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

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Abstract

Argo is an international project that is deploying an array of temperature and salinity profiling floats over the global ocean. Here we use the error formulation derived from Optimal Statistical Interpolation to estimate statistical errors associated with the recovery of the temperature field in the North-East Atlantic ocean. Results indicate that with the present distribution of floats (119 in the considered domain), scales of wavelength larger than 500 km can be recovered with a relative uncertainty (rms error relative to the standard deviation of the field) of about 7% at 50 m, 8% at 200 m and 10% at 1000 m. This corresponds to mean absolute errors of 0.111 °C at 50 m, 0.104 °C at 200 m and 0.073 °C at 1000 m.

The splitting of total errors into instrumental and sampling contributions reveals that, in the present scenario, errors are more due to the small number of floats than to instrumental errors, especially at upper levels. 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 become approximately equally limiting factors for the accuracy of the temperature field mapping, with total relative errors of less than 2% at upper levels and about 3% at 1000 m.

Keywords: Profiling floats; Objective analysis; Error analysis; North Atlantic Ocean

1. Introduction

Argo is an international project that is deploying an array of temperature and salinity profiling floats over the global ocean. It constitutes a pilot project of the Global Ocean Observing System (GOOS) and a major contributor to the Global Climate Observing System (GCOS) (Gould and Belbeoch, 2003). Applications of the Argo project to climate studies and operational oceanography are being evaluated by the Climate Variability and Predictability Experiment (CLIVAR) and the Global Ocean Data Assimilation Experiment (GODAE) (Le-Traon et al., 1999). One of the capabilities is the recovery of the decadal variability of the Subtropical North Atlantic by comparing float data with previous WOCE hydrographic transects (e.g., Parrilla et al., 1994; Joyce and Robbins, 1996; Vargas-Yáñez et al., 2004). In a more global context, the Argo

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project is expected to produce an accurate global climatology, with error bars and variability statistics obtained from monthly mean data (Argo Science Team, 1998).

The design of the array of profiling floats has not a unique solution and needs of a continuous revision of over/sub-sampled regions with respect to the expected Argo achievements. Hence, the evaluation of the information contents of the float array is a key issue for the planning of future deployments. 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. The work has been undertaken in the framework of the Gyroscope project (Desaubies, 2003), which is itself a major European contribution to the Argo project.

In a recent paper, Guinehut et al. (2002) evaluated the accuracy of the recovery of North Atlantic temperature fields by sampling model output of the region at different numbers of regularly distributed points. Those synthetic observations were then interpolated (via Optimal Statistical Interpolation, hereafter OI) onto the model grid and compared with the original model values. The result was a table with temperature errors as a function of the station spacing at several levels and for two different low-pass filtering processes (cut-off wavelengths of 1000 and 500 km).

Here we face the problem using a different methodology. First, the error values provided by Guinehut et al. (2002) correspond to a particular set of realizations (assumed to be representative) of the temperature field. Instead, we use the error formulation derived from OI theory to directly compute statistical errors, i.e., those that would be obtained by averaging a very large number of different temperature fields having a common set of prescribed statistical properties. Second, we use actual float distributions instead of synthetic regular distributions as observation points. Moreover, all the parameters used on input by the OI formulation have been derived from actual float data, instead of from model data.

Finally, and perhaps most important, we not only produce total errors, but also split them into the contribution attributed to instrumental noise (hereafter 'observational errors') and that derived from the station distribution (hereafter 'sampling errors'). This will be a first key issue of this work, given the different impact that the number of floats has on each error contribution. It will be useful, for instance, to decide whether it is more convenient putting the efforts in increasing the number of floats or in improving the accuracy of their sensors (provided both initiatives were equally possible).

A second key issue of this work is the concept of spatial scale. This is crucial when talking about errors, since these depend critically on the ratio between the station separation and the scales intended to be resolved. When detailing the formulation, we will argue that the deviations of the interpolation field should not be measured with respect to the true field, but with respect to the recovered spectral range of the truth. Here we will focus on the recovery of scales with wavelength larger than 500 km, according to the present low-resolution deployment strategy (250 km) and also with the purpose of comparing our results with those obtained by Guinehut et al. (2002).

2. Data set and methodology

In the framework of the Gyroscope project, 84 profiling floats were deployed in the North-East Atlantic ocean from summer 2001 to the end of summer 2002. By March 2003 (considered here as the 'present time'), 75 floats remained active and a total of 2500 profiles had been recorded (Desaubies, 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 (ftp://www.coriolis.eu.org).

Argo floats work as follows: their mean density is accurately set as to have a neutral buoyancy at a prescribed depth (the so-called 'parking depth'), set to 1500 m in the Atlantic ocean. Therefore, they drift following approximately the isobaric currents at that depth. Every ten days the density of the floats is first increased and then decreased through volume compression/expansion, so as the float descends to about 2000 m and then goes up to the surface. All sensors are woken up just before the density modifications, in order to measure the properties of the water column in its way up to the surface. Once there, the float sends the measured profile to data centers by satellite transmission. Obtaining the profile and sending the data takes about 16 h, after which the float descends again to the parking depth. All temperature profiles reported by all active floats from January 2002 to March 2003 constituted the data base for the estimation of the statistical properties of the temperature field required for the application of the OI scheme. In the following, we first describe the OI