Contribution to the ICES Working Group on Oceanic Hydrography National report: France

April 2013

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Rapport LPO 13-04

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Summary

1 ARGO gridded temperature and salinity fields

The ARGO network of profiling floats has been set up to monitor the large-scale global ocean variability (http://www.argo.ucsd.edu/) . Argo data are transmitted in real time and hastily made available by the two Global Data Assembly Centres (Argo-GDAC). Delayed mode data undergo expert calibration processes and are delivered later. In the North Atlantic, the temperature and salinity conditions of the upper 2000 m are adequately described since 2002. This dataset is thus suitable for an overview of the oceanographic conditions in this basin, giving the general context for the repeat stations and sections collected mostly at the periphery of the basin by the partners of the ICES Working Group on Ocean Hydrography (WGOH).

1.1 ISAS: gridded temperature and salinity fields

Temperature and salinity fields are estimated on a regular half degrees (Mercator scale) grid using the In Situ Analysis System (ISAS), (Gaillard et al., 2009). The dataset is downloaded from the Coriolis Argo GDAC (http://www.coriolis.eu.org/). It should be noted that Coriolis assembles many types of data transmitted in real time, merging the ARGO data set with data collected by the GTS such as mooring data, marine animals, gliders, CTDs. However, the ARGO dataset remains the main contributor in the open ocean. The last year of the analyzed series uses the Near Real Time dataset prepared by Coriolis at the end of each month from real time data. Delayed mode data are progressively taken into account for the previous years, replacing the NRT data.

Data are pre-processed before entering the analysis. First we perform a climatological test to detect outliers then we vertically interpolate the profiles on 152 standard levels between the surface and 2000m. The analysis to produce gridded fields is performed at each standard level independently. The method is based on optimal estimation principles and includes a horizontal smoothing through specified covariance scales. The results presented here were produced with version 6 of ISAS (Gaillard, 2012). The reference state was computed as the mean of a 2004-2010 analysis (D2CA1S2) and the a priori variances were computed from the same dataset. The period 2002-2012 was fully reprocessed to take into account new delayed mode data and flags.

The complete set of figures for the North-Atlantic is available on:

http://wwz.ifremer.fr/lpo/La-recherche/Projets-en-cours/GLOSCAL/North-Atlantic-T-S

1.2 Surface layers

During winter, the near surface waters were anomalously cold and fresh in the North-West Labrador Sea and over a large area south of Greenland. The cold temperatures in the Labrador Sea were associated with a strengthening of North-easterly winds. Further South, waters were extremely warm and salty in the western basin along 40°N, indicating a northward shift of the Gulf Stream. The rest of the basin was still slightly warmer and saltier than normal.

Summer 2012 has been very warm over most of the basin, west of a line joining Spitzbergen to 40N-40W. It was only moderately warm South-East of the Iberian peninsula and slightly colder than normal in the central Atlantic and off Ireland. Unlike winter, summer salinity anomalies were not correlated to temperature anomalies. Waters were very salty in the Greenland Sea/Norvegian Sea and along the East Greenland coast. They were fresh along the western boundary: starting from the West Greenland coast, following the North American coast and from there, extending toward the west.

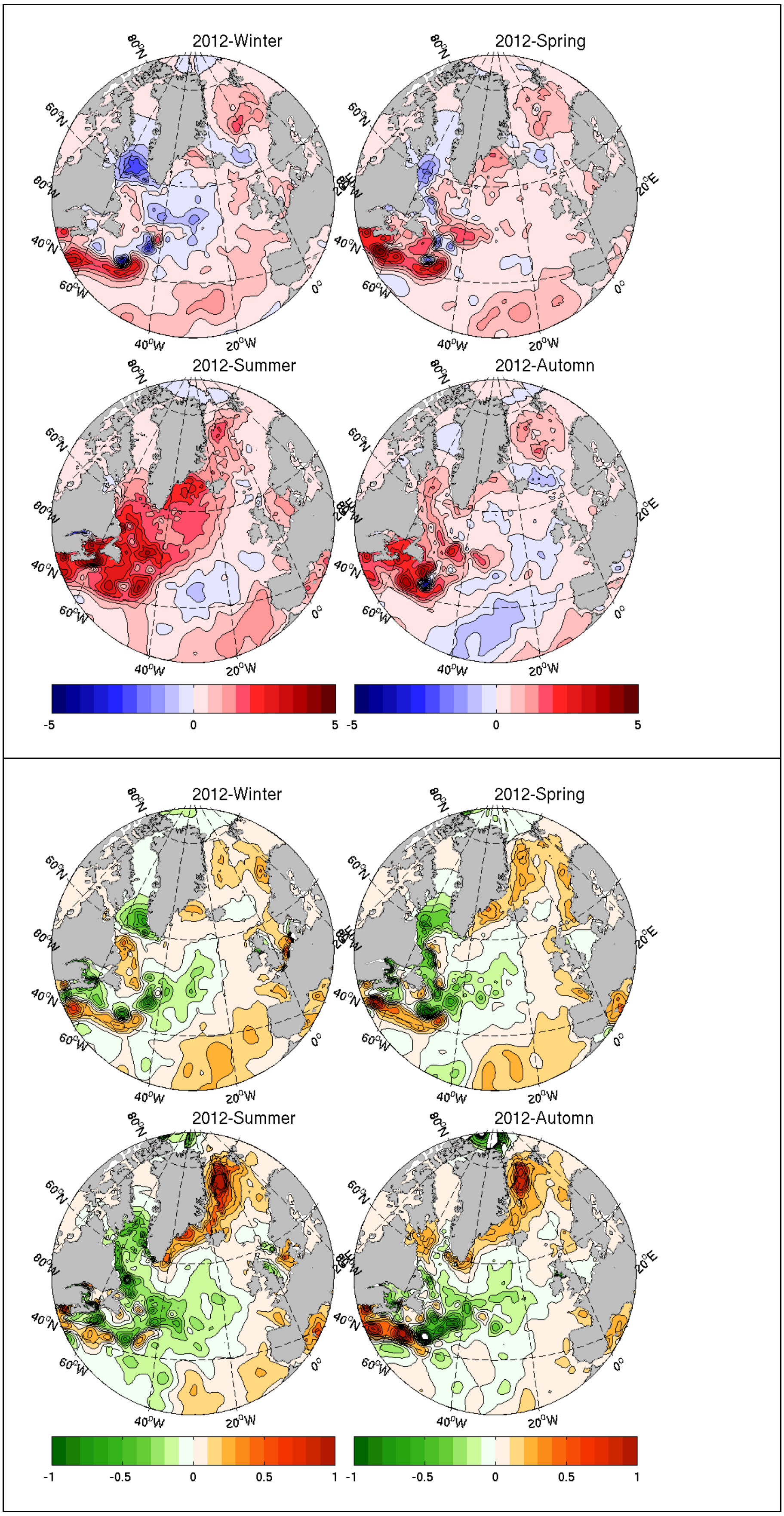


Figure 1: Near surface (10 meter) temperature (top) and salinity (bottom) averaged over Winter (JFM), Spring (AMJ), Summer (JAS) and Autumn (OND) 2012. The anomalies are shown relative to the World Ocean Atlas (WOA-05).

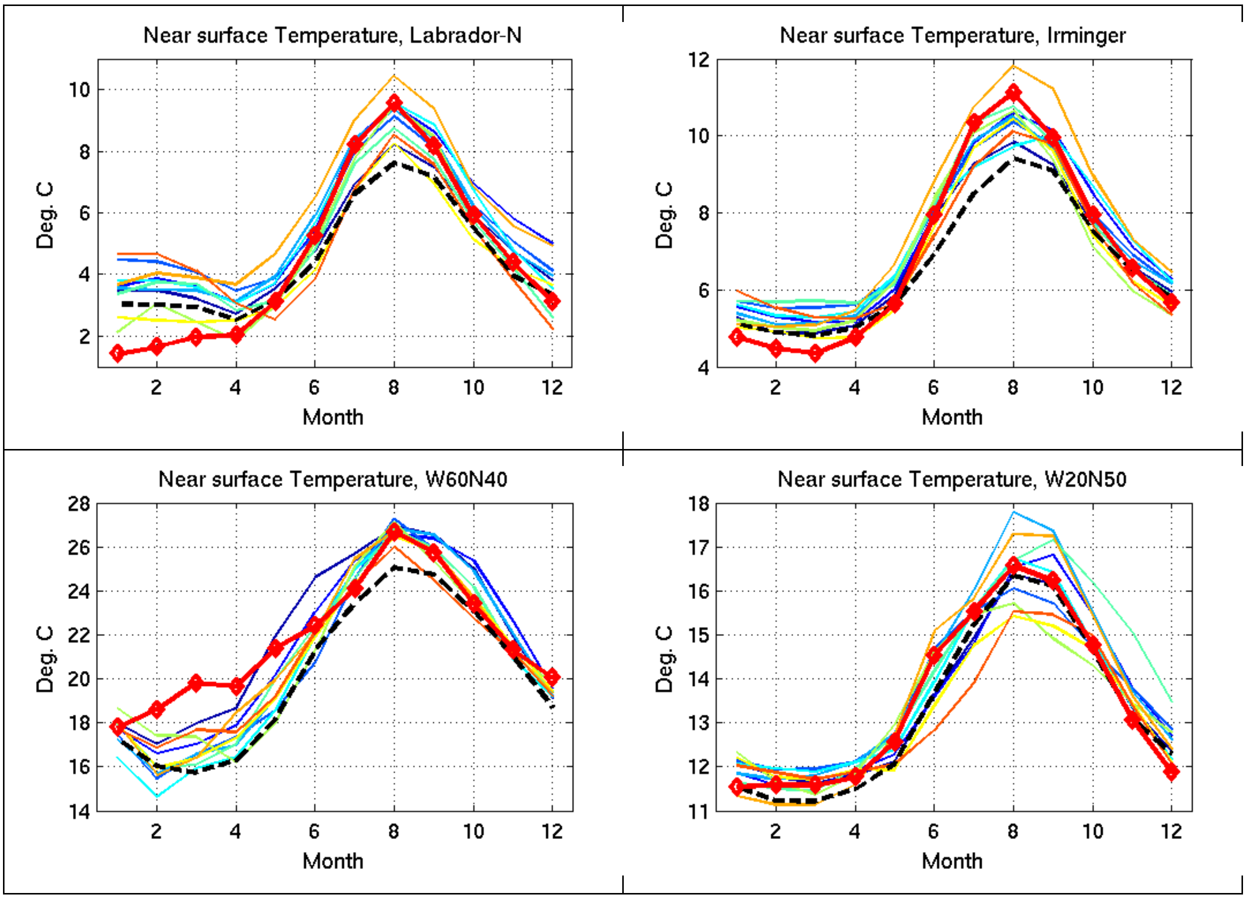
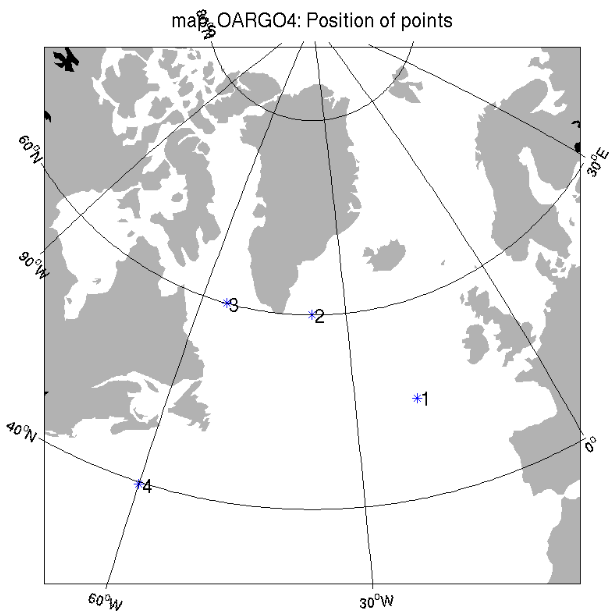


Figure 2: Seasonal cycle for temperature at 4 points in the North Atlantic basin. In heavy red the year 2012, in dashed black the WOA05 climatology, other curves show the years 2002-2011.



The year 2012 appears as an extreme in the 2002-2012 decade for the cold winter observed in the Labrador Sea and the Irminger Sea, (Figure 2) where temperatures went well below the climatological mean (nearly 2° lower in the Labrador Sea) and the warm temperature in the south-west part of the basin. The warm summer that extends over most of the basin except in the South-East part is clearly seen in the surface cycles but remains within the variability of this period.

Winter surface conditions determine the mixed layer properties. In order to compare all areas over the decade, we adopt a simple definition for the mixed layer depth, using the level at which temperature changes by more than 0.5°C with respect to the 10 meter depth. The month of February is selected as the common period for maximum mixed layer depth. This is not perfectly true since the time of the deepest mixed layer may vary from year to year at a single location and does not occur at the same time over the whole basin. During the year 2012 the area covered by a deep mixed layer (deeper than 600 m) is more extended than usual in the North of the basin (even more than during the winter of 2008), starting from the Labrador Sea, it includes nearly all the Irminger Sea and progresses southward along the coast of America (Figure 3). In the South-East of the basin, the deep mixed layer extension stops around 48/50°N such that only moderate mixed layer depths are observed along the shelf in the Bay of Biscay contrary to the 2009, 2010 and 2011 winters.

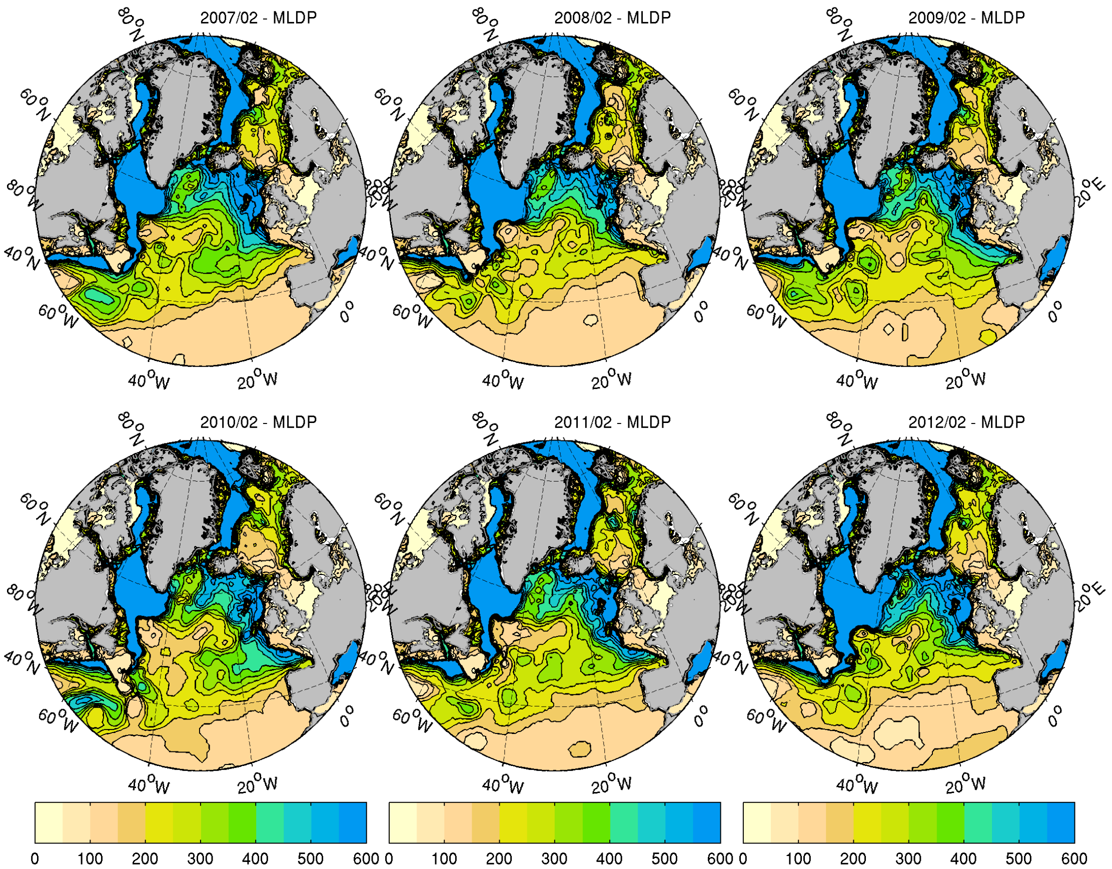


Figure 3: North Atlantic mixed layer depth in February from 2007 to 2012. The mixed layer is defined as the depth at which the temperature has decreased by more than 0.5° from the temperature at 10 m. This criterion is not suitable for areas of salinity compensation or very week stratification.

The most salient feature of the 2012 annual mean temperature is an intense warm anomaly over the western basin from the tip of Greenland to 40°N and the persistence of a moderately warm anomaly over the Greenland Sea and along the East Greenland coast (Figure 4).

The structure of the salinity anomaly is not correlated with the temperature anomalies. While the warm anomaly over the Greenland Sea is associated with saltier waters, a negative salinity anomaly is building up west of 20°W. It started in 2009 in the centre of the basin (50°N - 30°W) and has since then gradually increased both in size and intensity. In 2012, a large fresh anomaly, 0.5 PSS below the ‘normal’ WOA05 conditions, is observed.

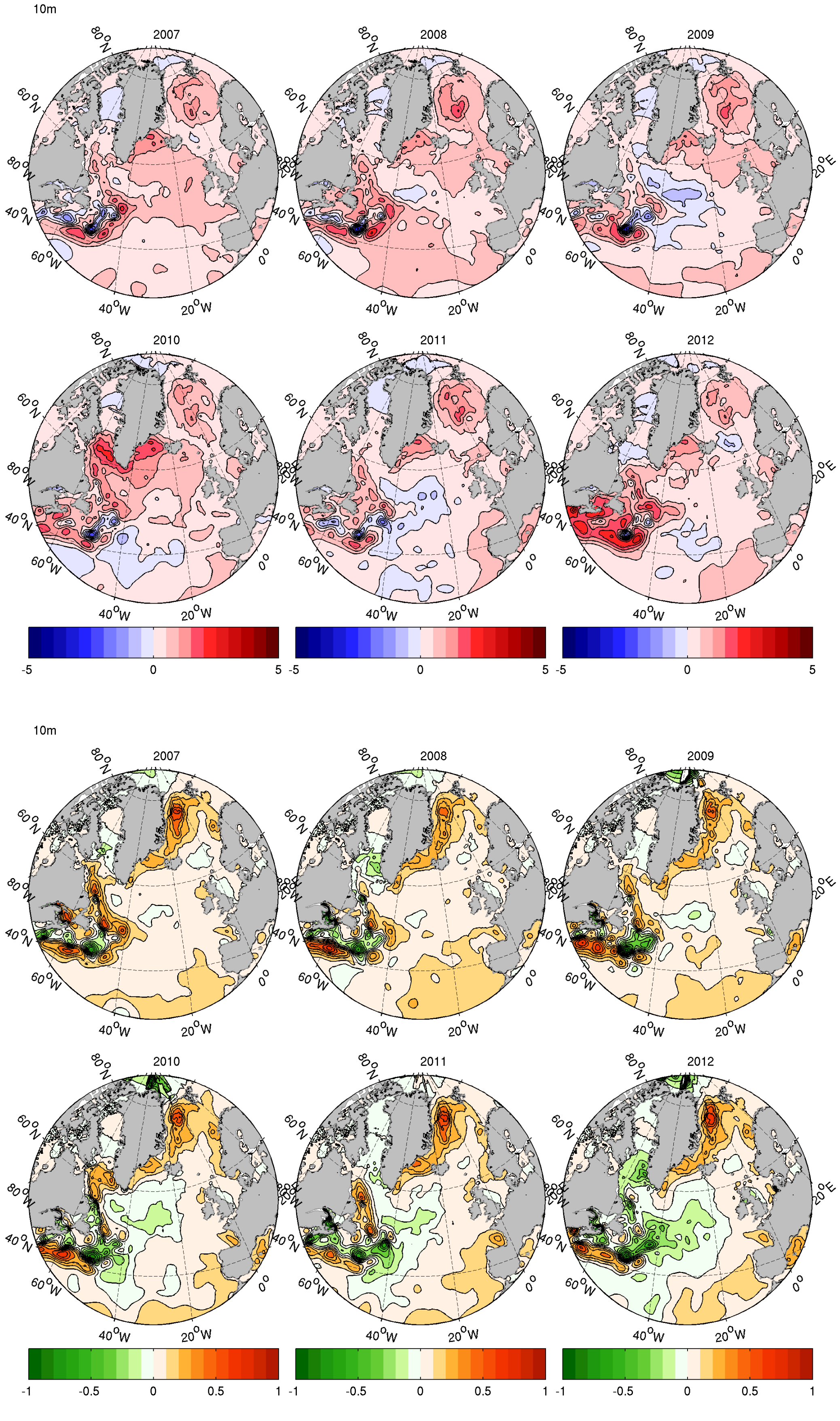


Figure 4: Annual average temperature (top) and salinity (bottom) anomalies at 10 m during 2007-2012

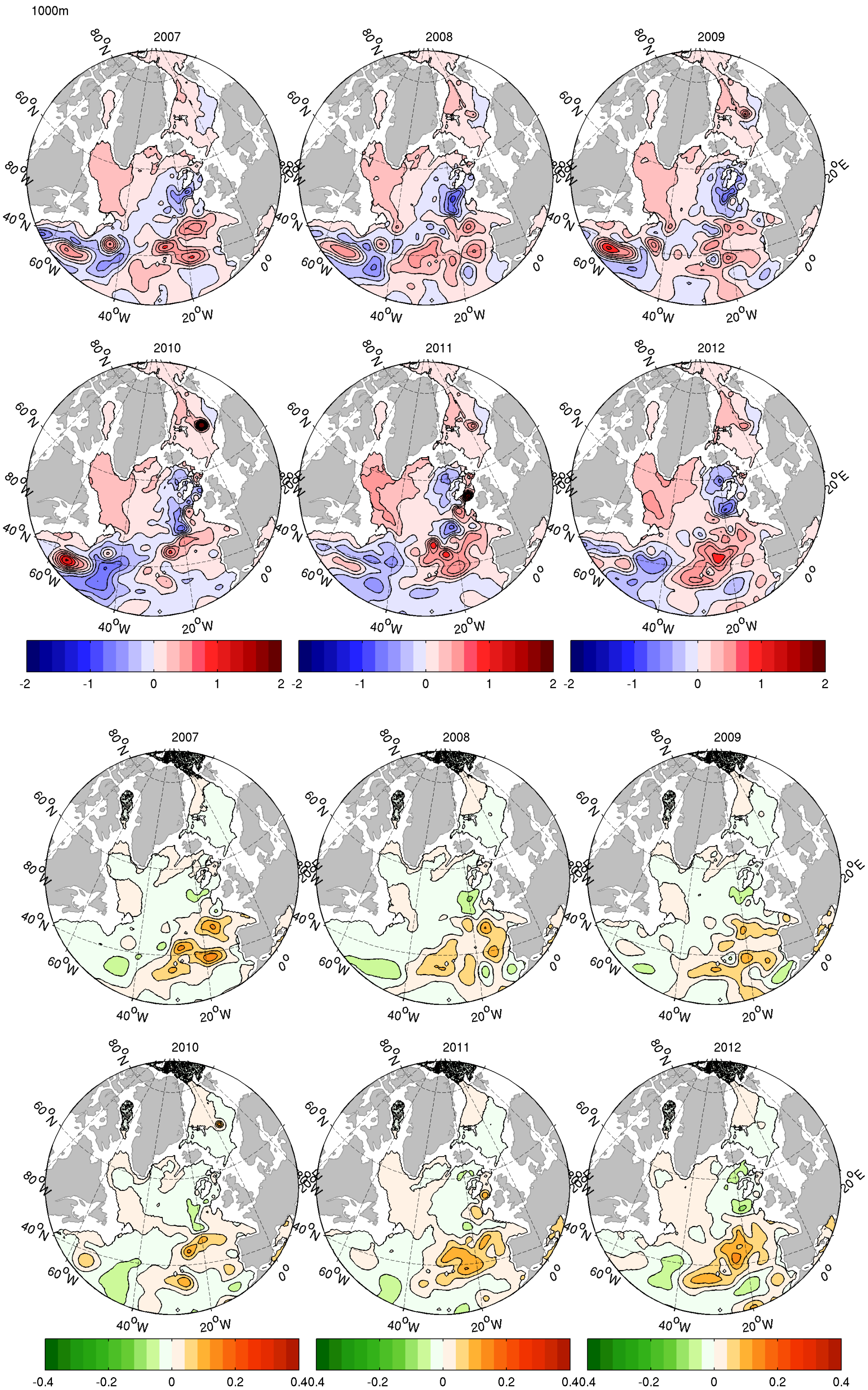


Figure 5: Annual average temperature (top) and salinity (bottom) anomalies at 1000 m during 2007-2012.

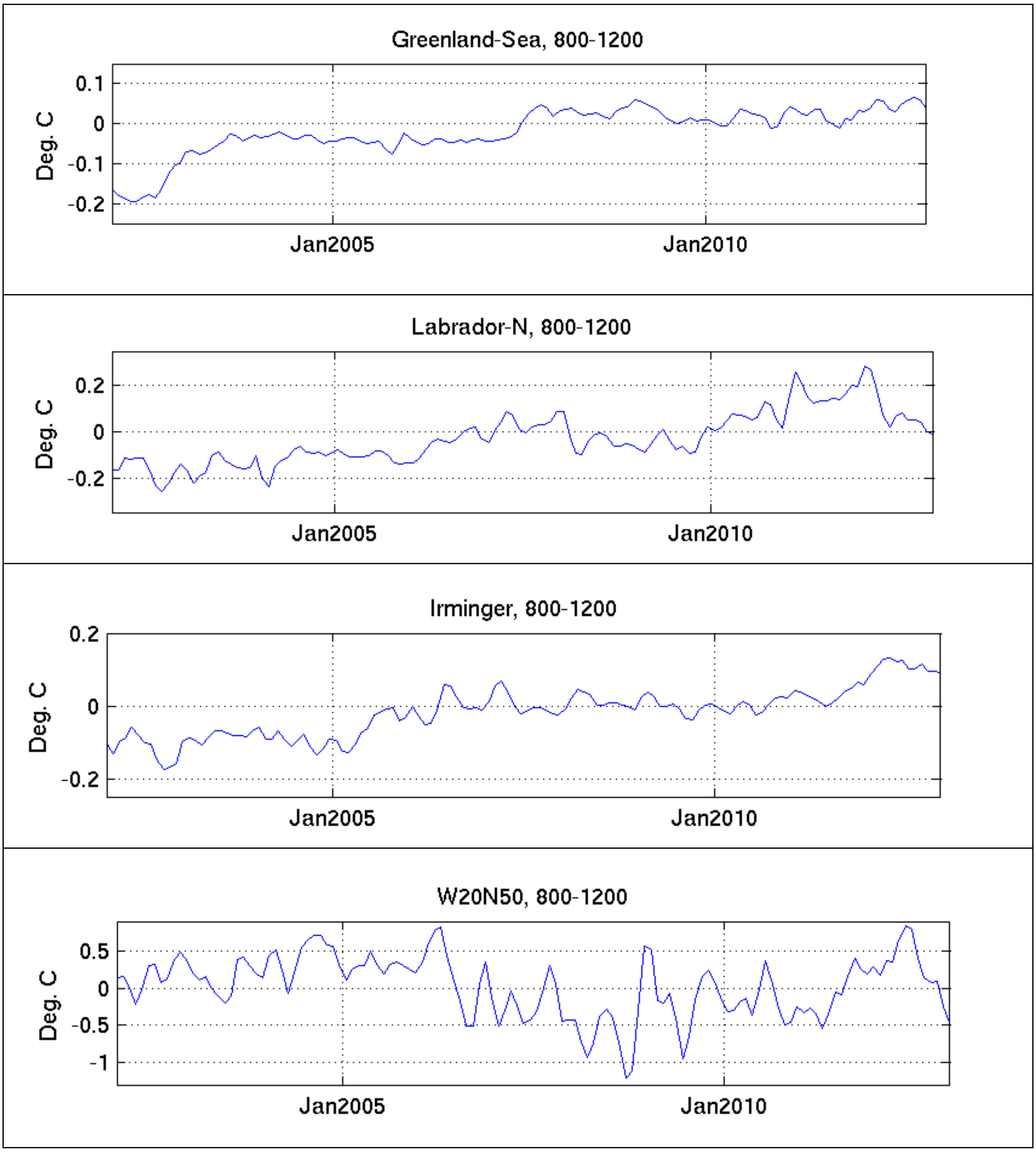


Figure 6: Time series of temperature anomalies averaged over the 800-1200m layer.

1.3 Deep layers

At 1000 m (Figure 5), the main points already noted in the previous years are confirmed:

- The Greenland Sea, the Labrador Sea and the Irminger Sea are warmer than normal and this is a clear tendency since 2002 as seen in the time series (Figure 6).
- The Mediterranean Outflow water seems warmer and saltier west of the Iberian peninsula and along the eastern boundary. The salt increase seems to extend over the basin.

- A cold and fresh anomaly stands from the South of Iceland down to Rockall trough
- A cold and fresh anomaly is observed south of the Gulf-Stream and Azores current (sub-tropical gyre).

1.4 References

Gaillard, F., E. Autret, V.Thierry, P. Galaup, C. Coatanoan, and T. Loubrieu , 2009 : Quality control of large Argo data sets. JOAT, Vol. 26, No. 2. 337–351.

Gaillard, F., 2012. ISAS-Tool Version 6: Method and configuration. Rapport LPO-12-02, http://archimer.ifremer.fr/doc/00115/22583/

2 Ships of opportunity along 60°N

Near surface temperature and salinity measurements are collected from ships of opportunity in the North Atlantic. Six merchant vessels equipped with thermosalinographs, contributing to the French ORE SSS (sea surface salinity research observatory, http://www.legos.obs-mip.fr/observations/sss) were part of this network, with support for salinity samples of the Reykjavik Marine Research Institute and the Nuuk Climate Center, and complement along-way data collected from research vessels or other merchant vessels (for example, Reykjafoss and Oleander by NOAA) (GOSUD project, http://www.ifremer.fr/gosud). On some of the vessels, ancillary data are also obtained to study inorganic carbon and nutrients in the upper ocean (we participate for that on the Reykjafoss). All the vessels have been active in 2012 (except one in the eastern Atlantic), and have reported useful data, although with a return of usable data that can be as low as 50% due to instrument failure or water shut-down. The ORE SSS vessels included the Nuka Arctica (AX01), usually between Denmark and west Greenland, the Santa Cruz between the British Channel and eastern South America, and two vessels (MN Toucan and Colibri) on an irregular basis between the British Channel, north-western Mediterranean and French Guyana. There is also one vessel (Matisse) between France, North America and Panama, crossing the North Atlantic 6 times each year. Water samples are collected on a nearly-daily basis on all the vessels, and comparison with nearby ARGO near-surface temperature-salinity data is also done, in order to correct the salinity data from the TSGs. In addition, water samples are collected on the Reykjafoss between Iceland and north-east North America four times in 2012 as part of a project to study ocean inorganic carbon changes.

Here, we report data from the Nuka Arctica TSG that are available since June 1997, and for which quality control and validation have been completed until December 2012 (by Denis Diverres (IRD) and Gaël Alory (LEGOS)). The system seems to have worked well most of the time in 2012, together with a pCO2 equilibrator system (University of Bergen) with an intake depth probably near 4-5m with fair weather (low flow however during part of the summer 2012). Preliminary analysis suggests that along 59°N but also other latitudes, 2012 remained anomalously warm near and west of the Reykjaness Ridge (not clear on the plots because of some missing data, but very clear in summer sections). It remains slightly anomalously salty between 35 and 40°W (but much less than in the peak period of 2008 to early 2010), as well as east of 15°W. On the other hand between 15°W and 35°W (Reykjanes Ridge and western Iceland Basin), there is a very clear fresh water salinity anomaly (as low as in 1996) that has developed since late 2009, and seems to be still there (anomaly largest in summer and autumn and weaker in winter).

Both the Nuka Arctica line (AX01) and the Reykjafoss line between Iceland and Newfoundland (AX02) are now lines identified as high resolution XBT lines. This is done since late 2010 each year with horizontal resolution of at least 30 km, with the goal of achieving 4 good sections. This could be implemented on the Nuka Arctica, but there is significant data loss during bad weather in winter (the December and March crossings). On Reykjafoss, we have less success, with one low section which could only be implemented at low resolution, and some gaps in the night sampling on most other sections (either bad weather or no automatic launcher working).

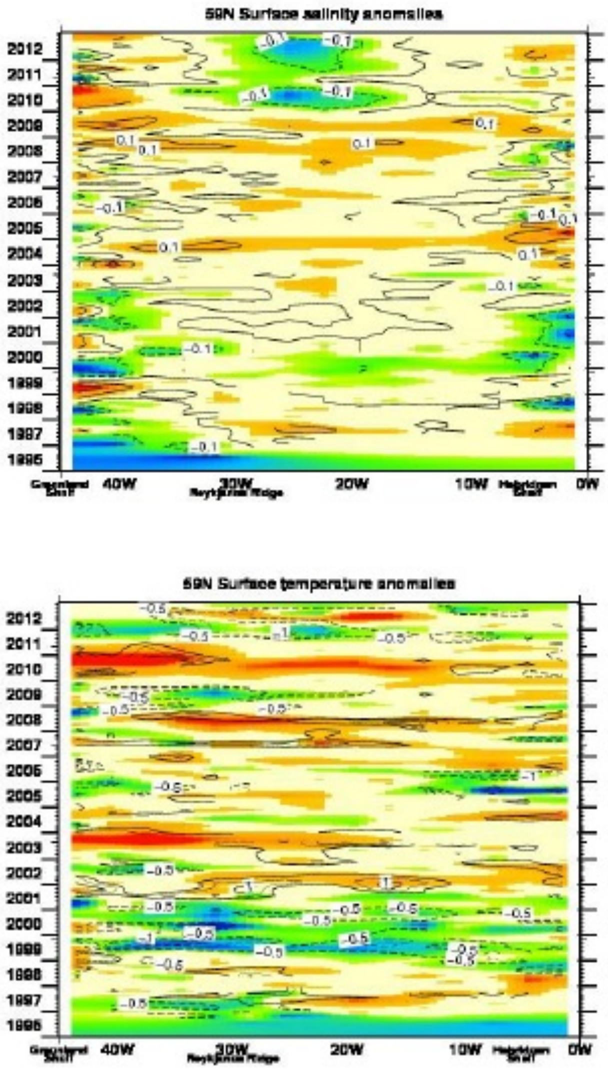


Figure 7: Monthly salinity (upper panel) and temperature (lower pannel) anomalies from the Nuka Arctica along 59°N from the shelf break south-east of Cape Farewell to the norht-west of Scotland

3 South western Channel: Astan and Estacade time series

Measurements collected twice a month at two stations located on the coastal area on the north coast of Brittany in France are presented here (red point on Figure 8). The Estacade site is located at the end of a pier in the city of Roscoff (France) where the bottom depth varies from 3 to 12 m depending on the tides. Measurements began in 1985. They are collected at 1 m depth. Its exact location is 3°58'58W and 48°43'56N. The Astan site is located 3.5 kilometres offshore from the Estacade site and measurements began in 2000 at 3°56'15W and 48°46'40N. Properties at this site are typical of the Western Channel waters. Bottom depth is at about 60 m depth and the water column is well mixed for most of the surveys. More details can be found at http://somlit.epoc.u-bordeaux1.fr/fr/

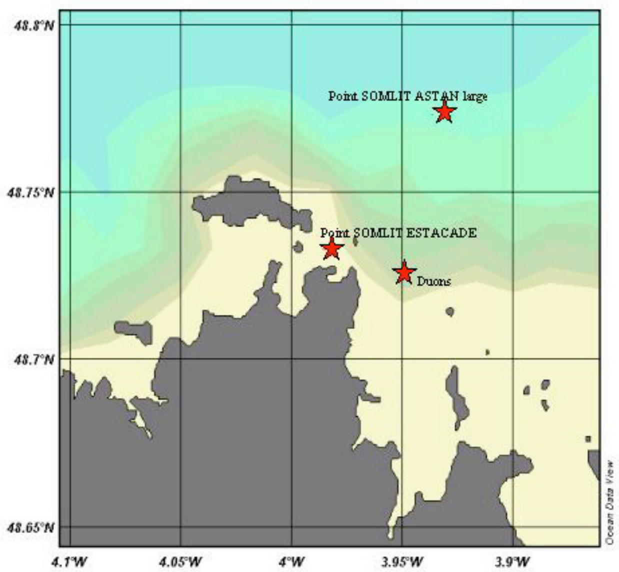


Figure 8: Localisation of the ESTACADE and ASTAN sites.

The first panels (Figure 9 and Figure 10) present the 2012 cycle of temperature, salinity and nitrate compared to the mean annual cycle at the Astan and Estacade stations. At both stations temperatures during 2012 showed seasonal deviations from the mean monthly cycle temperature cycle. During winter and early spring temperatures were higher (from + 1.21 °C in January to + 0.40 °C in April) than the average values observed at Astan station. During late spring and summer, temperatures were close to the average values observed becoming lower than average in late autumn (-0.30°C in November). Temperature cycle at the littoral Estacade station followed the same evolution as the coastal Astan (figure 3) excepted in summer when average temperatures became lower than the average values (e.g. -0.38°C in July). Salinity annual cycles at the two sites were characterized in 2012 by values that remained relatively constant (>35.3 at both sites). Differently from the mean annual cycle, salinity values were permanently higher than the mean monthly values during the first half of the year. Minimum values that were usually observed in March and April at Astan and Estacade stations were not recorded in 2012 due to a dry winter with low water precipitations and a reduced influence of the river inputs in the Western Channel. Significant higher than the mean monthly values were measured in March (respectively + 0.32 and + 0.36 at Astan and Estacade stations). During the rest of the year, salinity values were close to the mean monthly values. During 2012 nitrate concentrations were significantly lower than the averaged values during the first part of the year corresponding to the presence of the high salinity waters. Deviations increased regularly from -2.5 in January to -5.3 µmole/l^{-1} in April at Astan station corresponding to a significant decrease of nutrient inputs from the rivers in winter and early spring 2012 . A same evolution was observed at Estacade station at the same period. During summer, nitrate values were close to the usual mean monthly values with minimum concentrations observed in July. During summer as usually observed in the well-mixed waters Astan area nitrate concentrations were not exhausted by phytoplankton development (NO3 > 1.0 µmole/l-1).

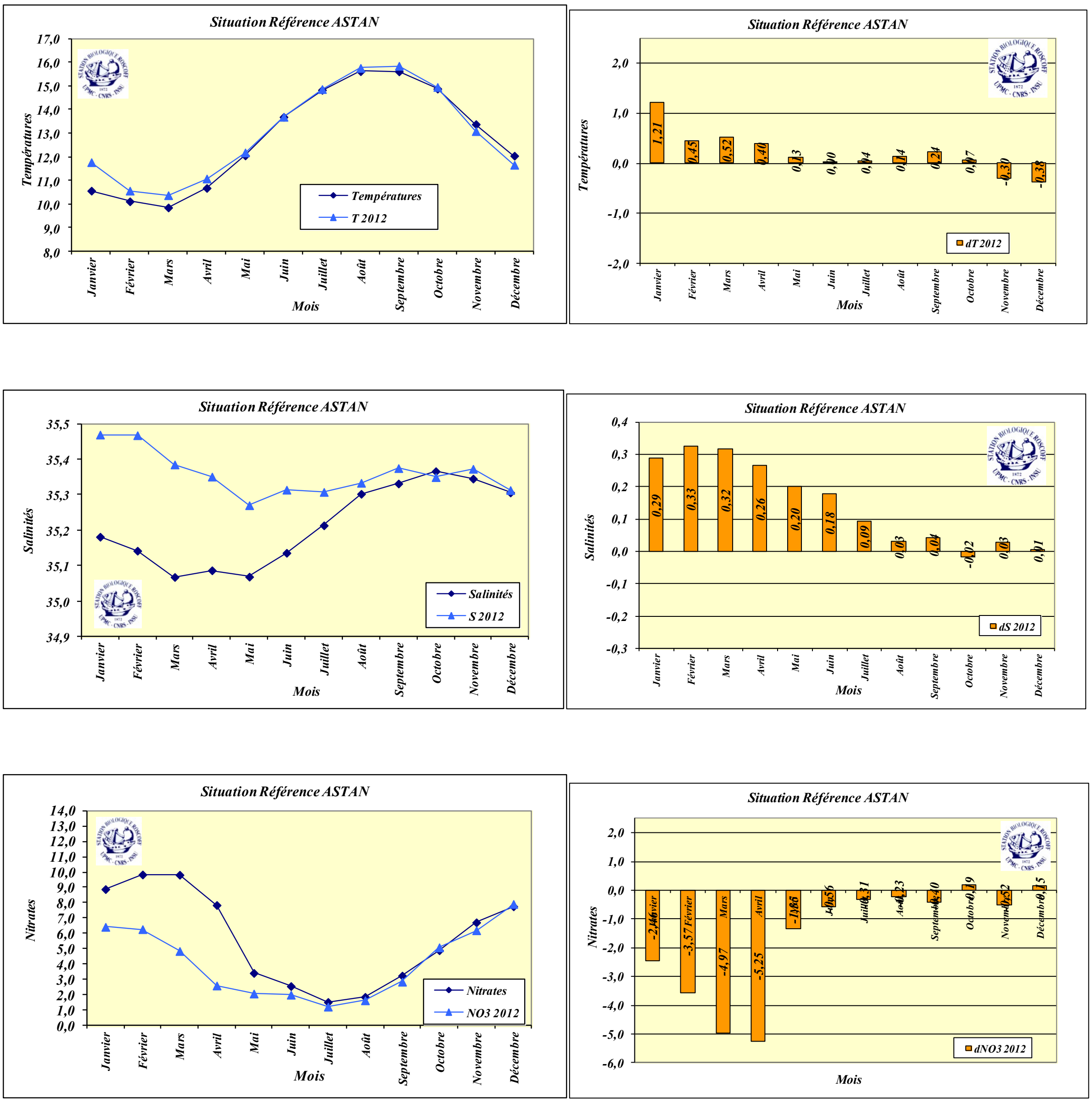


Figure 9: Comparison between times series of temperature (upper), salinity (middle) and nitrate (lower) at the ASTAN site in 2012 with the climatological cycle. (Left panels): Dark blue line represents the mean annual cycle and light blue line represent 2012 data. (Right panels) 2012 deviation to mean values

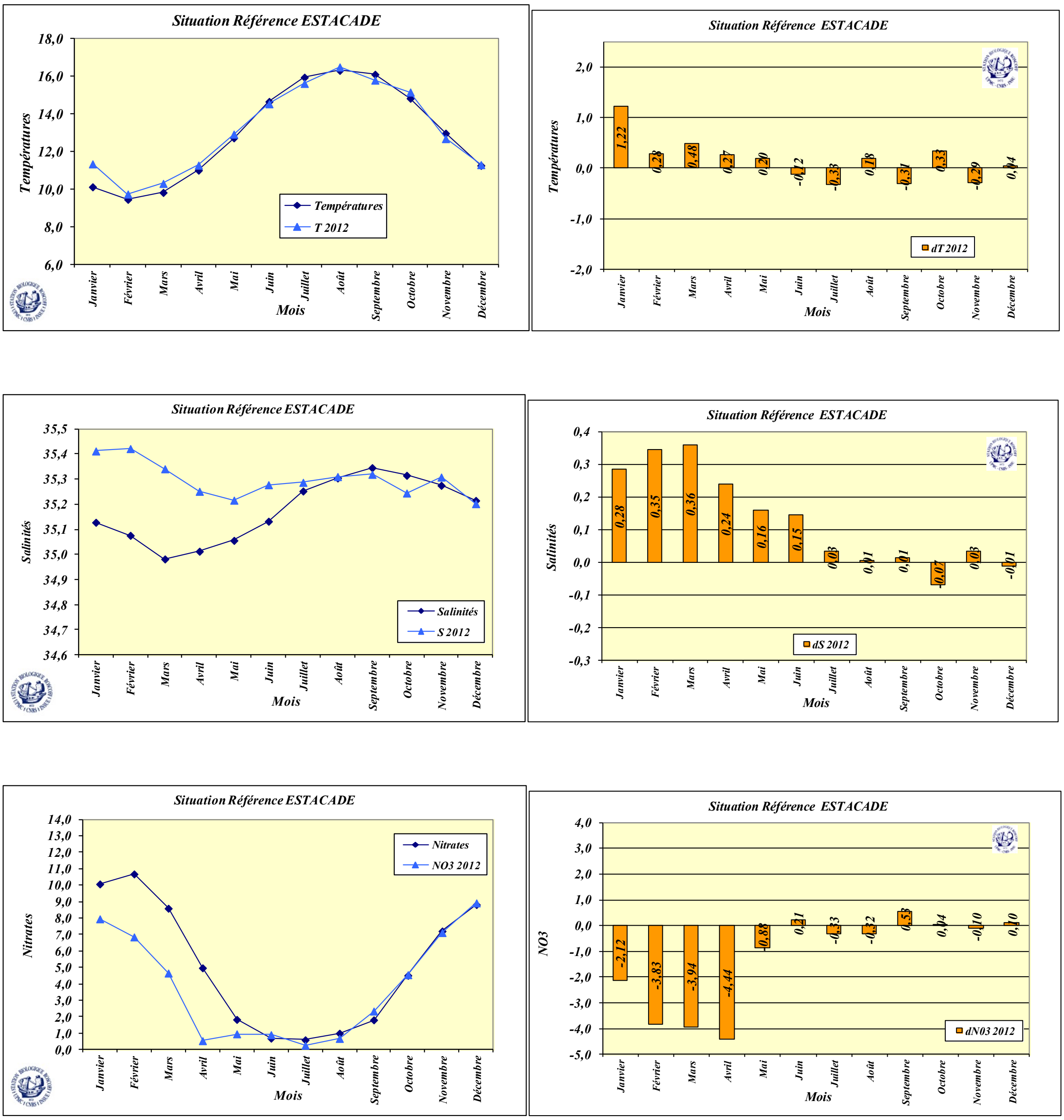


Figure 10: Comparison between times series of temperature (upper), salinity (middle) and nitrate (lower) at the ESTACADE site in 2012 with the climatological cycle. (Left panels) : Dark blue line represents the mean annual cycle and light blue line represent 2012 data. (Right panels) 2012 deviations to the mean values;

Figure 11shows the time series of temperature, salinity and nitrate at Astan over the period 2000-2012 and at Estacade over the period 1985-2012 with a large gap from 1992 through 2000 for salinity and nitrate measurements. At the Astan and Estacade sites, winter 2012 minimum temperatures were significantly higher than those observed during the last three winters. Minimum temperatures were in the same order than those observed during the 2006-2007, 2001-2002 and 200-2001 winters that were characterize by the presence of relatively warm waters in the Western Channel. As usually observed in this area, Western Channel waters were well-mixed over the entire water column during the whole year since no temperature differences between surface and bottom waters were observed (Figure 12, top). The low vertical temperature gradient observed episodically in late summer (late August-early September) during low wind - neaps tide period was not observed in 2012. As for temperature Western Channel waters were generally well-mixed over the entire water column since no salinity differences between surface and bottom waters were observed (Figure 12, bottom) even during the late summer surface heating.

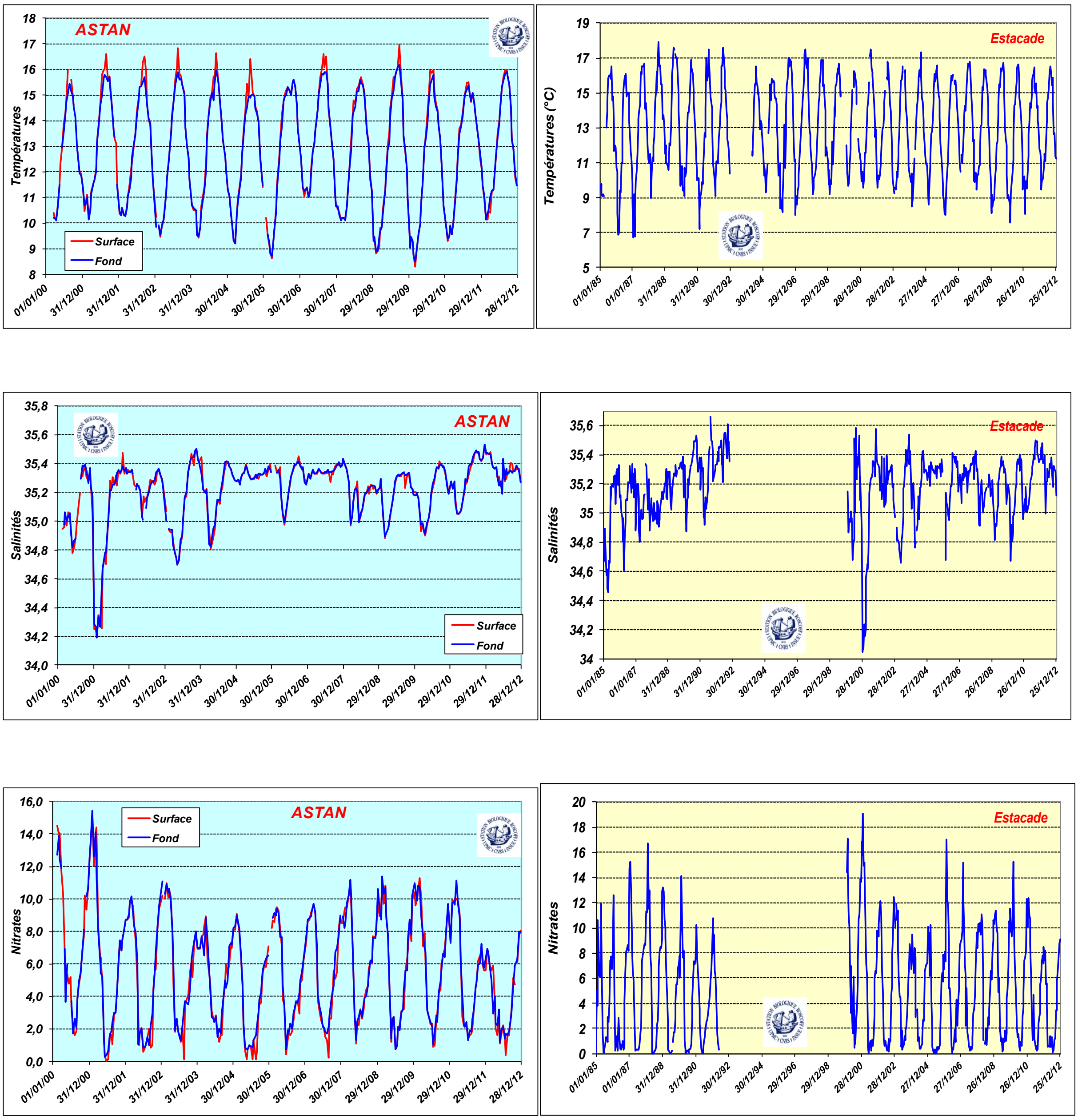


Figure 11: Interannual variability of the temperature, salinity and nitrate at the Astan site over 2000-2012 (left panels) and at the Estacade site over 1985-2012 (right panels).

In 2012, salinity cycle is characterized as mentionned above by higher values than those usually observed in this area (mean annual salinity = 35.359). Mean annual salinity at Astan in 2012 was the highest observed since 2000. Similarly, the minimum values that were observed in late winter – early spring were among the highest observed since 2000 (Figure 11) due to the very low influence of river inputs in southern Western Channel. Nitrate concentrations as salinity present a large interannual variablity particularly in the winter maximum values which is linked to the interannual variability in the oceanic influence in the Channel waters. Maximum nitrate winter concentrations ($\approx 6.4\ \mu M/l^{-1}$) were significantly lower than the previous winter values due to the reduced influence of the low salinity waters in the Western Channel. The mean monthly nitrate concentrations were the absolute minimum concentrations observed between January and April since 2000 at Astan. Nitrate winter and early spring stock for the spring phytoplankton development was reduced in 2012 when compared to the previous years. Residual nitrate values (≈ 1.0 µM/l^{-1}) were observed in surface waters during summer 2012 which may be explained by a lower phytoplankton uptake due to the existence of less favourable environmental conditions with a cloudy summer.

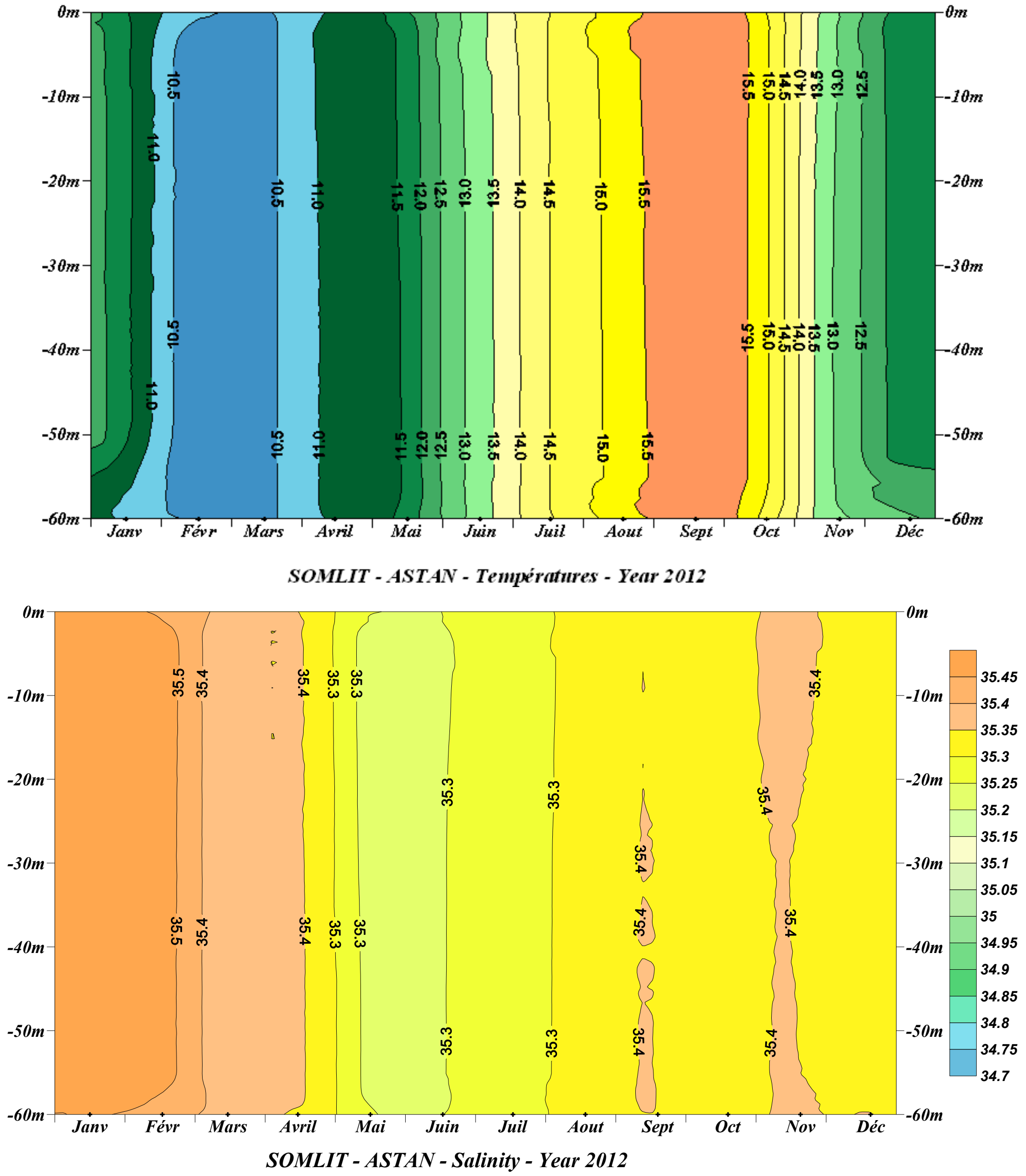


Figure 12: Vertical distributions of temperature (top) and salinity (bottom) at ASTAN site during 2012 (bimonthly CTD profiles). Well-mixed waters were observed during the whole year due to an enhanced vertical mixing by tidal currents