

Project	AtlantOS – 633211
Deliverable number	D7.12
Deliverable title	T,S,O2 EOv: T, S and oxygen syntheses and impact of AtlantOS observations
Description	[see DoA]
Work Package number	WP7
Work Package title	Data flow and data integration
Lead beneficiary	IFREMER
Lead authors	V. Thierry, N. Kolodziejczyk
Contributors	A. Prigent
Submission data	
Due date	[see DoA]
Comments	[in case the deliverable is late please explain why]



This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement n° 633211.

1 Executive summary/ Abstract

The ocean is a moderator of climate change as it has stored more than 90% of the excess of heat received by the earth system due to human activities. Besides changes in sea level, the ocean warming is expected to have a significant impact on the oxygen content that may decrease over the world's oceans.

To monitor those changes and to provide ocean climate indices related to the heat, freshwater and oxygen storage in the ocean, we produced gridded fields of temperature, salinity and dissolved oxygen concentration over the world ocean based on available *in situ* dataset. The gridded fields are produced by the In situ Analysis System tool (ISAS tool). As part of AtlantOS, the ISAS tool has been updated, from ISAS-V7 to ISAS-V8, in order to provide gridded fields down to the bottom, to include ship-based hydrographic profiles and to provide gridded fields of dissolved oxygen concentration.

The available products are:

(1) T and S gridded field on 152 levels from the surface to 2000m, at global scale and on monthly time scales. The gridded fields are based on the ISAS-V7 tool. They use delayed-mode data set for the period 2002-2015, and near real time dataset for the period 2016-2018.

(2) O₂ fields on 182 levels from the surface to 5500m, at global scale. Four gridded fields covering different time span are available (2006-2015, 2006-2010, 2011-2015, 2015-2018). They were produced by the ISAS-V8 tool.

Those gridded fields will be regularly updated.

2 Introduction

The objective of this task was to develop temperature (T), salinity (S) and dissolved oxygen concentration (O₂) syntheses of the Atlantic Ocean over the last 10 years to compute ocean climate indices such as heat and freshwater content and steric sea level variations and to complete existing T,S-based climate indices time series. The oxygen content is a new and important climate index as a potentially serious consequence of global warming is a decrease in the dissolved O₂ content of the world's oceans. We thus proposed to use AtlantOS O₂ data and O₂ data from other projects to provide dissolved O₂ fields for the North-Atlantic Ocean during the AtlantOS period.

To achieve those objectives, we used the In Situ Analysis System (ISAS) tool developed at LOPS by the French Argo program (SNO Argo-France) to provide gridded fields of T, S and O₂.

The T and S gridded field on 152 levels from the surface to 2000m, based on a delayed-mode dataset and on the ISAS-V7 tool, are available at global scale and on monthly time scales for the period 2002-2015. The dissolved O₂ gridded field are available on 182 levels from the surface to the bottom and at global scale. Compared to T and S, less O₂ data are available. As a consequence the gridded fields are not available on a monthly basis but over larger time span (eg. 2006-2015, 2006-2010, 2011-2015, 2015-2018).

3 The ISAS tool

The In Situ Analysis System (ISAS) is an optimal interpolation (*Bretherton, 1976*) tool that was developed to produce gridded fields of temperature and salinity that preserve as much as possible the time and space sampling capabilities of the Argo network of profiling floats (*Gaillard et al., 2016*). Since the first global re-analysis performed in 2009 (*Gaillard et al., 2009*), the system has

been extended to accommodate all types of vertical profile as well as time series. ISAS gridded fields are entirely based on in-situ measurements. The system aims at monitoring the time evolution of ocean properties for climatological studies and allowing easy computation of climate indices.

The V7 version of the ISAS tool provides gridded fields of T and S data on 152 levels ranging from 0 to 2000 m depth (5 to 10 m resolution within the shallowest 500 m depth, 20 m depth), on a half degree horizontal grid. The interpolated dataset is delayed mode Argo profiles downloaded from the Coriolis Global Data Center (GDAC), TAO/PIRATA/RAMA mooring data (www.pmel.noaa.gov/tao), Marine Mammals profiles (www.meop.net), Ice Tethered Profilers Arctic profiles (www.whoi.edu/page.do?pid=20756). The ISAS dataset preprocessing includes a climatological test applied to the dataset, followed by visual checking of any suspicious profiles. The detailed method is described in *Gaillard et al.* (2016).

As part of the AtlantOS project, the V8 version of ISAS has been developed. Compared to ISAS-V7, the V8 version of ISAS presents the following new capabilities:

- ISAS-V8 can include ship-based measurements in the dataset to be interpolated
- the interpolation can be done from the surface to the bottom, that is on 182 levels down to 5500m. Below 2000m, the gridded fields will be based on ship-based measurements and Deep-Argo profiles.
- ISAS V8 is able to provide gridded fields of O₂ in addition to T and S.

The ISAS-V7 tool is freely available on demand at nicolas.kolodziejczyk@univ-brest.fr. The ISAS-V8 tool is still in the qualification phase. It will be freely available on demand early 2019.

The ISAS-V7 is currently used by the Coriolis data center for operational use as part of CMEMS. The tool is used to produce gridded field in near-real time (see Section 4.2). The ISAS-V8 version will be transferred to the Coriolis data center in January 2019 to produce surface to bottom gridded products of T, S and O₂ parameters.

4 Temperature and salinity gridded fields

4.1 The ISAS15 products et indices

The last release of the ISAS products, named ISAS15, is a monthly interpolation of *in situ* data available in delayed mode over the period 2002–2015 (*Kolodziejczyk et al.*, 2017). The ISAS15 analysis is based on the ISAS-V7 tool and differs slightly from the product presented by *Gaillard et al.* (2016) in two respects: the reference climatology and the optimal interpolation parameters. While *Gaillard et al.* (2016) used a reference climatology based on the ISAS11 analysis that covered the period 2004–2010, ISAS15 used the climatology based on the ISAS13 analysis that covered the period 2004–2012. For this configuration two spatio/temporal covariance scales have been chosen: the first is 300 km with 30 days, which is the nominal Argo sampling; the second is function of the deformation radius, that means a decreasing horizontal correlation scale towards the pole, and zonally elongated (600 km) scale along this equator. Products, indices and further details are freely available on : www.umar-lops.fr/SNO-Argo/Products/ISAS-T-S-fields (*Kolodziejczyk et al.*, 2017).

4.2 Near-Real time analysis provided by Coriolis

ISAS-NRT provides gridded fields of temperature and salinity. It is based on ISAS-V7 and presents the same features as ISAS15, except that the interpolated data are based on the data available in real time mode, i.e. no DMQC have been performed on the dataset. ISAS-NRT is used to fill the gap between 2016 and now. ISAS-NRT product is available through CMEMS Copernicus: http://marine.copernicus.eu/services-portfolio/access-to-products/?option=com_csw&view=details&product_id=INSITU_GLO_TS_OA_NRT_OBSERVATIONS_013_002_a.

4.3 The upcoming ISAS17 products

The upcoming update of ISAS T/S products will be released under the ISAS17 name. It will cover the period 2002-2017 and will be produced by the new ISAS-V8 tool, which means that the ISAS17 analysis will include both full depth delayed mode hydrological data and deep Argo float. The qualification of the dataset is ongoing and the release is scheduled for spring 2019.

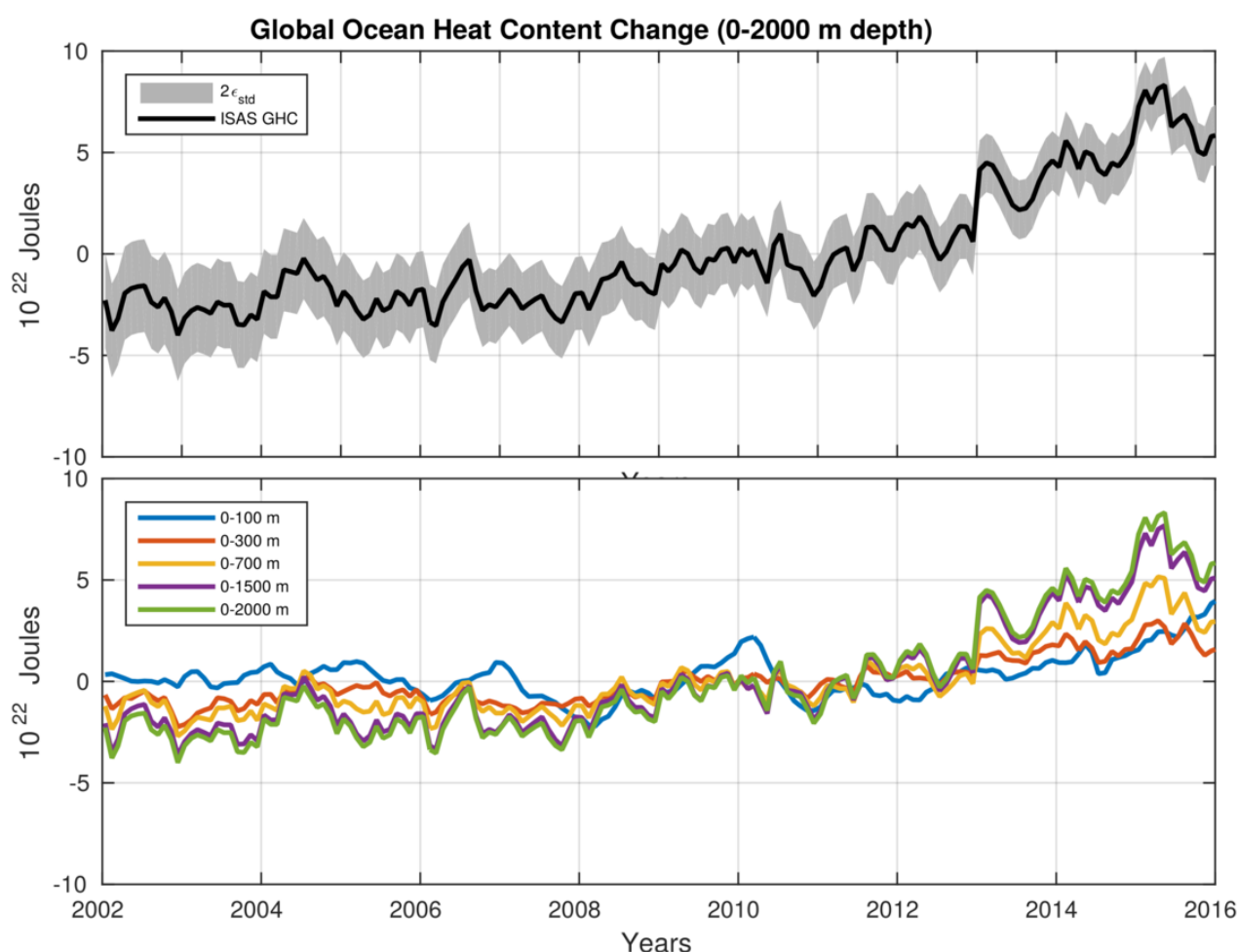


Figure 1: Global Ocean Heat Content change computed from ISAS15 (<http://www.umr-lops.fr/SNO-Argo/Products/ISAS-T-S-fields/Climatology-and-climate-indices>).

5 Oxygen gridded field

The ISAS-V8 beta tools has been used to produce the first gridded field of O_2 over the global ISAS grid with 182 levels over the vertical (0-5500 m depth) and 0.5° of horizontal resolution. Four analyses, covering four different periods, have been produced: over 2006-2015, 2006-2010, 2011-2015 and 2015-2018.

Two datasets have been included in the analysis to produce the gridded fields. The first dataset is calibrated full depth ship-based O_2 profiles from scientific cruises carried out over the Atlantic Ocean during the period 2006-2018. The data were downloaded from the CCHDO (<https://cchdo.ucsd.edu/>) or were provided by AtlantOS PI (such as the OVIDE line data, WP4).

The second dataset are O_2 profiles from Argo floats (referred to as Argo- O_2 profiles in the following), and in particular the AtlantOs Deep-Argo floats and the BGC floats (WP3). The data were downloaded from the Coriolis data center. Before downloading the data, we first performed as part of the AtlantOS project a careful delayed mode quality control on the floats that were in the North-Atlantic Ocean and that are under our responsibility. Those quality controls are necessary as the oxygen sensor are generally biased toward low oxygen concentration and subject to a temporal drift (Bittig *et al.*, 2018). They strictly follow the procedures that we defined as part of the Argo program (Thierry *et al.*, 2018a,b). Gallian and Thierry, 2018 provide a report on this qualification.

The difference between the 2006-2015 fields and the World Ocean Atlas 2013 (WOA13) at 390m is displayed Figure 4 (upper panel). Red colors in the percentage map (Figure 4, lower panel) show where were the data. It highlights the position of scientific cruises as well as the region were Argo floats with oxygen sensors were deployed. The quality of the gridded field is not homogenous as all Argo- O_2 profiles have not been through the full DMQC process. However, most Argo- O_2 data were available in delayed-mode in the North-Atlantic which makes the O_2 gridded fields reliable there.

This product will be regularly updated as function of data availability. We will consider only delayed-mode Argo- O_2 profiles and we will complete the dataset with any available qualified ship-based measurements. We plan also to validate the gridded products by comparison to bottle samples from the GLODAPv2 database.

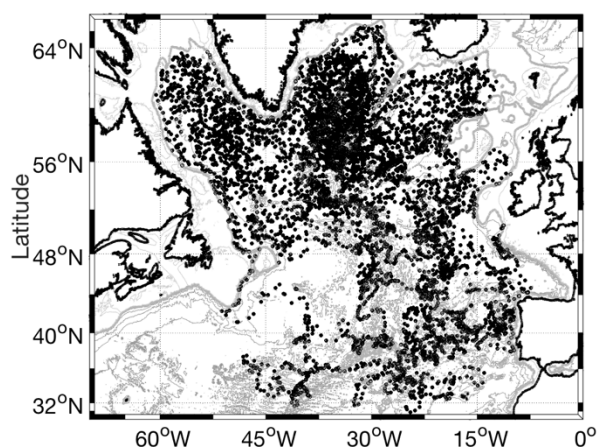


Figure 2: Position of the Argo- O_2 profiles located north of $30^\circ N$, corrected as part of the AtlantOs project (Gallian and Thierry 2018) and included in the ISAS- O_2 analysis.

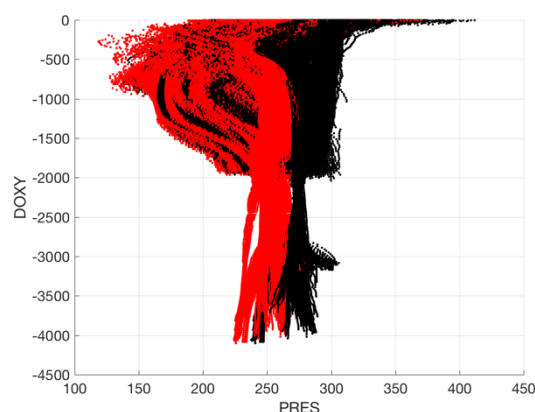


Figure 3: Argo- O_2 profiles before correction (red) and after correction (black).

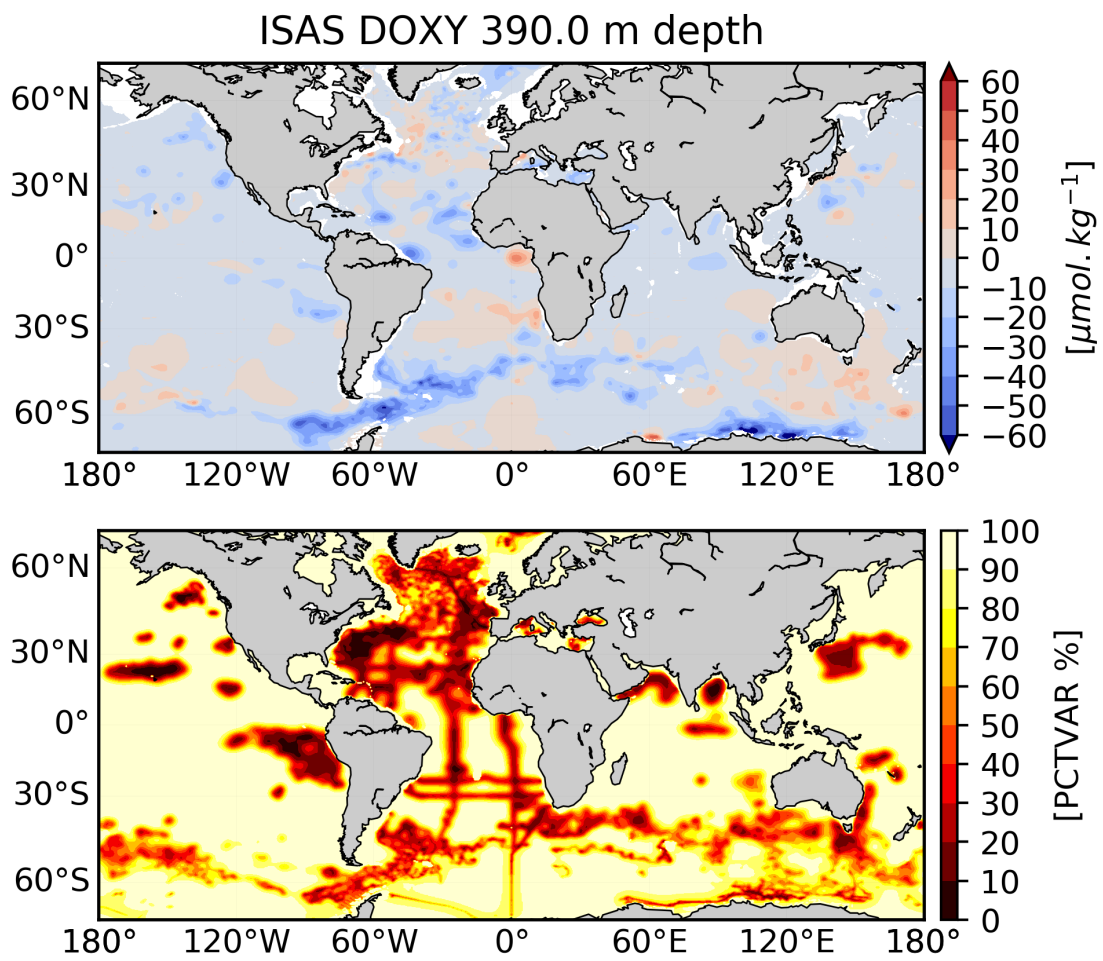


Figure 4: First O₂ global gridded fields over the period 2006-2015 provided by ISAS-V8. (Upper panel) Difference between the ISAS-O₂ field at 390m and the World Ocean Atlas 2013 (*Garcia et al., 2014*). (Lower panel) Error on the O₂ field expressed as a percentage of variance. The lowest values are found where data are available.

6 References

- Bittig HC, Körtzinger A, Neill C, van Ooijen E, Plant JN, Hahn J, Johnson KS, Yang B and Emerson SR (2018) Oxygen Optode Sensors: Principle, Characterization, Calibration, and Application in the Ocean. *Front. Mar. Sci.* 4:429. doi: 10.3389/fmars.2017.00429
- Garcia, H. E., R. A. Locarnini, T. P. Boyer, J. I. Antonov, O.K. Baranova, M.M. Zweng, J.R. Reagan, D.R. Johnson, 2014. *World Ocean Atlas 2013, Volume 3: Dissolved Oxygen, Apparent Oxygen Utilization, and Oxygen Saturation*. S. Levitus, Ed., A. Mishonov Technical Ed.; NOAA Atlas NESDIS 75, 27 pp.
- Print. Off., Washington, D. C. Gaillard F., E. Autret, V. Thierry, P. Galaup, 2009: Quality control of large Argo datasets. *Journal of Atmospheric and Oceanic Technology*, 26, 337-351, doi: 10.1175/2008JTECHO552.1.
- Gaillard F., T. Reynaud, V. Thierry, N. Kolodziejczyk, K. von Schuckmann, 2016. In-situ based reanalysis of the global ocean temperature and salinity with ISAS: variability of the heat content and steric height. *J. Climate*, 29, 1305–1323. doi: <http://dx.doi.org/10.1175/JCLI-D-15-0028.1>
- Gallian M. and Thierry V., 2018. Delayed-mode quality control of dissolved oxygen concentration measured by ARGO floats in the North- Atlantic with LOCODOX - Floats deployed in 2012, 2014, 2015, 2016 and 2017. <https://doi.org/10.13155/58314>
- Kolodziejczyk Nicolas, Prigent-Mazella Annaig, Gaillard Fabienne (2017). **ISAS-15 temperature and salinity gridded fields**. SEANOE. <http://doi.org/10.17882/52367>
- Thierry V., H. Bittig, D. Gilbert, T. Kobayashi, K. Sato, C. Schmid, 2018a: Processing Argo OXYGEN data at the DAC level, v2.3.1, <http://dx.doi.org/10.13155/39795>
- Virginie Thierry, Henry Bittig, and the Argo-BGC team (2018b). Argo Quality Control Manual for Dissolved Oxygen Concentration, v2.0 <http://dx.doi.org/10.13155/46542>

Stakeholder engagement relating to this task*

<p>WHO are your most important stakeholders?</p>	<p><input type="checkbox"/> Private company If yes, is it an SME <input type="checkbox"/> or a large company <input type="checkbox"/>? <input checked="" type="checkbox"/> National governmental body <input type="checkbox"/> International organization <input type="checkbox"/> NGO <input type="checkbox"/> others Please give the name(s) of the stakeholder(s): Research laboratories, Copernicus-Marine Environment Monitoring Service (CMEMS)</p>
<p>WHERE is/are the company(ies) or organization(s) from?</p>	<p><input checked="" type="checkbox"/> Your own country <input checked="" type="checkbox"/> Another country in the EU <input checked="" type="checkbox"/> Another country outside the EU Please name the country(ies): All countries involved in oceanographic studies and oceanographic applications</p>
<p>Is this deliverable a success story? If yes, why? If not, why?</p>	<p><input checked="" type="checkbox"/> Yes, because we provided gridded fields of temperature, salinity and dissolved oxygen concentration over the world ocean owing to an updated version of the ISAS tool. The system is in place and the gridded fields will be regularly updated, which will be used to provide climate indices related to the heat, freshwater and oxygen storage in the ocean and to monitor oceanic response to climate change.</p>
<p>Will this deliverable be used? If yes, who will use it? If not, why will it not be used?</p>	<p><input checked="" type="checkbox"/> Yes, the deliverable will be used by the research community and the Coriolis Data Center. The gridded products are freely available (http://doi.org/10.17882/52367, www.umr-lops.fr/SNO-Argo/Products/ISAS-T-S-fields). They will be used by the research community. The ISAS tool used to provide the products is also available on demand and will be transferred to Coriolis data center for operational services as part of CMEMS.</p>

NOTE: This information is being collected for the following purposes:

1. To make a list of all companies/organizations with which AtlantOS partners have had contact. This is important to demonstrate the extent of industry and public-sector collaboration in the

obs community. Please note that we will only publish one aggregated list of companies and not mention specific partnerships.

2. To better report success stories from the AtlantOS community on how observing delivers concrete value to society.

*For ideas about relations with stakeholders you are invited to consult D10.5 Best Practices in Stakeholder Engagement, Data Dissemination and Exploitation.