

# REGIONAL HEAT- AND FRESHWATER BUDGETS OF THE OCEAN SURFACE LAYER

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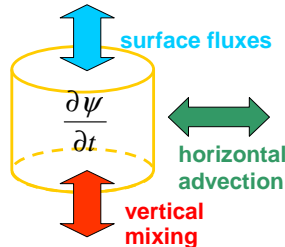
## ABSTRACT

The variability of heat and freshwater content of the ocean surface mixed layer is driven by surface fluxes, vertical mixing and horizontal advection. The aim of this work is to quantify the contributions of these processes to the heat/freshwater content and thus to compile heat/freshwater budgets of the surface mixed layer in different regions of the world oceans.

## I. CONCEPT

$$\frac{\partial \psi}{\partial t} + \vec{u} \nabla \psi = K_z \frac{\partial^2 \psi}{\partial z^2} + F$$

$\psi$  – heat/freshwater content,  $t$  – time,  $\vec{u}$  – velocity,  $K_z$  – vertical mixing coefficient,  $z$  – depth,  $F$  – surface fluxes



Temporal changes in the surface mixed layer content of heat/freshwater are calculated from ARGO float profile data.

The contribution from the atmosphere to the heat/freshwater content is estimated using four different data sets.

The difference between heat/freshwater content and surface fluxes gives the order of magnitude of vertical mixing and lateral advection. To separate these two processes in a second step a criterion will be used to derive the varying depth of the mixed layer and thus the effect of vertical mixing. The residuum needed to close the budget is then assigned to lateral advection.

## II. ATMOSPHERIC FLUX DATA

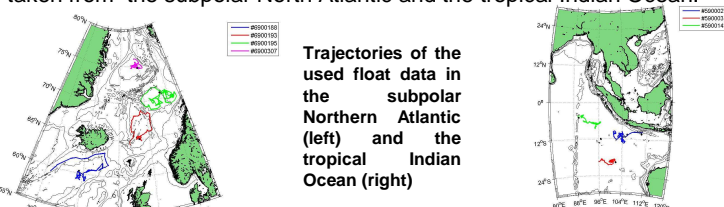
FLUXES FROM SATELLITE	MODEL RE-ANALYSIS
HOAPS-C [1]	NCEP/NCAR [2]
No SWRS or incoming LWRS data available	No evaporation data available
⇒ NCEP components	⇒ calculated from LHFL, density and SST

- HEAT**
- Sensible heat flux (SHFL)
  - Latent heat flux (LHFL)
  - Shortwave radiation (SWRS)
  - Long wave radiation (LWRS)
- FRESHWATER**
- Evaporation
  - Precipitation

REGIONAL MODEL	MODEL FORECAST
REMO [3]	ECMWF [4]
Regional Model	No heat flux data, synoptic data available only
⇒ Data available only for the North Atlantic	⇒ calculated by bulk formulae

## III. HEAT/FRESHWATER CONTENT

Temporal changes in the surface mixed layer content of heat/freshwater are calculated from ARGO float profile data [6]. The development of heat- and freshwater budgets along selected float trajectories are estimated from one profile to the next. Float data are taken from the subpolar North Atlantic and the tropical Indian Ocean.



Trajectories of the used float data in the subpolar Northern Atlantic (left) and the tropical Indian Ocean (right)

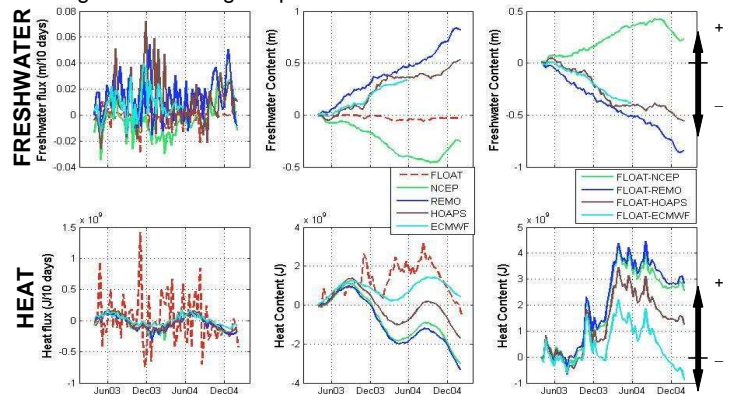
The heat/freshwater content of the upper 200 m of the profile is calculated as an approximation for the surface mixed layer.

## IV. BUDGET CALCULATIONS

Two parts from the heat/freshwater budgets are calculated: the temporal development of the heat/freshwater content and the contribution of the surface fluxes to this development. Their difference gives the order of the contribution from vertical mixing and lateral advection to the budget.

Along an individual float trajectory the temporal change of the heat/freshwater content is calculated and assigned to the position lying in between two successive surface positions. The associated surface flux data are interpolated from the surrounding grid points to this position.

The budget calculations are demonstrated for a float from the Norwegian Sea during the period 03/2003-02/2005:



Float derived changes in the surface layer compared with the surface fluxes

Accumulated flux values and change in freshwater- and heat content of the upper layer

Residuum gives the contribution of the processes vertical mixing and lateral advection

**Comparison:** The example demonstrates that the surface flux data are not consistent. In the HOAPS, REMO and ECMWF data precipitation exceeds evaporation, which requires an outflow (-) of freshwater from the area of interest through vertical mixing and lateral advection to close the budget. Contrary, for the NCEP data the higher evaporation over precipitation rate leads to an input (+) of freshwater.

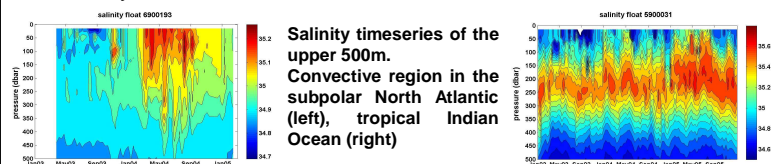
## V. OUTLOOK

The budgets will be calculated for explicit large-scale regions, using mean values of ensembles of float profiles. Planned regions are the subpolar North Atlantic and the tropical Indian Ocean. The contribution of lateral advection and vertical mixing will be separated. By taking into account the varying depth of the mixed layer the underlying effect of the vertical mixing will be approximated in the budget. This is part of the diploma thesis (Antje Müller-Michaelis, in preparation).

### Regional budgets:

A haline stratification in the upper pycnocline can prevent the heat transfer between the deep ocean and the upper layer and thus lower the heat exchange between ocean and atmosphere.

At high latitudes (subpolar North Atlantic), a low-salinity upper layer can inhibit deep convection, whereas in tropical regions (tropical Indian Ocean) 'barrier layers' can lead to strong warming of the upper ocean layer.



Salinity timeseries of the upper 500m. Convective region in the subpolar North Atlantic (left), tropical Indian Ocean (right)

### Variable depth of the mixed layer:

Two definitions will be used for calculating the mixed layer depth:

- Critical gradient criterion: The depth where a critical temperature or density gradient is exceeded.
- Net change criterion: Net temperature or density change from surface isotherm or isopycnal.[5]

The criteria have to be adapted to regional features.

[1] Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data (HOAPS) project (<http://www.hoaps.org>), Germany  
 [2] NOAA/OAR/ESRL PSD, Boulder, Colorado, USA (<http://www.esrl.noaa.gov/psd/>)  
 [3] Regional Climate Modelling REMO of the Max Planck Institute for Meteorology (MPI-M), Hamburg, Germany  
 [4] European Centre for Medium-Range Weather Forecasts (ECMWF), Reading, U.K. (<http://www.ecmwf.int>)

[5] Sprintall, J., M.F. Cronin (2001) Upper Ocean Vertical Structure. 3120-3128 Academic Press  
 [6] These data were collected and made freely available by the International Argo Project and the national initiatives that contribute to it. (<http://www.argo.org>) Argo is a pilot programme of the Global Ocean Observing System.

