Temperature and Salinity annual anomalies in the North Atlantic from CTD data - Estimating the seasonal cycle

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Aims of the project

- estimating temperature and salinity annual mean anomalies on a coarse resolution grid (1°x 1°) from CTD and Argo floats data
- reconstructing the variations of the large scale ocean circulation

Aims of this study

- estimating the seasonal cycle from CTD data

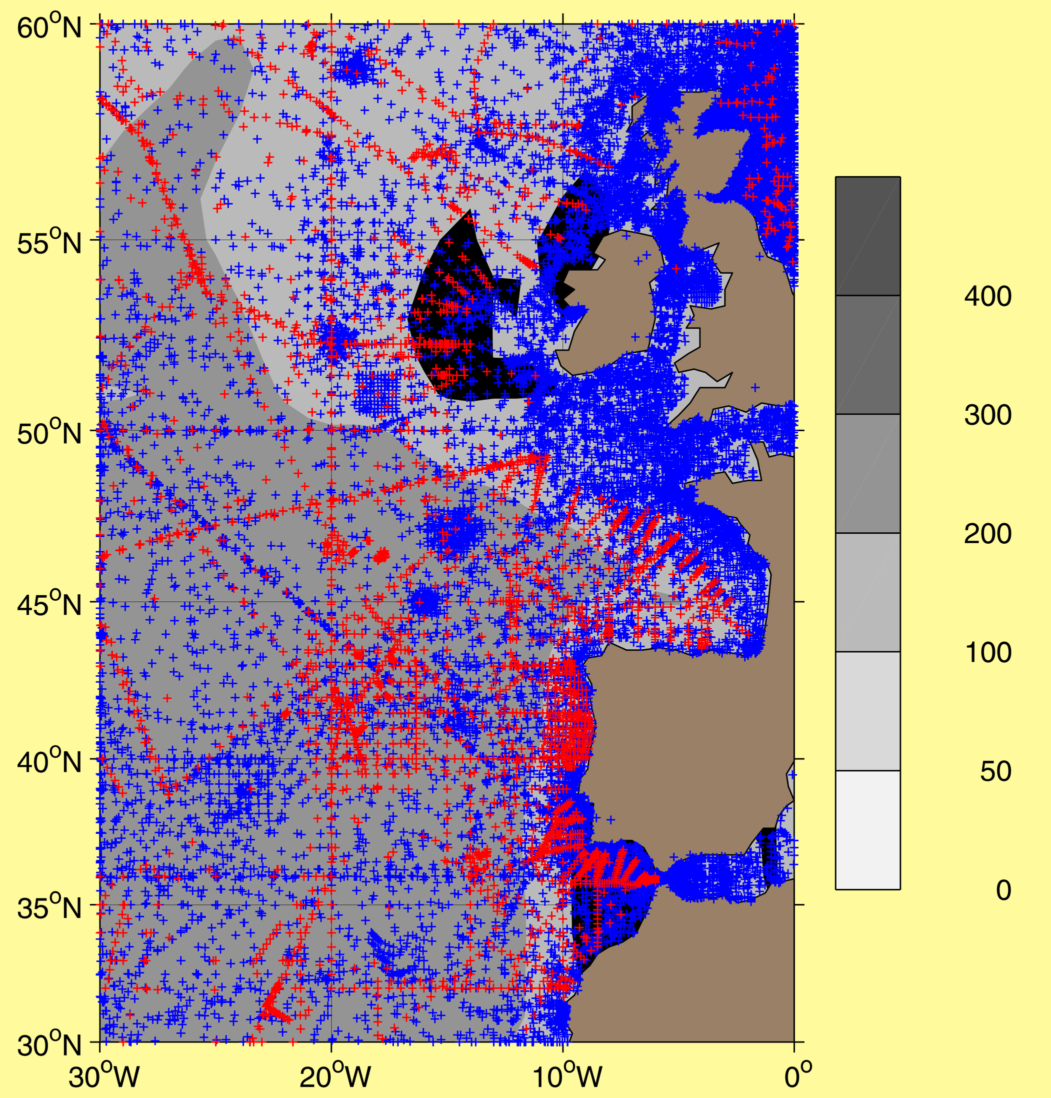

Figure 1: Positions of Hydrographic Data at 100m in the North Eastern Atlantic (historical years in blue/Woce years in red). The radius of influence field (km) is shown in gray.

Method

The final aim of this study is the production of anomaly fields on a relatively coarse resolution grid.

We assumed that the observed signal is made of several contributions with distinct space-time properties:

- noise
- meso-scale variability (more or less high frequency with short wavelength (several times the deformation radius)
- a clear seasonal cycle at surface
- an interannual signal with relatively long periods that we try to estimate

It seems important to properly correct observations from the seasonal cycle which is the largest signal, especially in upper layers.

Let X_i (i=1:n) be a series of measure at times t_i (i=1:n). We try to fit a seasonal cycle with 2 (m) harmonics through a least-square minimization method, that is, to adjust the set of coefficients (C_1,C_2,C_3,C_4,C_5) that minimizes the deviation of the data to the seasonal cycle:

$$X(t) = c_1 + c_2\cos(\omega t) + c_3\sin(\omega t) + c_4\cos(2\omega t) + c_5\sin(2\omega t)$$

where $\omega=2\pi/1$ year. Then we try to minimize:

$$G = \frac{\sum w_i (x_i - X(t_i))^2}{\sum w_i}$$

where W_i are gaussian weights added for taking into account the spatial distribution of observations located near the the grid point of interest.

The coefficients c_k result from solving the linear system A C = B,

$$A_{ij} = \left(\sum_{k=1}^{N} w_k\right)^{-1} \sum_{k=1}^{N} w_k\, f_i(t_k)\, f_j(t_k)$$

$$B_i = \left(\sum_{k=1}^{N} w_k\right)^{-1} \sum_{k=1}^{N} w_k\, x_k\, f_i(t_k)$$

$$f_1 = 1$$
$$f_2 = \cos(\omega t)$$
$$f_3 = \sin(\omega t)$$
$$f_4 = \cos(2\omega t)$$
$$f_5 = \sin(2\omega t)$$

The coefficients c_1 is the annual mean value, $c_2^2+c_3^2$ is the annual variability while $c_4^2+c_5^2$ is associated with the semi-annual variability. The phase of the signal could also be extracted from the coefficients.

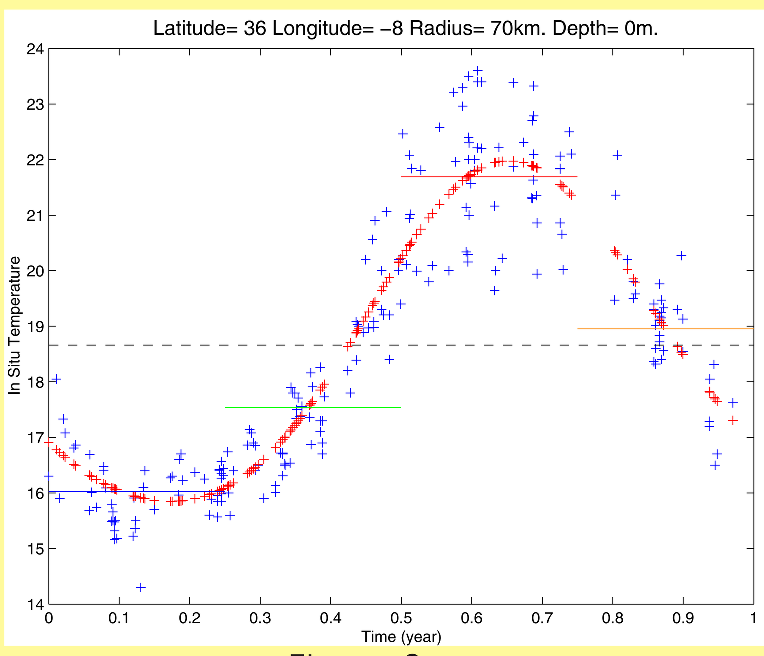

Figure 2a

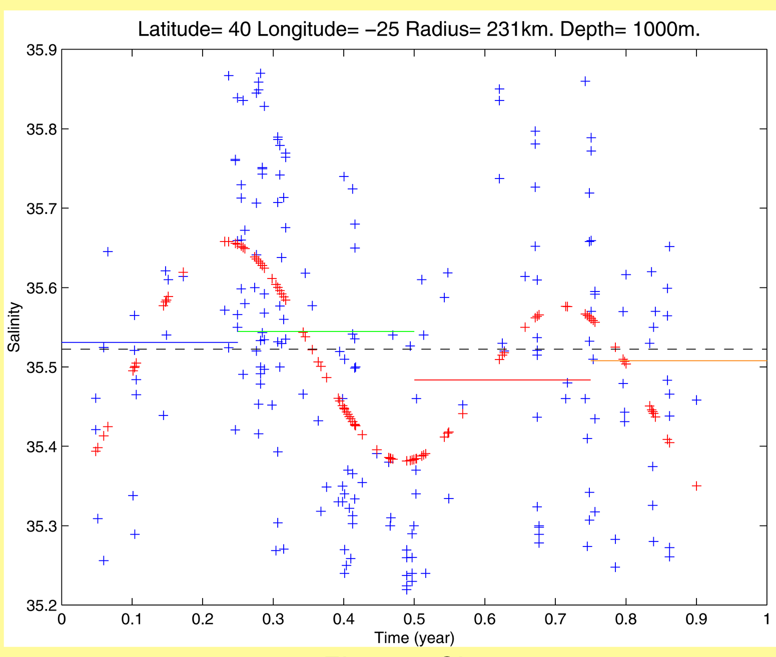

Figure 2b

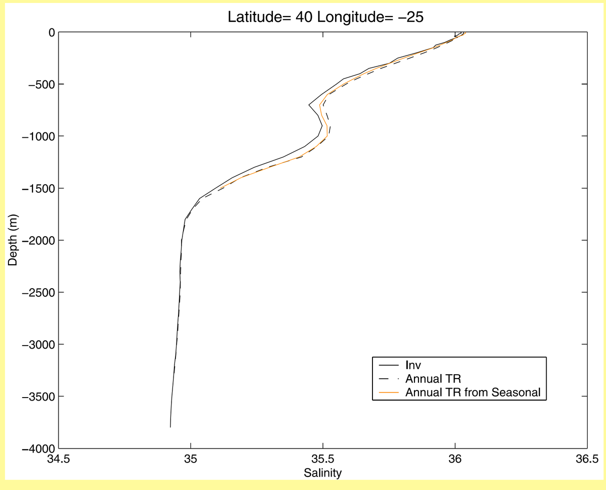

Figure 3a

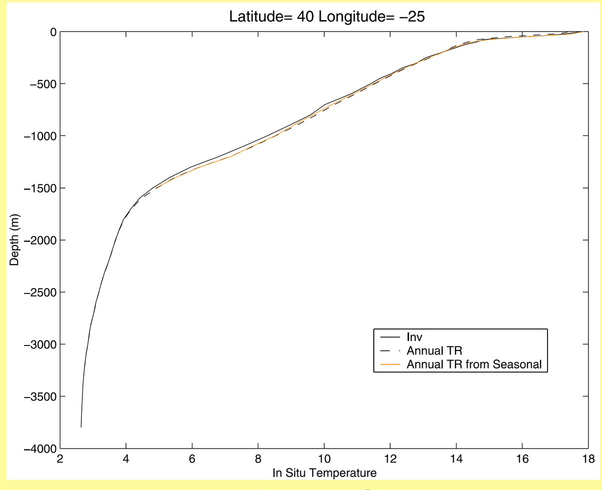

Figure 3b

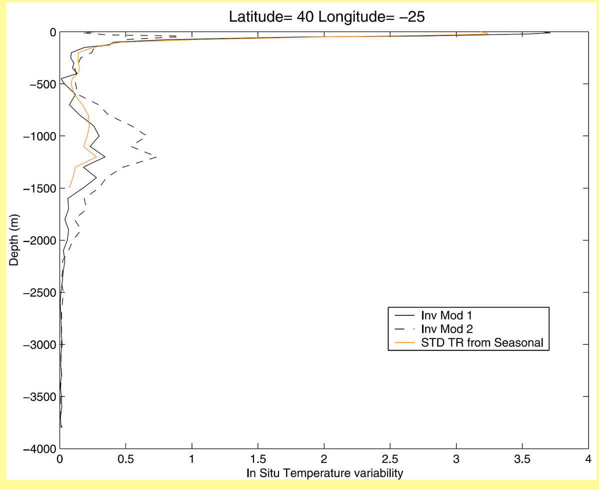

Figure 3c

Application

In order to verify if this analysis is working, we want to be able to compare its results with temperature and salinity climatologies. We thus decided to use the same radius of influence as Reynaud et al (1998) for selecting data around the grid point and for calculating the gaussian weigths. Our results are then compared with upgraded versions of Reynaud et al annual and seasonal climatologies. Figure 2 illustrates the behavior of the method for both temperature and salinity at two different locations and depth. Figure 3 compares vertically the annual mean profiles with Reynaud et al (2005) climatologies.

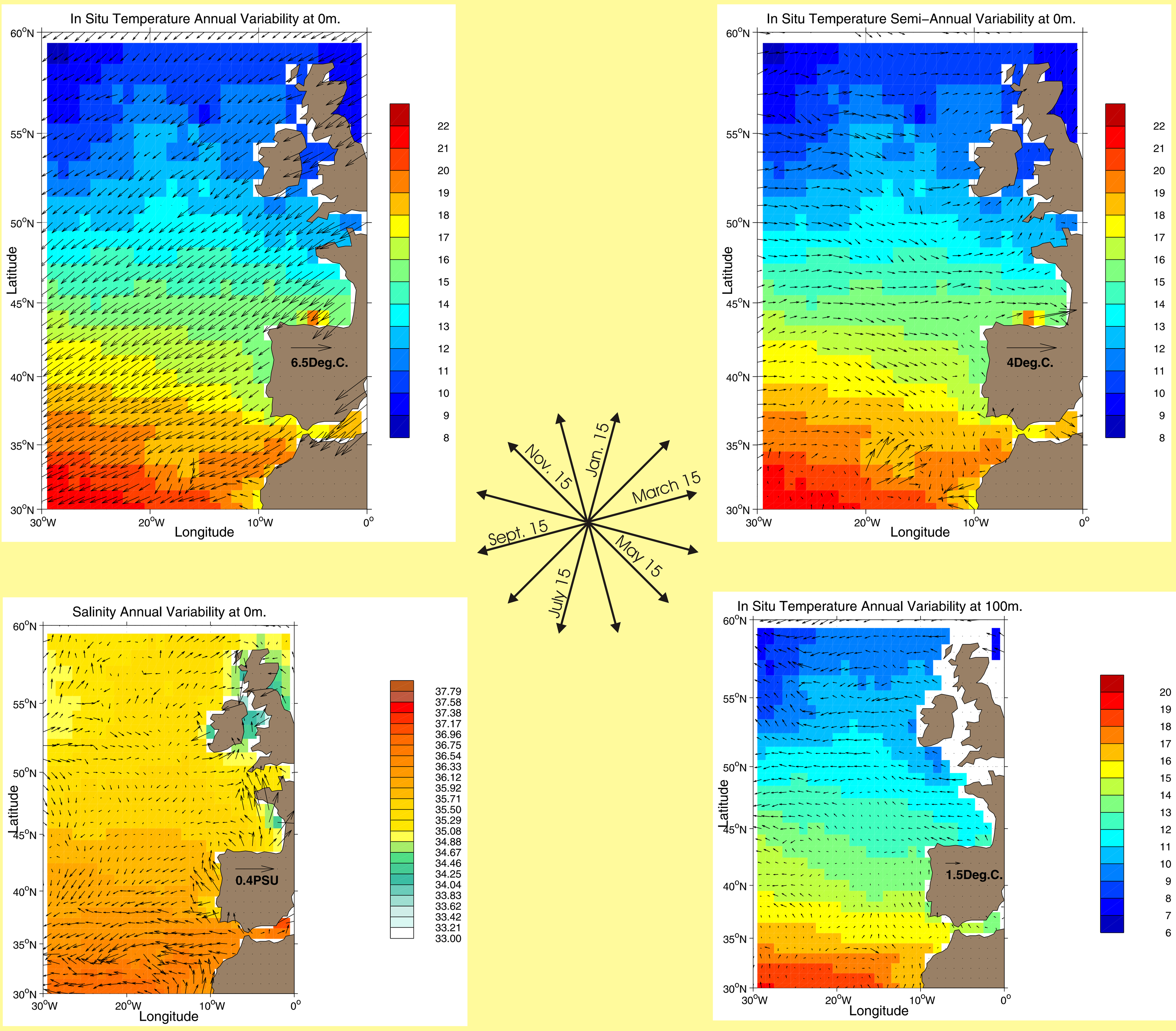

Figure 4: Annual mean fields and signal phases. The Signal phase are vectorially represented.

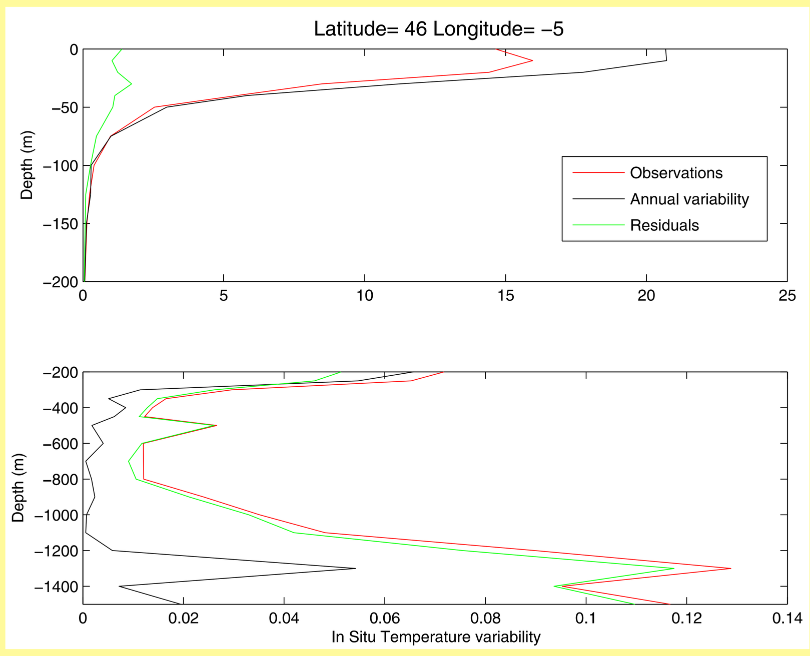

Figure 6

DISCUSSION

This method will be used to produce a climatology for these 5 harmonic coefficients (mean, annual and semi-annual cycle) in the Atlantic Ocean.

These should improve significantly the estimation of temperature and salinity anomalies, at least in the upper layers (Figure 6) , by substracting a seasonal cycle that is a continuous fonction of time. Indeed this seasonal cycle do reproduce much better the annual extrema, as compared to seasonal climatologies, yet using all the available data in the minimization process (seasonal climatology use data binned for each timeframe).

Once we have computed accurately the anomalies, we will use the optimal interpolation routines (objective analysis) developped by F. Gaillard and E. Autret, to estimate the annual mean anomalies of temperature and salinity from the Coriolis database.

References:

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