Mean structure of the North Atlantic subtropical permanent pycnocline from in-situ observations

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Outline
The large scale ocean stratification is a key characteristic of the ocean that plays a role in heat uptake, nutrient supply and the distribution of anthropogenic carbon. Assessing the structure and variability of the permanent pycnocline is of major interest for the understanding of the climate system. Although a key concept of the large scale ocean dynamic, the permanent pycnocline does not have a rigorous definition. Here we propose to define the permanent pycnocline as the layer trapped between two water masses ventilated at different time scales (seasonally and larger time scale) that allow for the development of an original algorithm to characterize it. The algorithm is able to characterize the permanent pycnocline from any profile, whether at low, mid or higher latitudes and along the eastern or western boundaries. A 0.5° x 0.5° resolution reference state of the permanent pycnocline characteristics based on the Argo array is constructed for the 2004-2014 period and the North Atlantic Ocean. It is the first time such a climatology is produced based on in situ observations. It reveals a surprisingly complex structure of the permanent pycnocline with inhomogeneous properties.

Motivations
Global warming of the ocean
It is the most intense in the North Atlantic subtropical gyre and it seems to be constrained by the structure of the permanent pycnocline.

The permanent pycnocline in the North Atlantic subtropical gyre
Characterized by a strong density/temperature gradient.

Method to characterize the permanent pycnocline with in-situ profiles
Process
Characterization of the permanent pycnocline in terms of depth and thickness

Pycnocline depth
Permanent pycnocline depth (max of N²)
below a mode water (min of N²) below a mixed layer

Potential density (kg/m³)
Potential density (kg/m³)
Temperature

Typical subtropical summer-like (A) and winter-like (B) profiles in the North Atlantic subtropical gyre

Application with Argo data
The Argo database in the North Atlantic Ocean
147069 profiles from 1452 floats
Time period: May 1998 - December 2014

Results: permanent pycnocline mean state estimate
Pycnocline depth (m)
Pycnocline top thickness (m)
Pycnocline total thickness (m)
Pycnocline bottom thickness (m)

Depth and thicknesses
The large scale description of the pycnocline depth as a classic bowl shape is well captured with specific structures at local and regional scales. The pycnocline has an asymmetric structure around its depth.

Thermohaline properties
Central and Subpolar Mode Water are found at the depth of the permanent pycnocline. There are gradients in potential density. The permanent pycnocline can be approximated by an isopycnic only in small areas. Stratification is stronger in the west than in the east of the gyre.

Ongoing Work
Heat content and permanent pycnocline change in the North Atlantic subtropical gyre
(Hovmöller plot for the North Atlantic anomalies of the zonally and full depth integrated heat content (x10¹⁰), adapted from Williams et al. 2014, 2015).

Change in the depth of the permanent pycnocline (a maximum in the stratification) cannot be anticipated by looking at changes in the vertical displacement of isopycnics.