# Using profiling floats to estimate the upper layer heat budget during POMME


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## 1. Introduction

The POMME experiment took place from September 2000 to October 2001 in the eastern North Atlantic off the Iberian Peninsula between 15°W and 24°W in longitude and 38°N and 45°N in latitude (Figure 1). The goal of the experiment was to study the role of the mesoscales on the formation and subduction of the 11°C-12°C mode waters as well as on the carbon cycle and the biology [Mémery et al., J. Geophys. Res., 2005].

Based on the POMME data, this study focuses on the Lagrangian regional heat balance estimated from profiling floats. Accurate air-sea heat fluxes, which were derived especially for the experiment by Caniaux et al. [J. Geophys. Res. 2005], will allow us to check the accuracy of our estimates. A novelty of the study is to derive, from the profiling floats, an estimate of the vertical advection of heat.

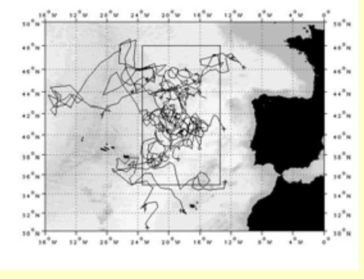
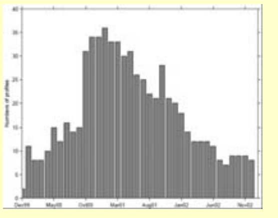


*Fig 1:The trajectories of the 14 profiling floats launched during POMME. The black box is referred to as "the POMME area" in the following.*

## 2. Datasets

Fourteen PROVOR profiling floats were deployed in the POMME region between October 1999 and April 2001 (Figure 1). Most of them were set up to drift at 400 meters at the core of the northeast Atlantic mode water and to make a temperature profile between 2000 m and the surface every ten days.

*Figure 2: Numbers of available temperature profiles as a function of time. The maximum occurs during the intensive phase of the POMME experiment*



The air-sea heat fluxes are from the NCEP/NCAR reanalysis [Kistler et al., Bull American Met. Soc. 2001] and from CNRM [Caniaux et al., J. Geophys. Research Oceans, 2005]. These latter fluxes were derived by combining in situ data, satellite observations and outputs of a meteorological model. The CNRM fluxes are available between 1 September 2000 and 17 October 2001 in the POMME area (Figure 1) with a spatial resolution of 5 km. Performing sensitivity studies, Caniaux et al. [2005] estimated 10 W $m^{-2}$ for the error on the mean CNRM fluxes. Averaged on the POMME area, the net air-sea fluxes from CNRM and NCEP are equal to 4.8 and -9.4 W $m^{-2}$, respectively. NCEP reanalysis appears to underestimate the net air-sea flux in the POMME area. Caniaux et al. [2005] noted that ECMWF analysis underestimated the net air-sea heat fluxes by 26 W $m^{-2}$.

## 3. Method

The heat balance in the mixed layer was described by e.g. Stevenson et Niiler [J. Phys. Oceanogr. 1983], Gaspar et al. [J. Geophys. Res. 1990], Caniaux et Planton [J. Geophys. Res. 1998]. The balance is derived from the heat conservation equation. For a layer of constant depth, neglecting the vertical shear of the horizontal velocity and diffusion, the balance simplifies to :

$$h\frac{d_H}{dt}<\theta>+\left[<\theta>-\theta(-h)\right]w(-h)-Q_{net}=0 \quad (1)$$

$$\frac{d_H<.>}{dt}=\partial_t<.>+<U>\nabla<.> \quad (2)$$

$\theta(t, z)$ is the heat content, $h$ the (constant) layer thickness, $U$ the horizontal velocity vector, $w$ the vertical velocity and $Q_{net}$ the net air-sea heat flux. The vertical mean is denoted as <•>. (2) includes both the local time rate of change and the advection along the float trajectory [Rossby et al. J. Phys. Oceanogr. 1986]. Gill [1973] showed that this balance prevails at seasonal time scales.

The successive temperature profiles allow us to estimate the heat content and its variability along the float trajectory. $w$ will be estimated following Mariano et Rossby [J. Phys. Oceanogr. 1989]. The method assumes that the flow occurs on an isothermal surface (no diffusion) such that $w$ can be rewritten as:

$$w=-\frac{d_H T}{dt}\left(\frac{\partial T}{\partial z}\right)^{-1} \quad (3)$$

The vertical velocity $w$ will be computed at the drifting depth of the profiling float where the measurements allow us to accurately estimate the Lagrangian derivative $d_H/dt$. The three terms of the heat balance (1) are estimated every ten days (derivatives are computed using centered finite differences). The air-sea heat fluxes are averaged along the float trajectory, which is reconstructed between the surface localizations of the float using a linear interpolation. Estimates from all floats are then binned in 10-day time intervals and averaged. Finally, the time series are low-pass filtered using a Butterworth filter with a 1/90 day cut-off frequency to remove time scales smaller than the seasonal time scale.

## 4. Results and Conclusion

The Lagrangian heat budget (1) is studied for the 0-400 meter layer. The lower limit of the layer was chosen at the drifting depth of the profiling floats where the vertical velocity can be estimated using (3). This allows a straightforward estimation of the vertical advection of heat. The three terms of the heat balance (1) are plotted as a function of time on Figure 3 and the residuals of the heat balance are plotted on Figure 4.

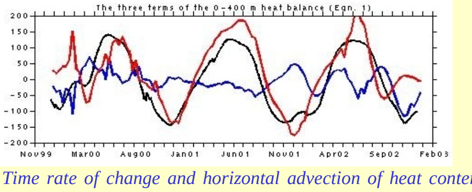



*Figure 3: Time rate of change and horizontal advection of heat content (red). Vertical advection of heat (blue). Heat flux from the NCAR/NCEP reanalysis (black). In W $m^{-2}$. The vertical advection has a mean contribution of 9 W $m^{-2}$.*

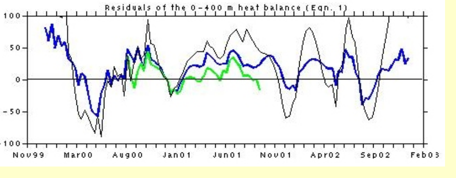



*Figure 4: Residuals of the heat balance (1). No vertical advection and heat fluxes from NCEP (black). Vertical advection and NCEP fluxes (red). Vertical advection and CNRM fluxes (green). In W $m^{-2}$.The mean residuals in the POMME area are equal to -25.1 ± 20.6, -16 ± 13.2, -6.2 ± 12.2 W $m^{-2}$ respectively.*

The time rate of change and advection of heat content are in near balance with the air-sea heat fluxes for times scales equal or larger than the season. The mean vertical advection of heat is a small contribution (9 W $m^{-2}$), which however improves the heat balance. The mean residual of the heat balance derived with the CNRM fluxes is equal to -6.2 ± 12.2 W $m^{-2}$ which, given the high accuracy of those fluxes, seems to indicate that the neglected terms (diffusion, horizontal velocity vertical shear) are either small or cancel out.