

Using the Argo Dataset to Describe the North Atlantic SubPolar Mode Water

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OBJECTIVES- DATASET-METHOD

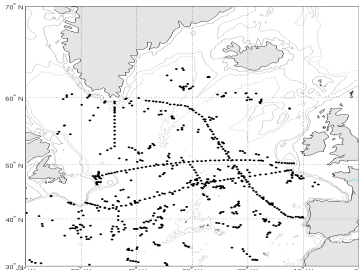


Figure 1 Example of the geographical distribution of profiles for a 2-month window centered on June 15th, 2002.

The Method

The good space time sampling of high quality profiles of temperature and salinity allowed the interpolation of the fields via an Objective Analysis program adapted from a work by E. Autret and F. Gaillard.

The anomalies of the different parameters around the Reynaud's climatology were interpolated on a $1/3^\circ$ resolution grid. The correlation function was chosen to be the sum of two Gaussians with a large scale (300km) and a meso-scale fixed to $2 \times$ Rossby radius in the area (the North Atlantic Ocean was divided in 40 zones). The analyses were realized on pressure and potential density levels using a 2-month window for data selection.

Objectives:

After having defined the ability of the ARGO data set to describe the SPMW by comparing objectively mapped data with previous studies, we describe the general properties of SPMW (geographical distribution, depth, density ranges occupied by the different varieties) and the bringing of this new data. We then present an annual cycle of potential vorticity along $20^\circ W$ to describe the seasonal variability of SPMW in this region and the distribution of the deep mixed layers. We finally explore the inter-annual variability by comparing two years of study.

The dataset

The data set consists in high quality profiles of temperature and salinity from Lagrangian floats deployed since 2001 and CTDs realized during several campaigns (OVIDE, 48°N,...)

DATASET CONSISTENCY

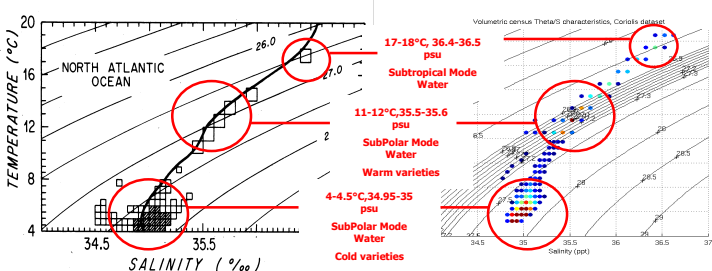


Figure 2 Comparison between a volumetric census plotted in a potential temperature/salinity diagram made by Wright & Worthington (1971) on the left and the same census obtained from the objectively mapped data for August 2002. The three most noticeable accumulations of volume observed by Wright and Worthington can be observed with our dataset

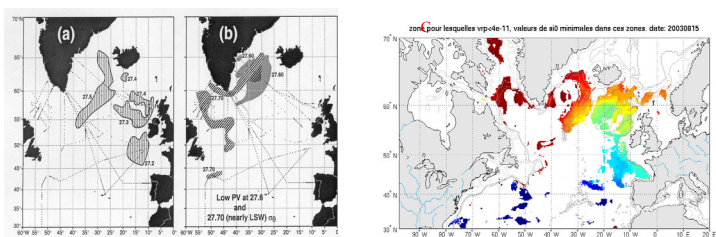


Figure 3 (left: a) Areas of potential vorticity less than $4.10^{-11} \text{ m}^{-1} \cdot \text{s}^{-1}$ for isopycnals 27.2 to 27.5, based on WOCE Hydrographic sections collected in May-August 1997 (from Talley, 1999). (left-b) Potential vorticity less than $6.10^{-11} \text{ m}^{-1} \cdot \text{s}^{-1}$ at 27.6 and less than $3.10^{-11} \text{ m}^{-1} \cdot \text{s}^{-1}$ at 27.7, for the same data set (from Talley, 1999). (right) Potential density in the areas of potential vorticity less than $4.10^{-11} \text{ m}^{-1} \cdot \text{s}^{-1}$ based on our interpolated data set.

The large scale structure of the SPMW distribution is close to that observed by Talley (1999). In both studies SPMWs are found around the outer periphery of the Subpolar Gyre. SPMW with different densities are distributed in large areas west of the NAC and in more patchy structures to the east. The density ranges are nearly discontinuous with density jumps occurring in geographical regions of small extent. Thus, our data set and method of interpolation allow the observation and description of the different varieties of SPMW. However, they seem to carry mesoscale information revealed by smaller scales structures.

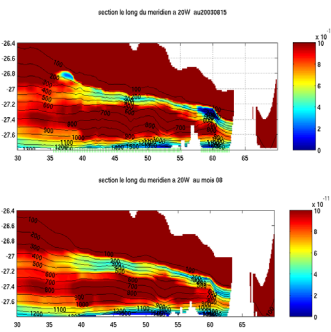


Figure 4 Representations of isopycnal potential vorticity along $20^\circ W$ in potential density coordinates. (a) results from an objective analysis of potential vorticity on isopycnals for the data from a 2-month window centered on August 15th. The green dashes at the bottom of the figure indicate that a float profile is nearby. (b) Same section plotted with data from Reynaud's climatology for August.

Along $20^\circ W$ (figure 4) many varieties of SPMW are present. The staircase shaped distribution of the homogeneous layers renders obvious the discontinuity in density. Indeed, five varieties of SPMW are present along this section:

- $\sigma_\theta \sim 27.48-27.52$ (south of Iceland),
- $\sigma_\theta \sim 27.27-27.35$ (north of Rockall Bank),
- $\sigma_\theta \sim 27.25$ (south of Rockall Bank),
- $\sigma_\theta \sim 27.05-27.15$ (between $42^\circ N$ and $50^\circ N$ and south of $42^\circ N$ as a less homogeneous subducted form)
- $\sigma_\theta \sim 26.85-26.95$ (south of $42^\circ N$, superposed to the latter but more homogeneous and shallower).

The data actually brings new information. Indeed, the patches north of Rockall are thicker and occupy a larger range of density compared to Reynaud's climatology. The apparition of a secondary thermocline south of $40^\circ N$ is also a contribution from the new dataset.

AN ANNUAL CYCLE OF SPMW- SEASONAL VARIABILITY

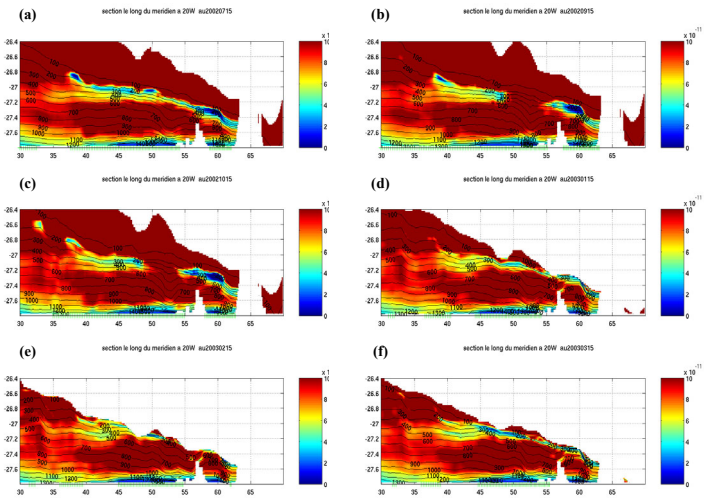


Figure 5 Representations of isopycnal potential vorticity along $20^\circ W$ in potential density coordinates. For 2-month windows centered around (a) July 15th 2002, (b) September 15th 2002, (c) October 15th 2002, (d) January 15th 2003, (e) February 15th 2003 and (f) March 15th 2003. Part of the signal comes from the variability in the amount of data during the temporal window. In July 2002 for instance several more homogeneous patches can be observed throughout the section (around $50^\circ N$) but they disappear in August, don't come back in July 2003 (less data were available at that period) and are not contained in climatology. The presence of mode water between $50^\circ N$ and $55^\circ N$ on some plots is also due to this bias: when there is sufficient data in this region the analysis tends to deny the presence of SPMW between 50 and $55^\circ N$ that was previously inferred from the climatology. Finally the presence of the two branches of mode water south of $40^\circ N$ are also confirmed when there is sufficient data. In general, there are consistent departures from climatology throughout the period of study. This annual cycle (figure 5) allows observation of the evolution (period of formation, restratification over the mixed layers, subduction) of the different varieties of SPMW at $20^\circ W$. The mixed layers reach the mode water depth in January and February in this region, restratification already occurs in March. The data confirms the presence of two branches of mode water south of $40^\circ N$. The upper branch extends further south to $35^\circ N$ at the same depth and is renewed in February. In October, another patch of mode water at 26.7, situated at the same depth as the 26.8- 26.9 patch, is found even more south. Those two patches could be the local remnants of the winter mixed layer but it could also be the signature of mesoscale eddies. The lower branch at 27.1 is less homogeneous and extends further south than an isopycnal. It is not renewed during the observed winter at that longitude: it has been subducted.

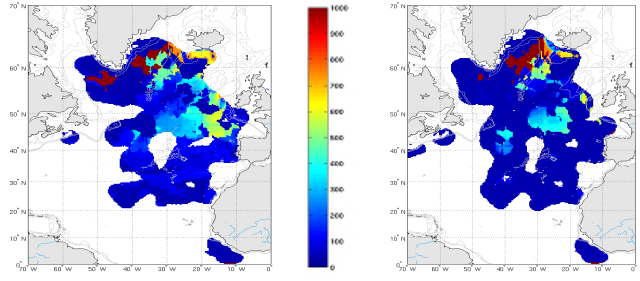


Figure 6 Mixed layer depth in the North Eastern Atlantic for February and March 2003 (data from a 2-month window and analysis centered around the 15th of each month). The depth of the mixed layers were calculated after an analysis of potential vorticity on isobaric planes. The very deep mixed layers (>1000m) appear in January near Iceland, then south of the Greenland tip and in the Irminger Sea in February. In March, most of the very deep mixed layers are found in the Irminger sea. The restratification gets really advanced in April except west of the Reykjanes Ridge. The deepest mixed layers are generally found immediately west of the Bay of Biscay, at the northern tip of the Iceland Basin, in the Irminger and the Labrador Seas. These results must be taken with caution and a further exploration of the raw profiles would allow more accurate conclusions.

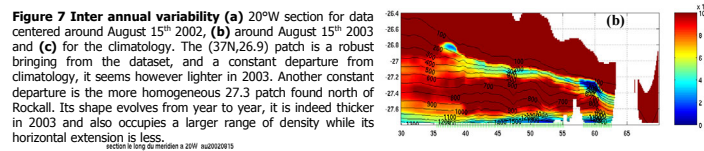


Figure 7 Inter annual variability (a) $20^\circ W$ section for data centered around August 15th 2002, (b) around August 15th 2003 and (c) for the climatology. The (37N,26.9) patch is a robust bringing from the dataset, and a constant departure from climatology, it seems however lighter in 2003. Another constant departure is the more homogeneous 27.3 patch found north of Rockall. Its shape evolves from year to year, it is indeed thicker in 2003 and also occupies a larger range of density while its horizontal extension is less.

CONCLUSIONS

This study confirmed some previous analyses (location, density trend...). The quality of the ARGO data set allowed :

- A more precise determination of density ranges occupied by the different SPMW varieties.
- The study of an annual cycle of SPMW.
- The observation of the seasonal variability.
- The observation of the monthly averaged mixed layer formation.
- A better comprehension of the differences between the varieties of SPMW.

PERSPECTIVES

- Look more precisely at the individual float profiles to investigate about the mode waters observed at $40^\circ N$ along $20^\circ W$ and those located on the eastern side of the Reykjanes Ridge.
- Investigate the mechanisms of deep mixed layer formation (the period of formation of the deep mixed layers, formation processes, time window during which it occurs, influence of the meso-scale eddies and topography).