Recovery of North-East Atlantic temperature fields from profiling floats: determination of the optimal float number from sampling and instrumental errors analysis

Authors: Simón Ruiz[1], Damià Gomis[1], Jordi Font[2] - sruiz@uib.es
[1]Cross-Disciplinary Oceanography Group, IMEDEA (CSIC-UIB), Baleares, Spain
[2]Physical Oceanography Group, ICM-CMIMA, Barcelona, Spain

1 Objectives of this work and data

Objectives of this work and data

This study intends to provide some guidance on the optimal number of floats required for the recovery of the temperature field in the North-East Atlantic ocean.

The optimization of the array is here defined as the number of floats required for the recovery of a prescribed spectral range of the temperature field with a given accuracy.

80 floats from Gyroscope project (EU-funded project 2001-2003)

For the purpose of this work, we also used data from other active temperature and salinity profiling floats deployed in the North-East Atlantic in the framework of other projects.

A **total of 119 floats** (including Gyroscope floats) distributed over a domain D2 (see Fig. 1) were obtained from the **Coriolis Data Center** public ftp server.

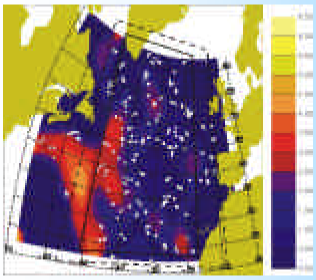


Figure 1. Left: Spatial distribution of the **temperature field variance** at 50 m with respect to the Levitus' 94 climatology (units are ºC2). The location of all active floats in the North-East Atlantic Ocean during March 2003 has been overplotted. Solid line and dashed line enclose the inner domain D1 and total domain D2 respectively.

This work has been developed in the framework of the EU-funded Gyroscope project, 2001-2003

2 Methodology

Methodology

Error formulation derived from Optimal Statistical Interpolation theory

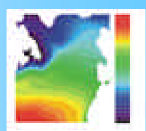
Following OI formulation (see for instance Bretherton et al., 1976), the mxm analysis error covariance matrix E_{gg} associated with the recovery of a 2D field at 'm' grid points from a set of 'n' scattered observations is given by:

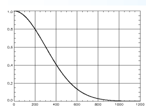
$$E_{gg} = V_{gg} - V_{go}(V_{oo} - E_{oo})^{-1} V^{T}_{go}$$

where
V_{gg} contains the covariance between grid points, V_{oo} contains the covariance between observation locations and V_{go} contains the covariance between grid points and observations points. For further details about formulation of the two error contributions (observational and sampling), please see Ruiz et al 2006 (accepted).

Parameters

• **Field Variance**: We computed the departures of observed profiles with respect to the Levitus 94 climatology. Largest variances (Fig. 1) are observed in the Gulf Stream region, with maximum values of about 4.5º C². However, within the domain D1, the variance is more homogenous, ranging between 2.0 and 2.5º C² over most of the domain (maximum values are between 3.0 and 3.5º C²).





Correlation function We assumed a gaussian model C(r)=exp[-R2/2L2], the characteristic scale L being set equal to 350 km. This was the value providing the best fit to observed lag correlations, which were computed by averaging all temperature anomaly pairs within 20 km distance lags**.**

A first reason to use a Gaussian function is that it fulfils all the assumptions required for the correlation between observations (e.g., a continuous derivative at zero distance). It is of course a simple model compared to other functions also fulfilling the assumptions, but it usually provides a reasonable approximation for the scale range studied in this work (scales larger that 500 km).
A second reason to use a Gaussian is that it can be analytically convoluted with a normal error filter (see Pedder, 1993).

Noise-to-signal ratio: We assumed an initial value for the instrumental noise variance of (0.01º C)2. Although the temperature accuracy of APEX floats is claimed to be 0.002º 2for laboratory controlled conditions, errors are likely to be significantly larger at open sea, due to sensor ageing and bio-fouling

Concept of spatial scale.
In order to eliminate non resolvable scales, the lag correlation function was convoluted with a normal error filter with cut-off wavelength equal to 500 km following the methodology described in Pedder (1993).

References:
Bretherton F. P., Davis R. E. and Fandry C. B., 1976. A technique for objective analysis and design of oceanographic experiments applied to MODE-73.Deep-Sea Research I, 23, 559-582
Guinehut, S., Larnicol, G., and Le-Traon, P. Y., 2002 Design of an array of profiling floats in the North Atlantic from model simulations, J. Mar. Sys., 35, 1-9
Pedder, M.A., 1993. Interpolation and filtering of spatial observations using successive corrections and gaussian filters,Mon. Wea. Review, 121, 2889-2902
Ruiz, S., Gomis, D., Font, J., Recovery of North-East Atlantic temperature fields from profiling floats: determination of the optimal float number from sampling, and instrumental error analysis, Journal of Marine Systems (in press)

3 Results

Results

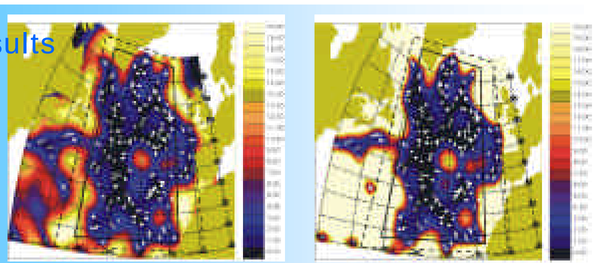


Figure 2. Distribution of observational (**left**) and sampling (**right**) relative errors (their standard deviation divided by the standard deviation of the (filtered) anomaly field). They correspond to the recovery of the temperature field at 50 m from all active floats during March 2003 . The accuracy of observations has been assumed to be 0.01º C.

Figure 2 shows the relative error field at 50 m corresponding to all active floats, split into **observational and sampling contributions**. The values are smaller for the first than for the second, but the two patterns are rather similar within the sampled domain. Maximum observational errors are about 11% (i.e., temperature errors of 0.175º C) in an isolated poorly sampled region in the middle of the domain. However, the mean observational error (averaged over domain D1) is only 3% (or 0.048º C). Sampling errors are more dependent on the station distribution, and hence they are larger in data voids (e.g., 16% or 0.254º C in the middle of the domain) and near the boundaries. The mean sampling error (see **Table 1**) is about 6% (or 0.095º C).

• Far away from data points, the influence of instrumental error decreases, indicating that random errors inherent to observations can not propagate much further than thecorrelation scale length.
• Sampling relative errors (andbtherefore total errors) approach 100% outside the sampled domain, due to the absence of observations. **Averaging total** (observational plus sampling) errors over the inner domain D1 gives a value of about **7%**

http://www.ifremer.fr/lpo/gyroscope/index.htm

Table 1
Observational, sampling and total rms errors involved in the recovery of the temperature field in March 2003. They are expressed relative to the standard deviation of the field associated with scales larger than 500 km (specified for each level).

Table 1

	Mean observat. error	Mean sampling error	Mean total error
T field variance at 50 m $\theta_f = 2.50(^{\circ}C)^2$			
Gyroscope floats	0.06	0.11	0.13
All active floats[a]	0.03	0.06	0.07
Active plus simulated floats[b]	0.01	0.01	0.02
T field variance at 200 m $\theta_f = 1.68(^{\circ}C)^2$			
Gyroscope floats	0.11	0.19	0.23
All active floats	0.04	0.06	0.08
Active plus simulated floats	0.01	0.01	0.02
T field variance at 1000 m $\theta_f = 0.54(^{\circ}C)^2$			
Gyroscope floats	0.08	0.14	0.16
All active floats	0.05	0.08	0.10
Active plus simulated floats	0.02	0.02	0.03

[a] All T/S active floats operating in the North-East Atlantic Ocean (119)
[b] All T/S active floats operating in the North-East Atlantic Ocean (119) plus 124 simulated floats located randomly but separated by at least 1.5° lat,lon from existing floats.

Note that the partition of total errors into observational and sampling contributions is formulated in terms of error variances i.e., in terms of the squares of the rms values quoted in Table 1. This is, the spatial mean of statistical errors associated with the recovery of the temperature field from the March 2003 float distribution is about 0.11º C at 50 m. This value is about 11 times larger than the accuracy assumed for observations (0.010º C).

When increasing the number of data points with fictitious floats, sampling errors reduce quite significantly, whereas observational errors reduce more moderately (Table1, figure 3)

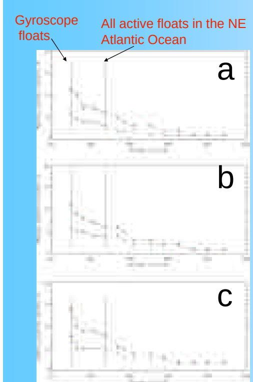
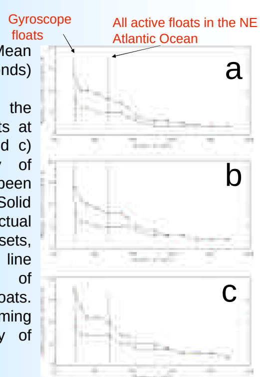


Figure 3. **Left**: Mean observational (diamonds) and sampling (asterisks) relative errors against the number of profiling floats at a) 50 m, b) 200 m and c) 1000m. The accuracy of observations has been assumed to be 0.01º C. Solid line corresponds to the actual float set and a few subsets, whereas the dashed line denotes the inclusion of additional, simulated floats. **Right**: Idem, but assuming an instrument accuracy of 0.025º C



4 Conclusions

Errors are more due to the small number of floats than to instrumental errors, especially at upper levels. Consequently, efforts should be devoted to the deployment of more floats rather than to the improvement of their sensors from the point of view of temperature mapping. For scales larger than 500 km this will hold true until 200-250 floats are deployed (less than 200 for deep levels). In such a simulated scenario, the number of observations and the technology would become approximately equally limiting factors for the accuracy of the temperature field mapping. Total errors have been estimated in less than 2% (at 50 m), which is comparable to the results at 20 m obtained by Guinehut et al. (2002) for a 3º x 3º array of profiling floats.