Black Sea thermo-haline characteristics during the period 2002-2008: State estimates based on modelling and observations

S. Grayek (1) and E. Stanev (2)

1) Institute of Chemistry and Biology of the Marine Environment, University of Oldenburg; Carl-von-Ossietzky Strasse 9-11; D-26111 Oldenburg, Germany; Email: sebastian.grayek@uni-oldenburg.de

2) Institute for Coastal Research, GKSS Research Centre, Max-Planck-Strasse 1, D-21502 Geesthacht, Germany

MOTIVATION

The described model set-up is part of the Spatial and Temporal Resolution Limits Project (STREMP) funded by the German Research Foundation as part of SPP 1257. The project deals with Mass changes and mass distribution in the Mediterranean and Black Sea and aims to link and analyse data from GRACE satellite, altimetry and numerical modelling. The aim of the presented study is to give an estimate of steric heights for the period of GRACE mission from the beginning of 2002 and to study mass changes and mass distribution based on available data and numerical modelling.

The main attention in analysis of results has been given to the identification of the relevance of specific sources and physical processes shaping the seasonal and inter-annual characteristics in the Black Sea. We use empirical orthogonal function (EOF) analysis of temperature and salinity fields and steric heights from ocean model and investigate their connection to simulated and observed sea surface anomaly (SLA) as an indicator for propagation of thermo-haline structures.

ALTIMETER OBSERVATIONS

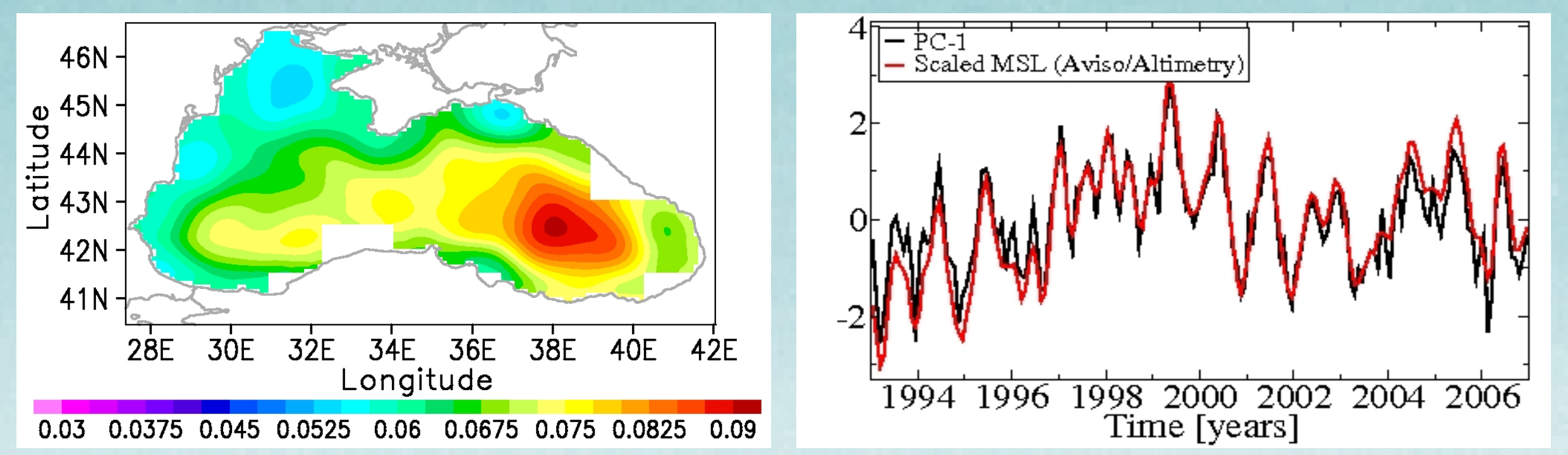

Fig. 1: EOF-1 and PC-1 from analyses of Aviso Altimeter observation. The red line shows scaled mean sea level signal in the observations.

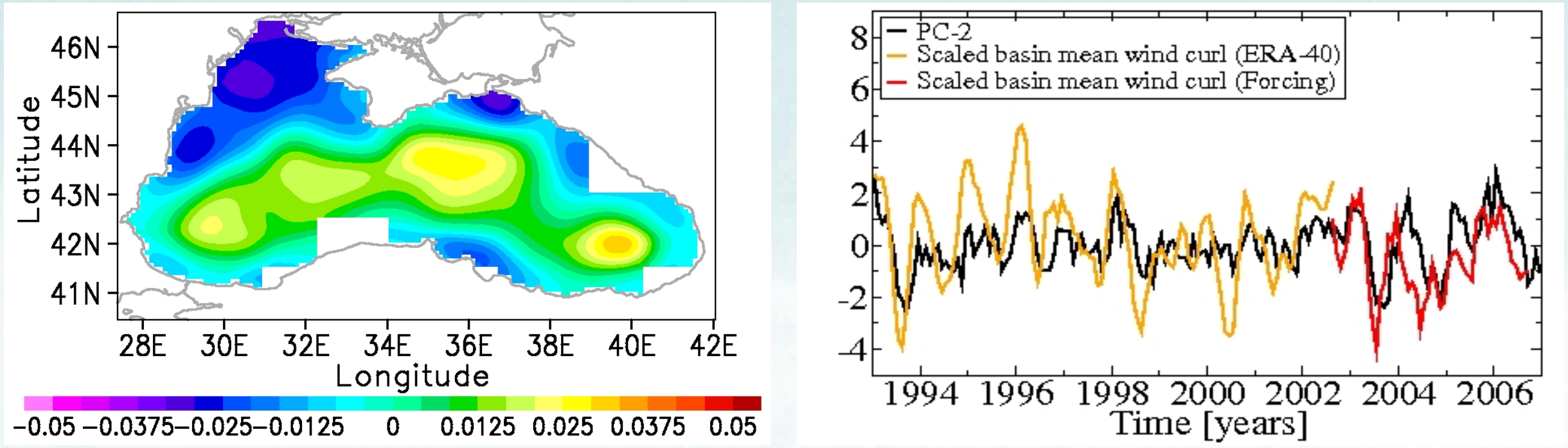

Fig. 2: EOF-2 and PC-2 from analyses of Aviso altimeter observation. The orange line shows scaled ERA-40 dat, the red line shows the mean wind curl (forcing).

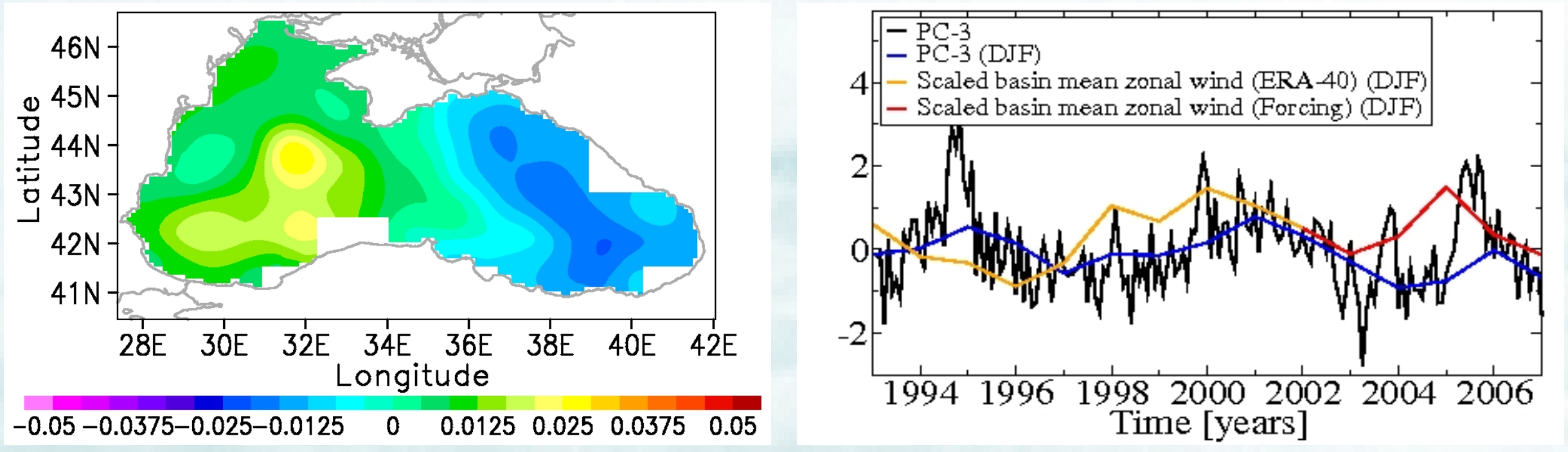

Fig. 3: EOF-3 and PC-3 from analyses of Aviso altimeter observation. The orange line and the red line shows scaled mean zonal winter wind. The blue line shows mean winter PC value.

Results from EOF analysis show that the major part of SLA variability during the examined period can be express through first two EOF modes which explain approximately 83.5% of the total variance and are well know to be connected to the general evolution of mean sea level (MSL) (1. mode) and the seasonal cycle of Rim Current's intensification (2. mode).

Higher degree EOF modes show more complex processes which are very interesting because these processes could not be found in older versions of altimeter observations and are mainly controlled by the distribution of water fluxes, in particular from rivers and transport through the Bosporus Strait.

MODEL RESPONSE TO FORCING

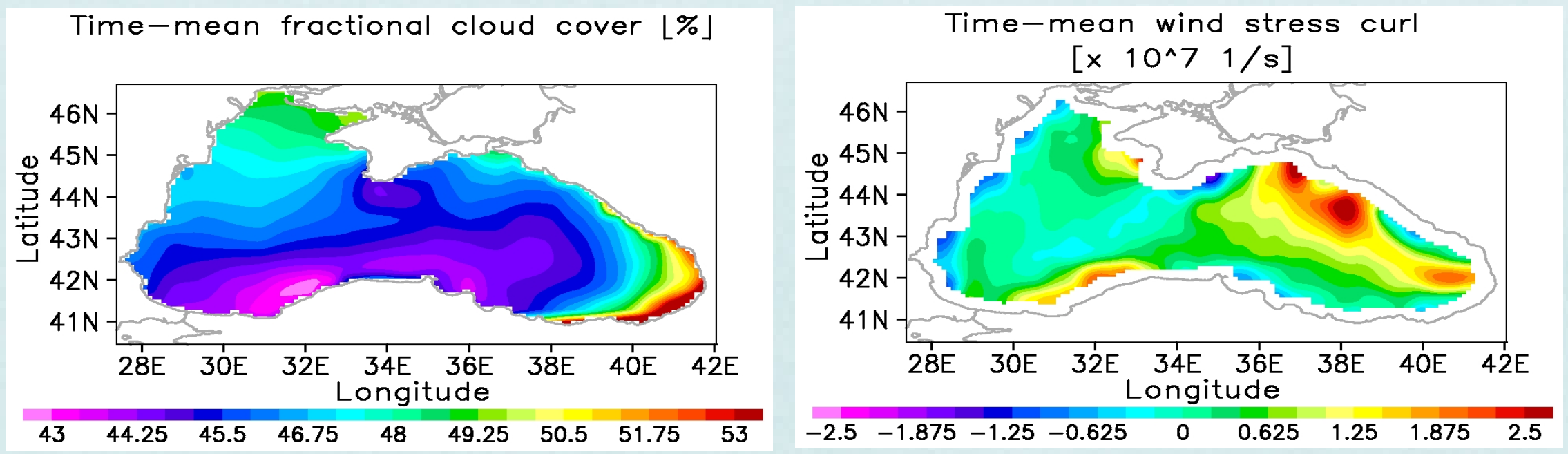

Fig. 4: Temporal mean of fractional cloud cover (left) and wind stress curl (right) for the period of simulation from 2002-2008

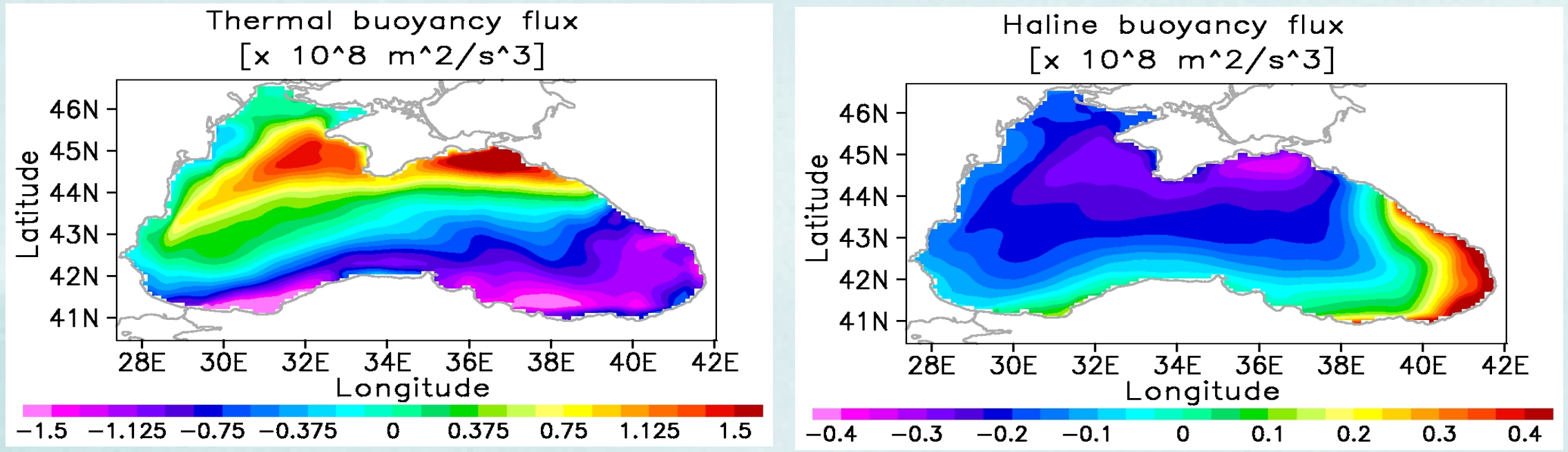

Fig. 5: Temporal mean of thermal (right) and haline (left) surface buoyancy flux for the period of simulation from 2002-2008

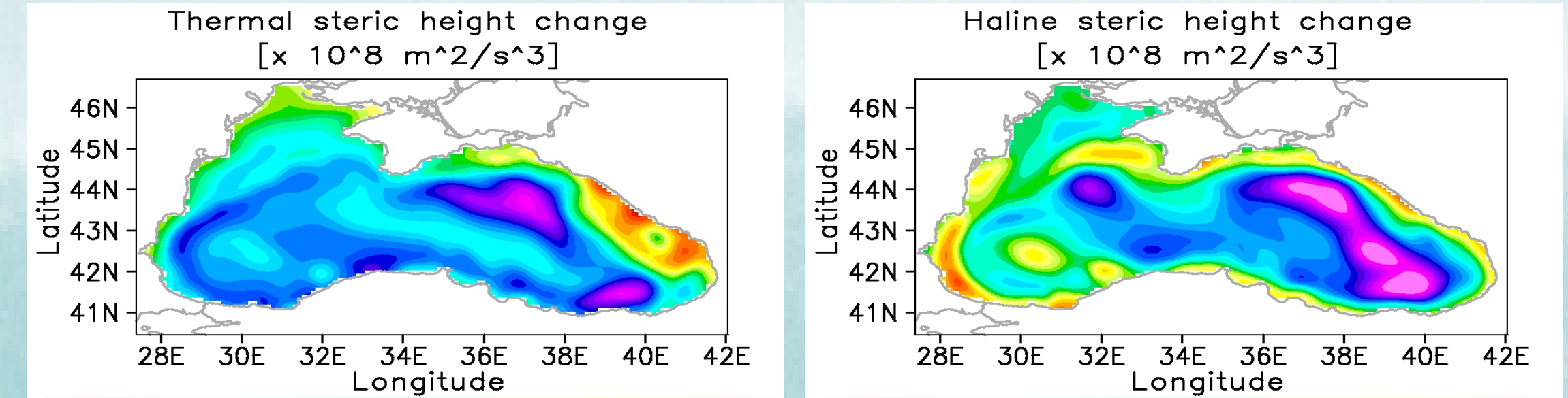

Fig. 6: Temporal mean of thermal (right) and haline (left) steric height change over the period of simulation from 2002-2008

The difference between the horizontal distribution of surface fluxes (Fig. 5) and the temporal change of heat and salt content of the water column (Fig. 6) displays the role of the transport. Without advection, the two figures should be identical, Comparison between the two patterns in Fig. 5 and Fig. 6 is instructive of how the surface fluxes propagate into the model.

The strongest cooling, as seen in Fig. 5 (remember that heat and buoyancy fluxes have opposite signs), is not maximum in the shallow-most coastal zone where temperature is minimum. This result has been previously discussed in detail by Stanev et al. (2003). Additionally, in Fig. 6 we see that the maximum cooling of the entire water column is along the eastern coast, which cannot be expected from Fig. 5. Fig. 6 reveals the interior part of the Black Sea as ’dry’ (losing water) while the coastal part is dominated by advection of river waters. However, some differences to Fig. 5 are explained by the fact that fresh water fluxes due to rivers (local sources in the model) are not accounted for in Fig. 5, while they are present in Fig. 6.

VALIDATION OF SIMULATED THERMO-HALINE CHARACTERISTICS AGAINST ARGO FLOATS

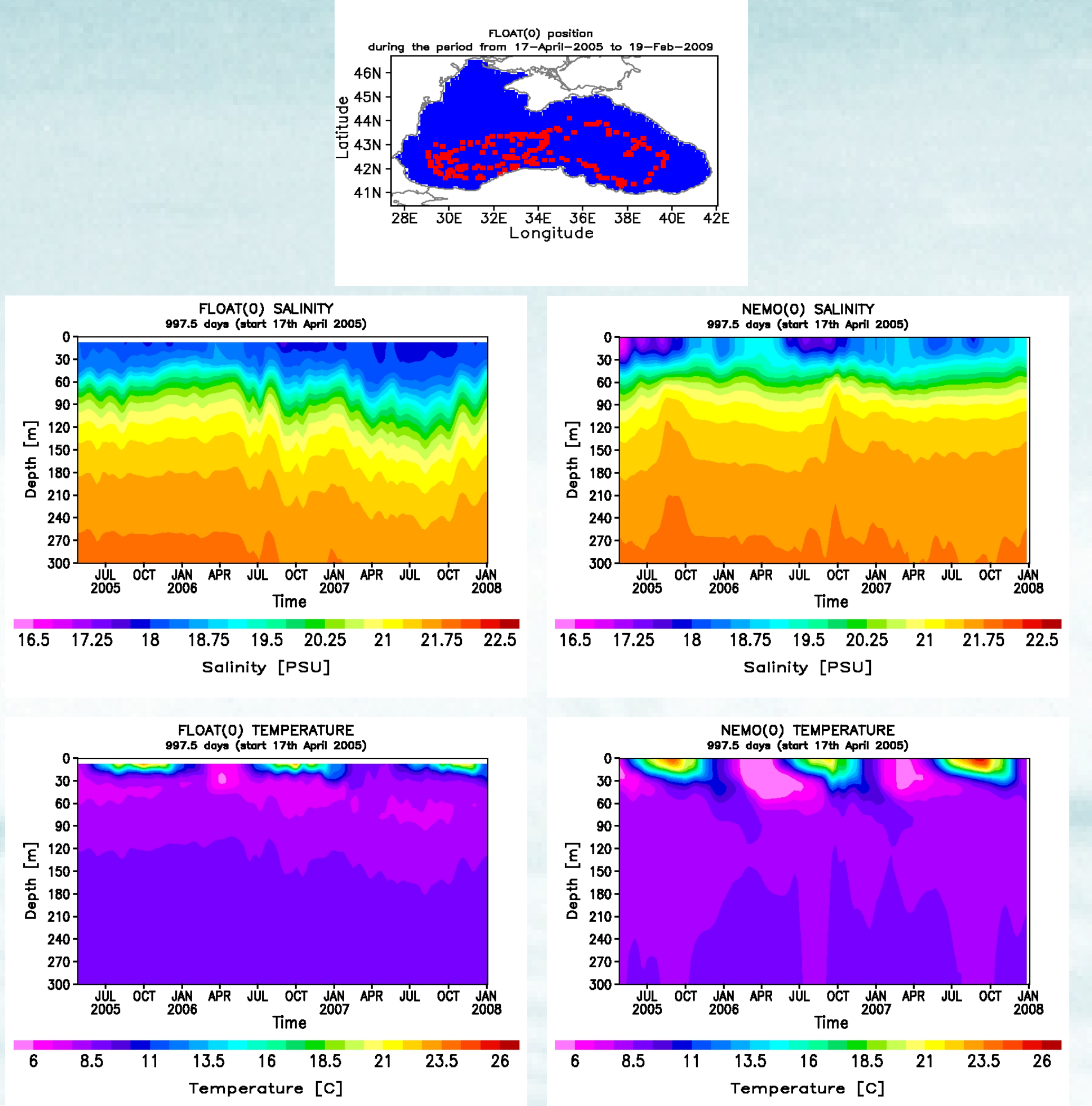

Fig. 7: Comparison of simulated (right hand side) and temperature and salinity profiles observed by ARGO floater (left hand side) during the period 15-Jun-2005 to 01-Jan-2008. Position of profile is show in the picture at the top.

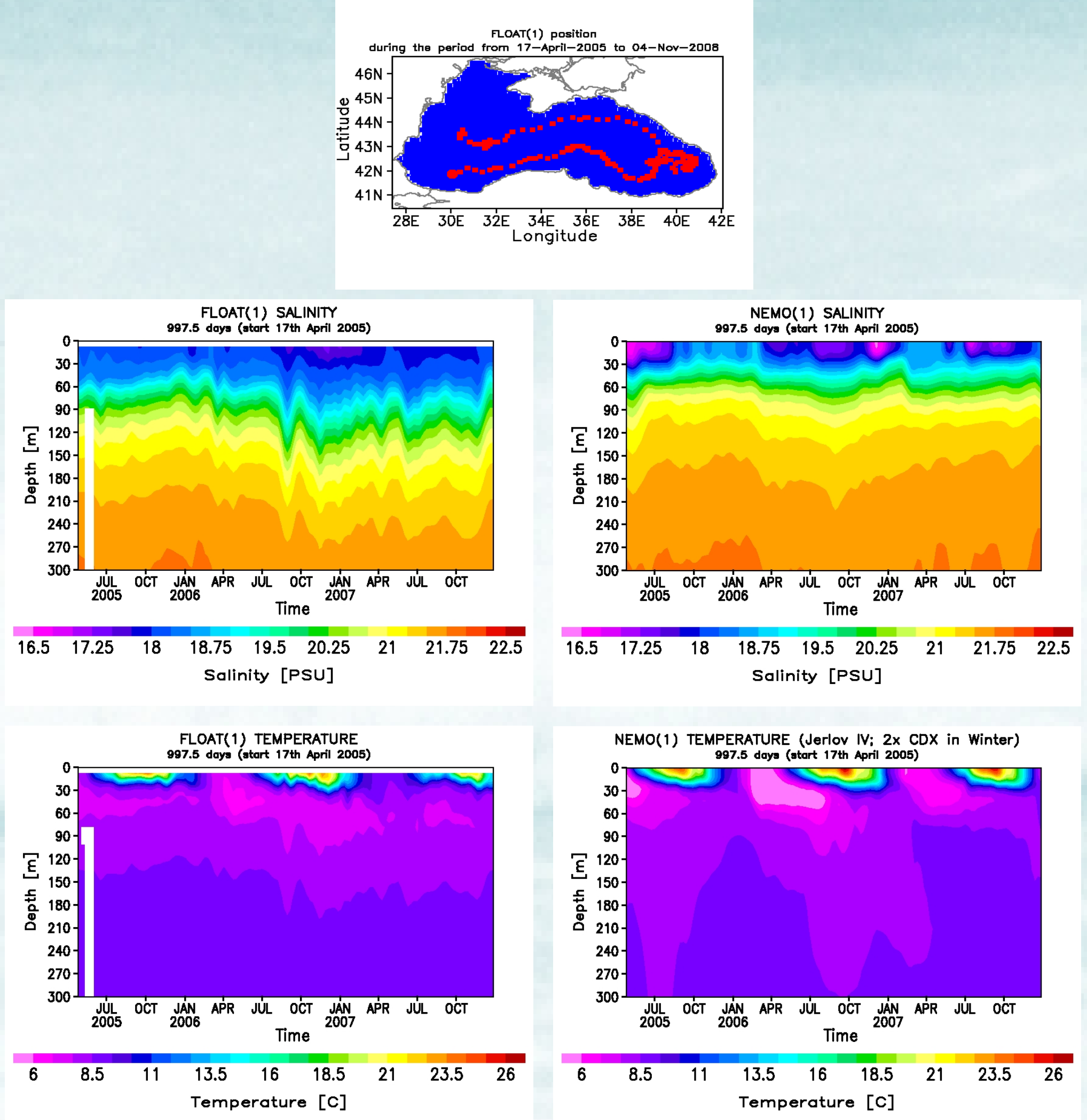

Fig. 8: Comparison of simulated (right hand side) and temperature and salinity profiles observed by ARGO floater (left hand side) during the period 15-Jun-2005 to 01-Jan-2008. Position of profile is show in the picture at the top.

For the Black Sea coverage of simultaneously taken observations from ARGO floaters is coarse. There are only four floaters available for the investigated period. However because of the stability of the Black Sea Rim Current, the ARGO floats enable deriving valuable measurements for the entire Black Sea inner basin (top of Fig. 7 and 8).

The comparisons show in Fig. 7 and 8 show that although the model output does not perfectly fit the observation the model reproduces reasonably well most important features of the Black Sea seasonal thermo-haline processes such as the formation of the cold intermediate water and the evolution of the seasonal pycnocline. The most important differences between simulated and observed profile can be found in salinity because the model, in genera,l seems to over-estimate the stratification.

MODEL CONFIGURATION

- Horizontal resolution: 133x76 (1/9° x 1/12°)
- Vertical grid: hyperbolic tangent stretching funct. 31 levels
- Horizontal tracer diffusion: geopotential laplacian operator
- Horizontal dynamic viscosity: geopotential bilaplacian operator
- Vertical viscosity/diffusivity: based on the TKE closure scheme with enhanced vertical diffusion parameterisation
- Vorticity schemes: vorticity trends: enstrophy conserving scheme
- Bulk formula parameterisation – metdata (Stanev et. al, 1995)
- ECMWF – data (T2,D2,U,V,Clouds)
- Water fluxes: ECMWF precipitation; statistical reconstructed river runoff based on Black Sea hydro-meteorological (BSHM) data (Peneva (2001) and ECMWF precipitation
- Bosporus: estimated from water conservation equation constrained by altimeter data (Peneva 2001)

CONCLUSION

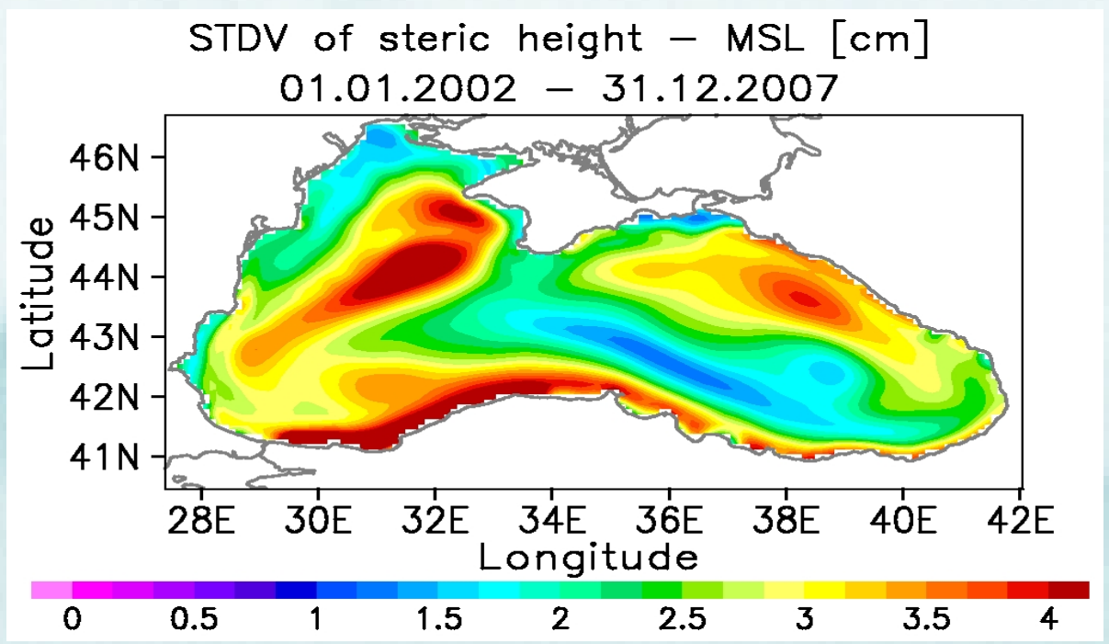

Fig. 9: Standard deviation (STDV) of steric heights - mean sea level signal (MSL) for the period of simulation from 2002-2008

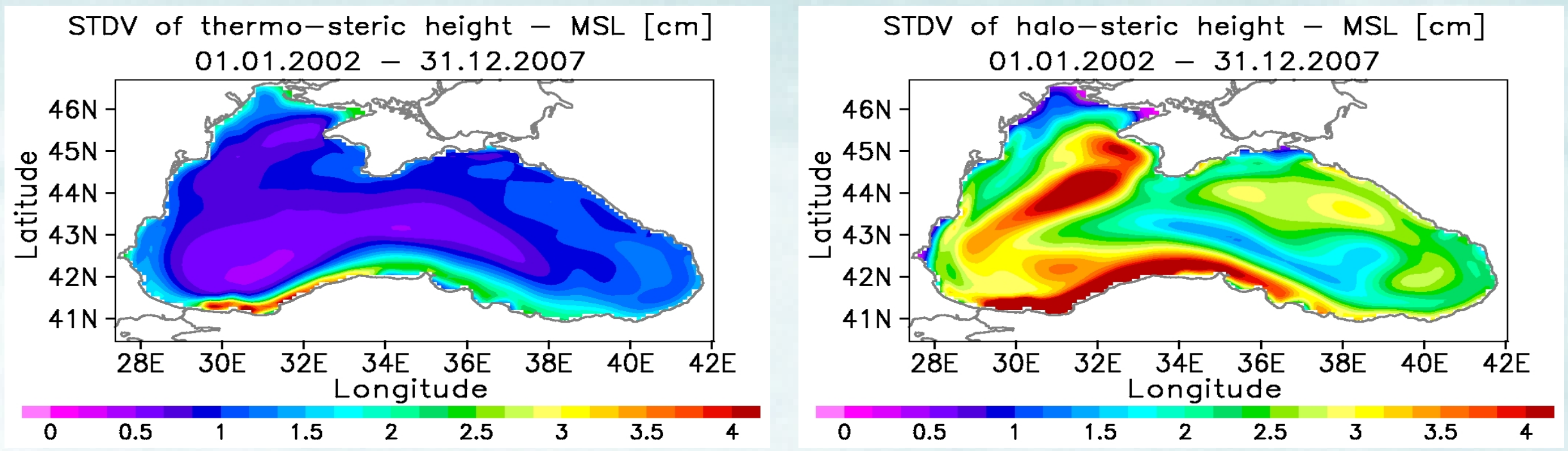

Fig. 10: Standard deviation (STDV) of thermo (left) and haline (right) steric heights - mean sea level signal (MSL) for the period of simulation from 2002-2008

Altimeter observation show the accumulated height of water mass distribution and thermo and haline steric effect. However, for studies of ocean dynamics and influencing processes it is important to separate these three factors from one another. Measurements from ARGO floats alone, or in combination with ocean modelling, are able to give an estimate for the individual signals, thus the derived information from such estimates may be helpful in setting up sophisticated altimeter assimilation algorithms.

From the comparison of temperature and salinity profile against observations (Fig. 7 and 8) on can draw the conclusion that our model is able to reproduce reasonably well the development of Black Sea temperature characteristics.

Furthermore, the thermo steric effect has an important influence on Black Sea seasonal and interannual mean sea level (MSL) development while the horizontal characteristics of sea level heights are mainly controlled by water mass distribution and haline-steric effect (Fig. 9 and 10).

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