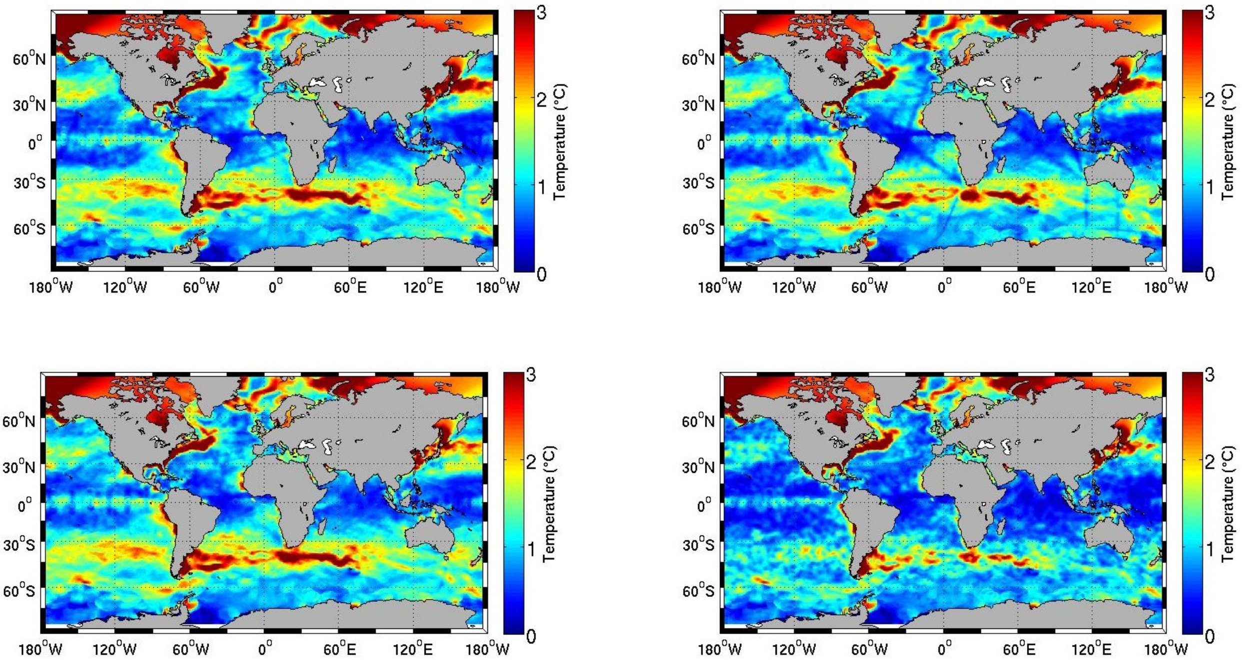

Figure 6: Estimated surface temperature error bar for January 1990 (top left), 1995 (top right), 2000 (bottom left) and 2010 (bottom right).

Figure shows the estimated error bar of the temperature field on surface. It shows the low decrease of the error bar in the 1990s. And the net decrease after the deployment of the ARGO network. During the early year, most of the error bar is related to the estimated ocean variability. During these years, a punctual transect can decrease locally the error bar. After 2003, the ARGO floats provide a global coverage of the ocean, leading to a lower level of error bar.

III VALIDATION RESULTS

Figure 7 gives the evolution of the global ocean heat content (GOHC) estimated by the INSITU_GLO_PHY_TS_OA_MY_013_052 product (blue curve) and by Von Schuckmann and Le Traon (2014) (orange curve). The GOHC calculation method is based on the Boyer et al. (2007) calculation of the local heat content and the integration to the global scale is based on the method by Von Schuckmann et al. (2009).

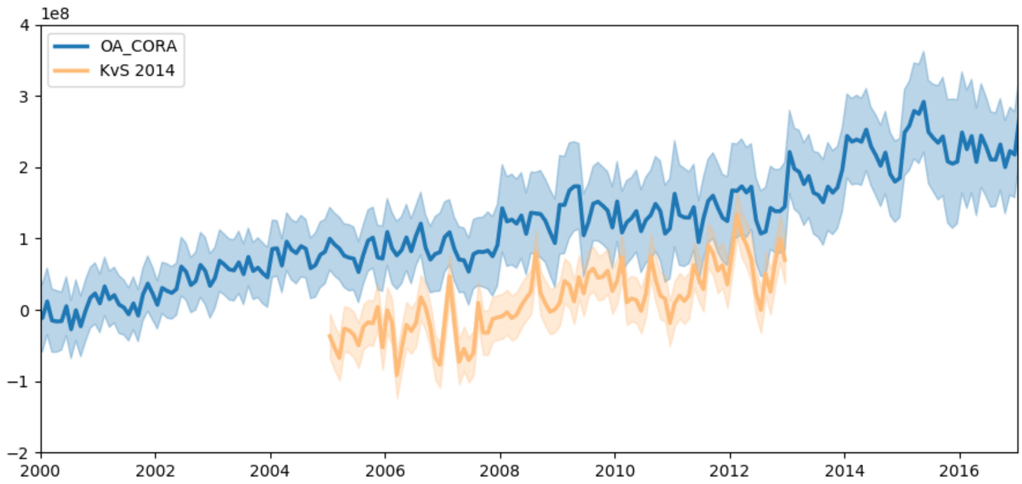

Figure 7: Ocean global heat content anomaly variability computed between 60°N and -60°N and between 10 and 1500 meters depth Blue curve: Yearly objective analysis results. Orange curve: GOHC estimation from Von Schuckmann and Le Traon (2014).

Figure 7 shows that the linear warm tendency of the first guess is close to the tendency observed by Von Schuckmann and Le Traon (2014). This is clearly an important step on the computing of the objective analysis since the previous versions of the CORA OA product first guess have constant annual mean heat content. This explains the realistic global warming tendency of the CORA OA field, even before the deployment of ARGO floats.

IV VALIDATION SYNTHESIS

This product gives a global 3D gridded synthesis of the Temperature and Salinity measurements provided by the product INSITU_GLO_PHY_TS_DISCRETE_MY_013_001. The objective analysis is performed by the ISAS tool (Gaillard et al., 2015). The accuracy of this product depends on both the ISAS parameters and the time repartition of the ocean measurements at a global scale. Unfortunately, the ocean sampling is far too low in the early years of the product (1990-2003) to reproduce the ocean variability at the scale from a Rossby radius to the global scale. The recent development on the INSITU_GLO_PHY_TS_OA_MY_013_052 product allows however to have a more accurate estimation of the ocean state in the low sampled zones, especially in the southern zones and in the deep ocean (800-2000 m).

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