Altimeter and Argo float data assimilation in the Black Sea

S. Grayek [1] , E. V. Stanev [1,2], J. Schultz-Stellenfleth [2] and J.-M. Brankart [3]

[1]: ICBM, University of Oldenburg, Postfach 2503, D-26111 Oldenburg, Germany, sebastian.grayek@uni-oldenburg.de

[2]: Institute for Coastal Research, GKSS Research Center, Max-Planck-Strasse 1, D-21502 Geesthacht, Germany

[3]: LEGI, 21 rue rue des Martyrs, 38000 Grenoble, France

Motivation

The described model setup is developed in the frame of Spatial and Temporal Resolution Limits Project (STREMP) funded by the German Research Foundation as part of SPP 1226. Aim of the 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 modeling.

Model description

General setup

Nucleus of **E**uropean **M**odelling of the **O**cean (**NEMO**)

- horizontal resolution: 1/9° x 1/12° approx. 10km x 10km
- vertical resolution: 31 z-levels

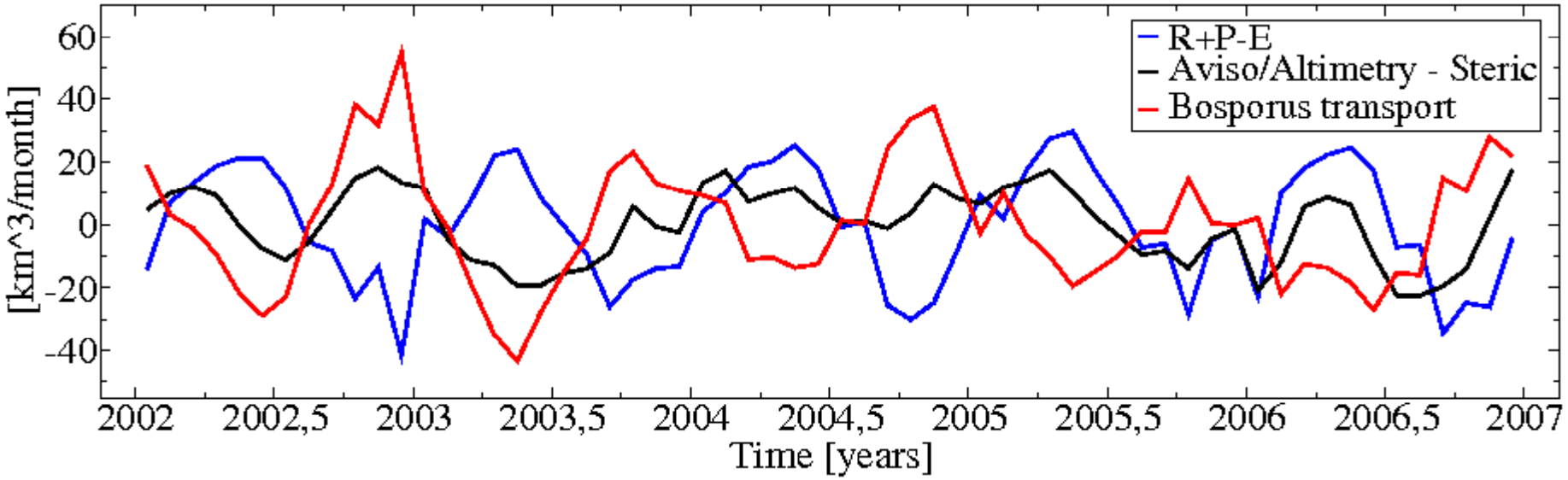
meteorological forcing: bulk aerodynamic formulas using ECMWF atmospheric temperature, humidity, winds and simulated SST

water-flux forcing: ECMWF precipitation (**P**), bulk formula evaporation (**E**), statistically reconstructed total river run-off (**R**), estimated Bosporus transport (**B**) constrained by altimeter observations – steric effect (**dM/dt**):

$$B = P - E + R - dM/dt$$

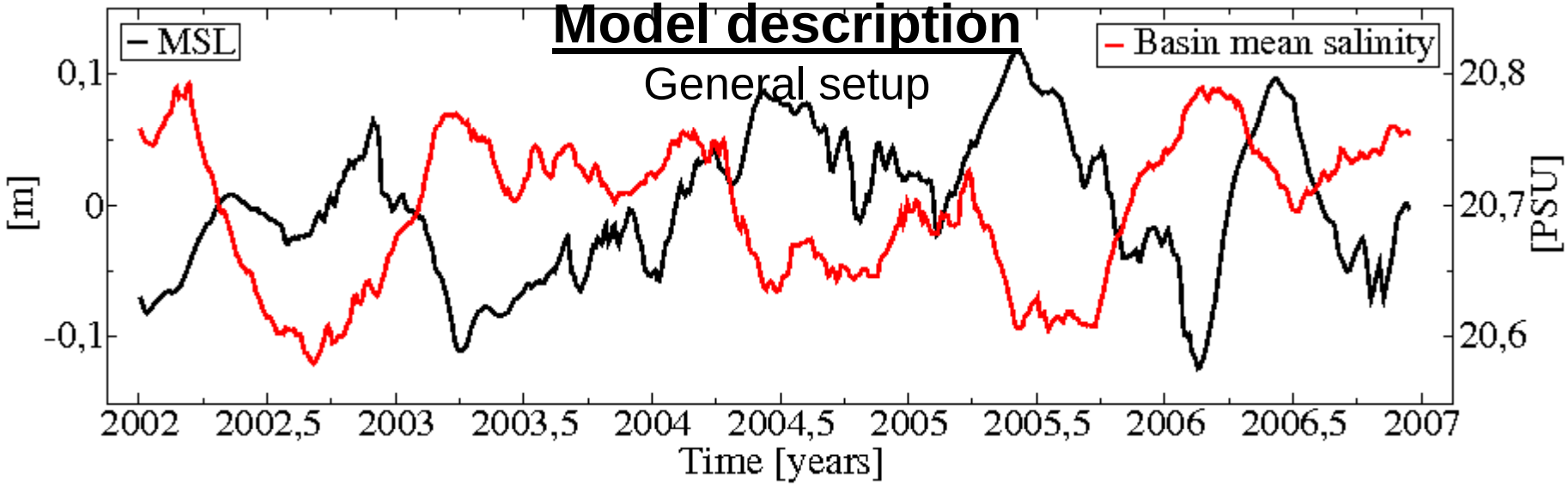
in assimilation run: direct insertion of T/S fields derived from kalman filter using partial signal of sea level anomaly, spatial anomaly of SST and optionally ARGO T/S profiles observations (implemented but still under development)

Estimation of Bosporus Inflow



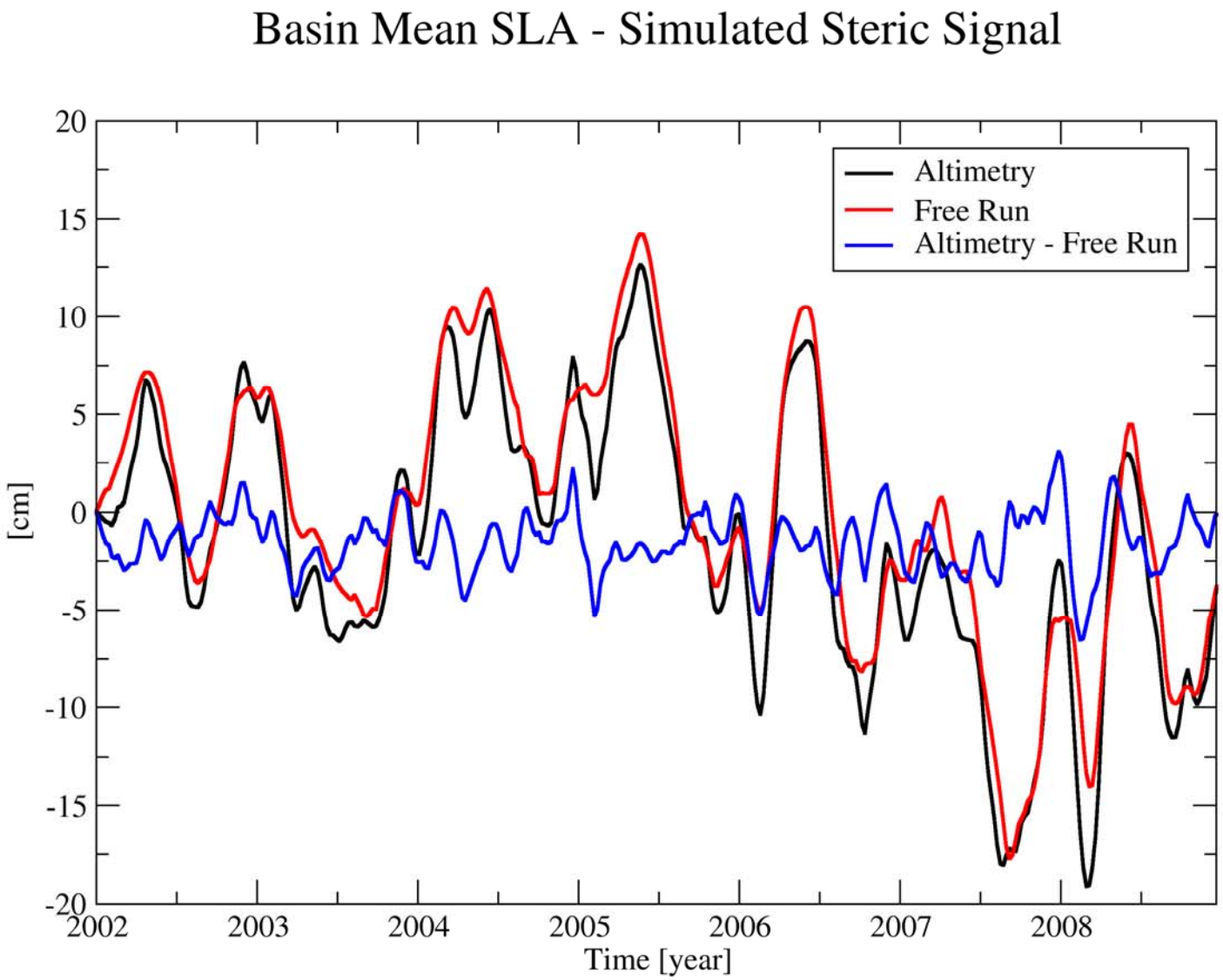
Model description

General setup



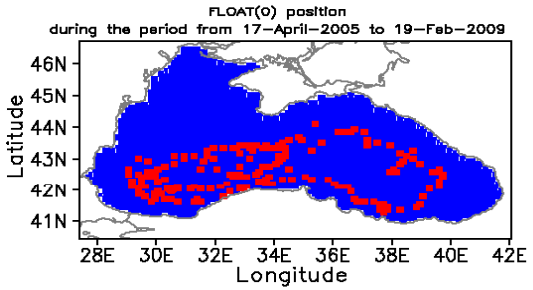
Validation of Free Run

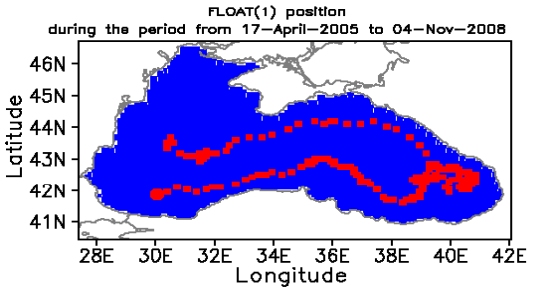
Simulated Mass Change

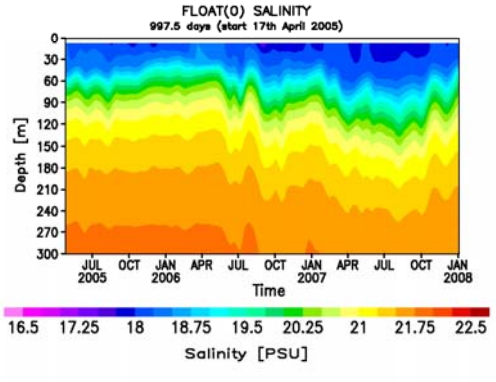


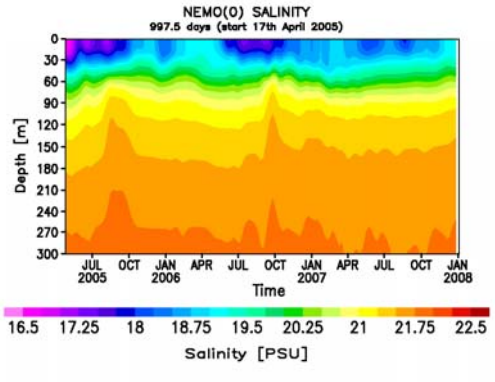
Validation of Free Run

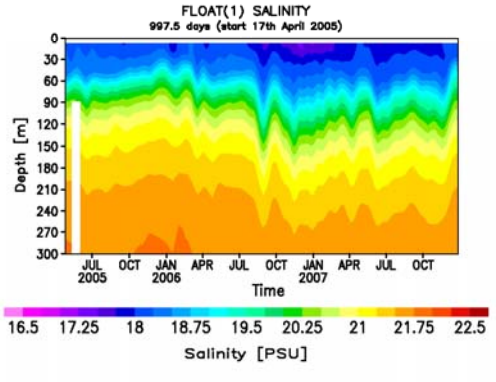
Temperature and Salinity

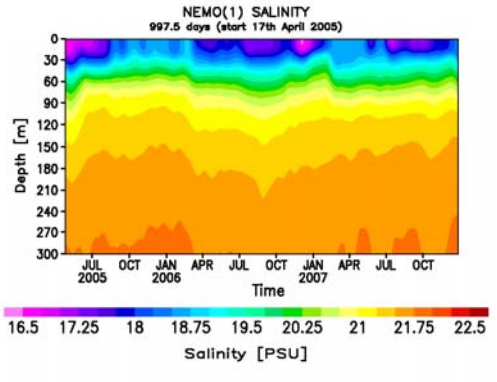


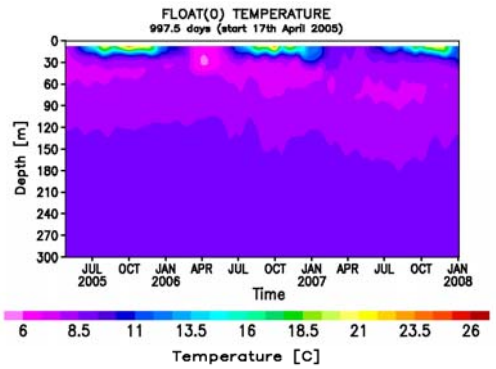


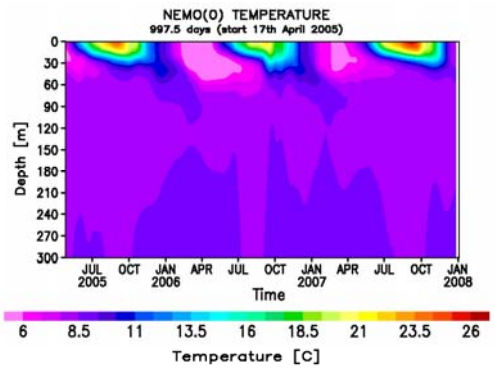


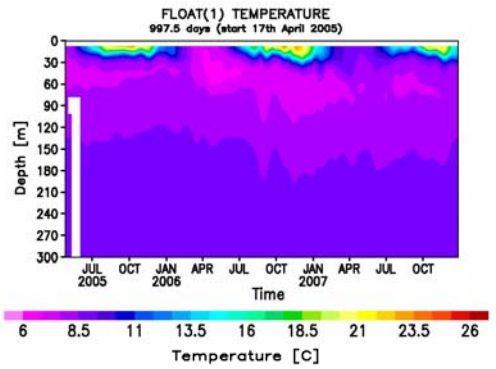


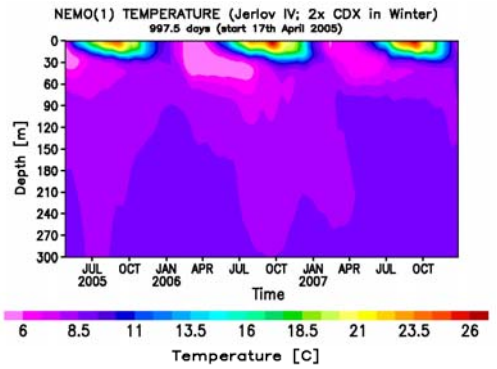












Assimilation scheme description

State and Observation Vector

$$x = \left(\mathrm{T}_{adj}, \mathrm{S}_{adj}, \mathrm{SST}_{adj}, \mathrm{SLA}_{adj}\right)$$

$$y = \left(\mathrm{SST}_{adj}, \mathrm{SLA}_{adj}\right)$$

$$\mathrm{SST}_{adj}(t_i) = \mathrm{SST}(t_i) - \overline{\mathrm{SST}}(t_i)$$

$$\mathrm{SLA}_{adj}(t_i) = \mathrm{SLA}(t_i) - \overline{\mathrm{SMC}}^{f}(t_i) - \overline{\mathrm{SLA}}^{f}_{\mathrm{T}}(t_i) - \overline{\mathrm{SLA}}^{f}_{\mathrm{S}}(t_i)$$

$$\mathrm{SMC}(t_i) = \mathrm{SLA}^{f}(t_i) - \mathrm{SLA}^{f}_{\mathrm{T}}(t_i) - \mathrm{SLA}^{f}_{\mathrm{S}}(t_i)$$

$$\mathrm{SLA}_{\mathrm{T}}(t_i) = -\frac{1}{\rho_{\mathrm{r}}} \int_0^{d_l} \left(\rho_{\mathrm{T},\mathrm{S}_r}(t_i) - \rho_{\mathrm{T}_t,\mathrm{S}_r}(t_i)\right) dz$$

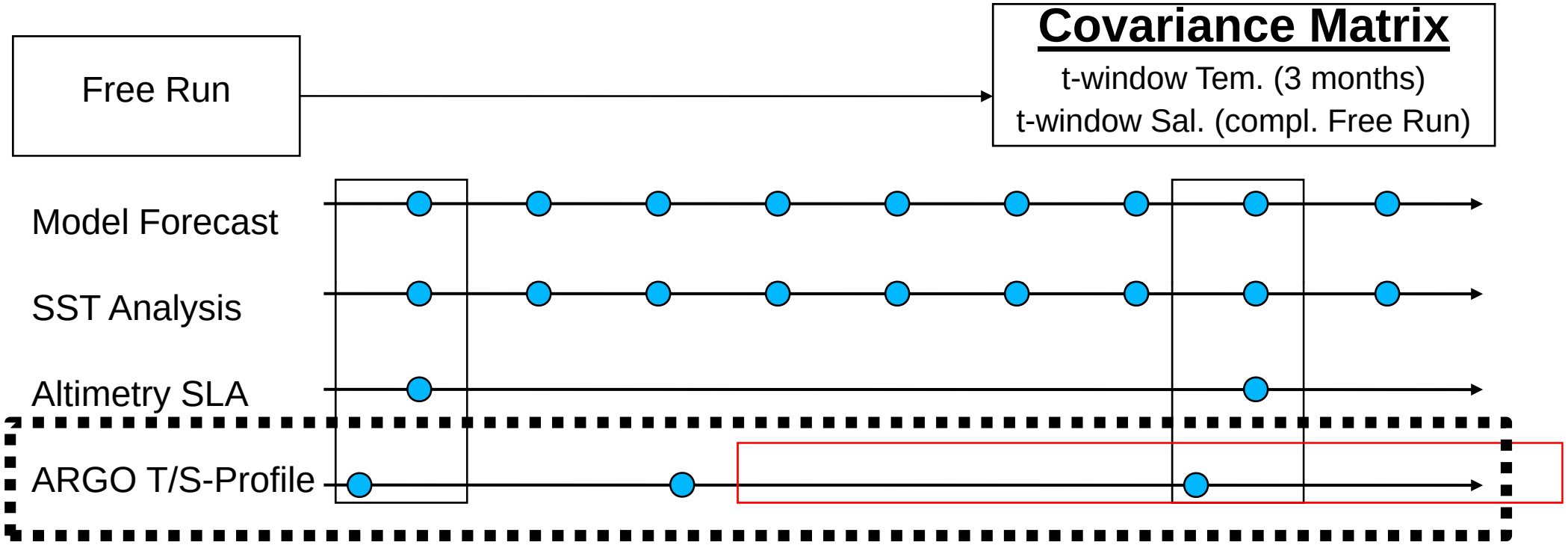
$$\mathrm{SLA}_{\mathrm{S}}(t_i) = -\frac{1}{\rho_{\mathrm{r}}} \int_0^{d_l} \left(\rho_{\mathrm{T}_r,\mathrm{S}}(t_i) - \rho_{\mathrm{T}_t,\mathrm{S}_r}(t_i)\right) dz$$

$$\mathrm{T}_{adj}(t_i) = \mathrm{T}(t_i) - \overline{\mathrm{T}}(t_i) - \mathrm{T}_r$$

$$\mathrm{S}_{adj}(t_i) = \mathrm{S}(t_i) - \overline{\mathrm{S}}(t_i) - \mathrm{S}_r$$

Assimilation scheme description

Time Windows and Intervals

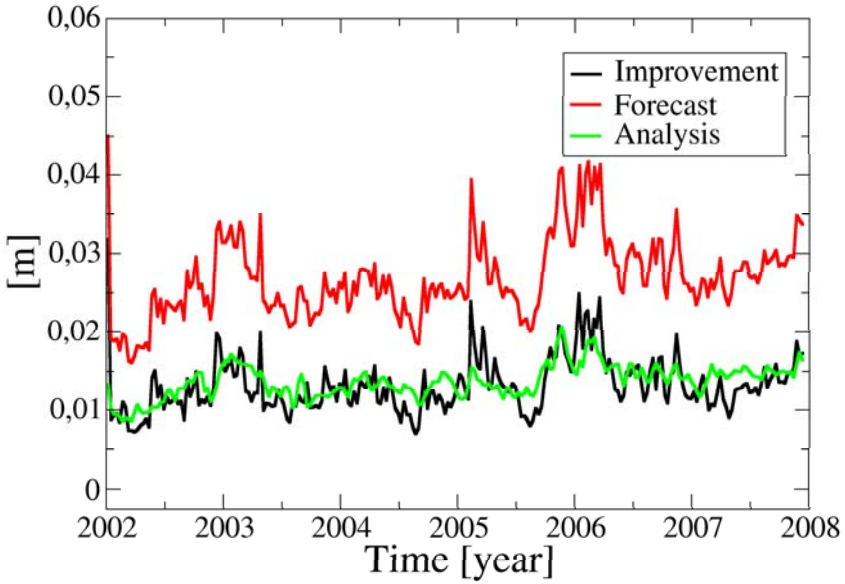


- SST Analysis (Reynolds et al; 2007) (resolution 1/4°x1/4°,daily)
- Observations of SLA derived from merged girded delayed time products distributed by Aviso (resolution 1/3°x1/3°, weekly).
- Argo T/S Profiles from four Argo Floats (resolution approx. every 7-8 day)

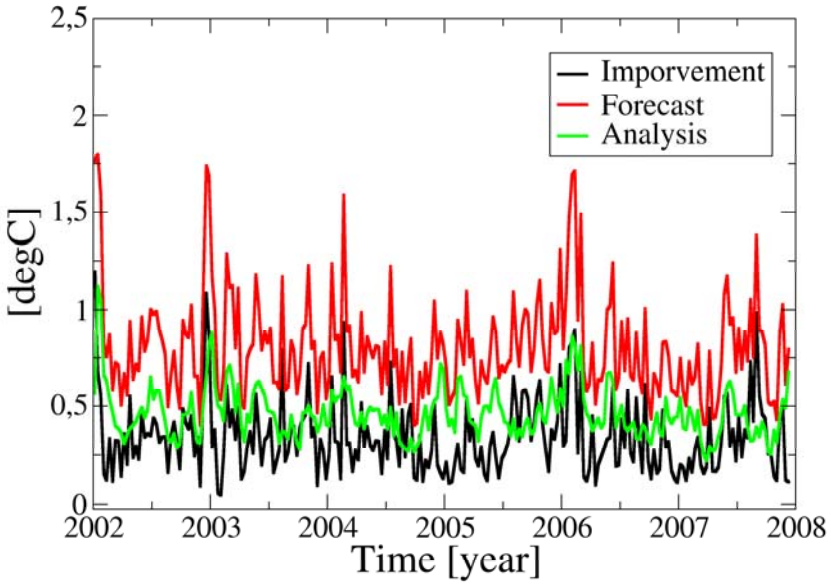
Validation of Assimilation Run

S-SLA and SST-A

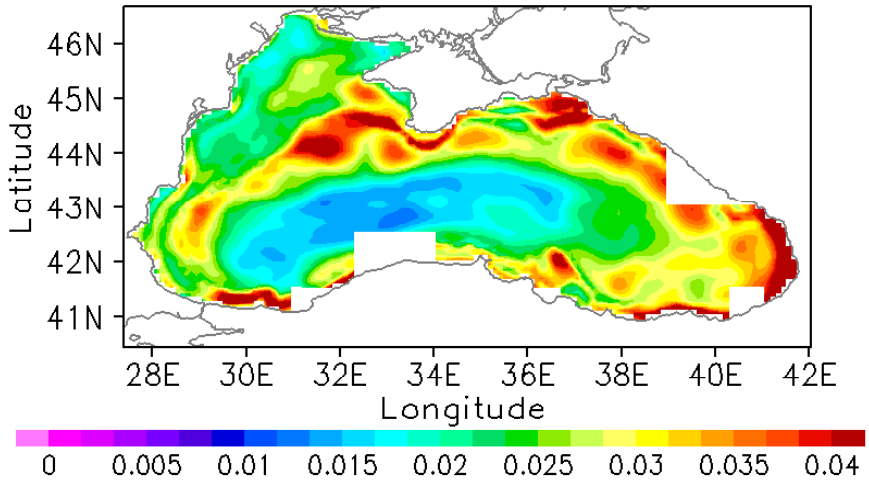
Basin-mean S-SLA RMSE



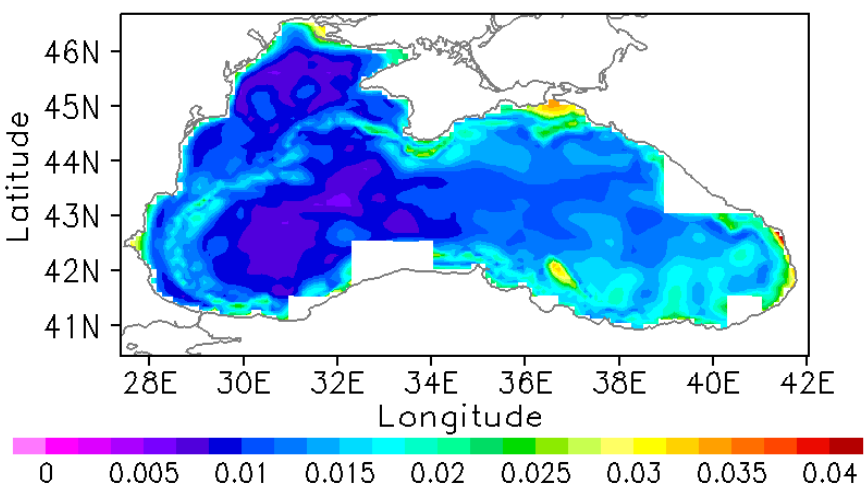
Basin-mean SST-A RMSE



Time−mean S−SLA RMSE of Forcasts [m]



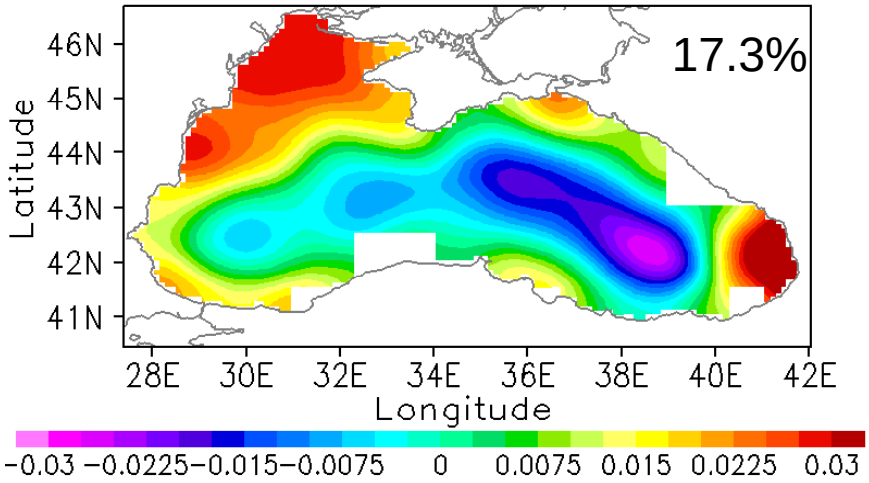
Time−mean S−SLA RMSE of Analyses [m]



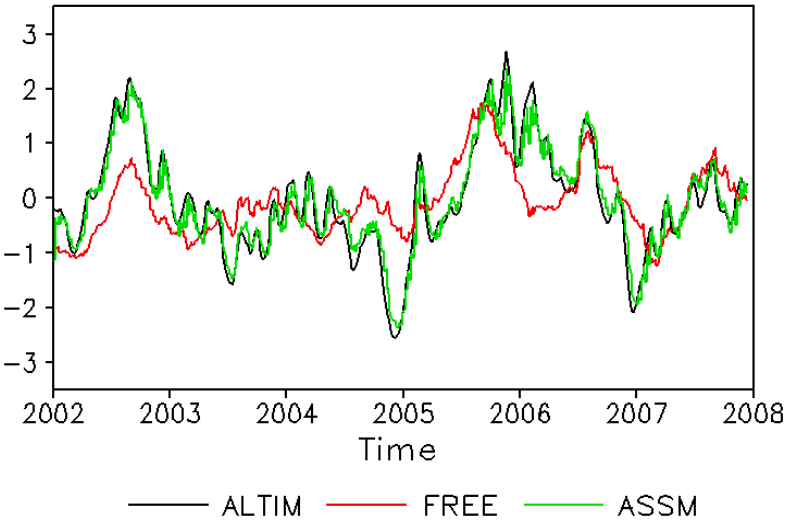
Comparison to Altimetry

Steric Sea Level Anomaly (2nd mode)

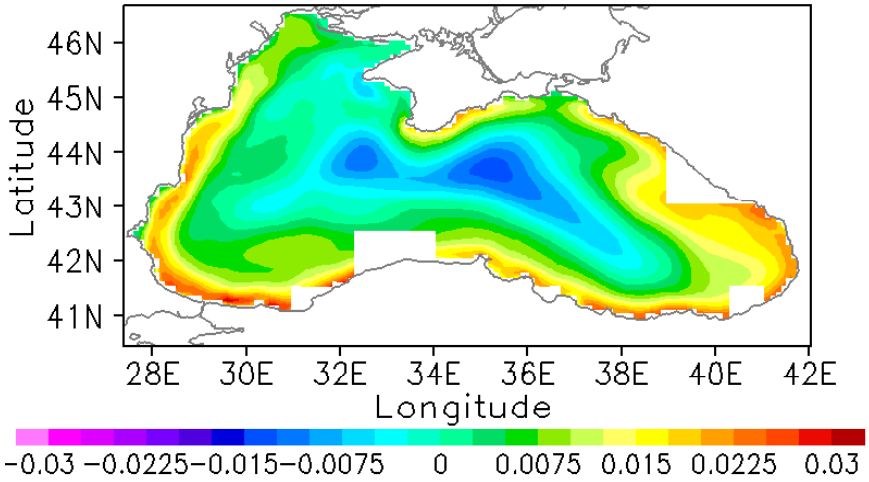
EOF-2 Aviso/Altimetry 2002-2008



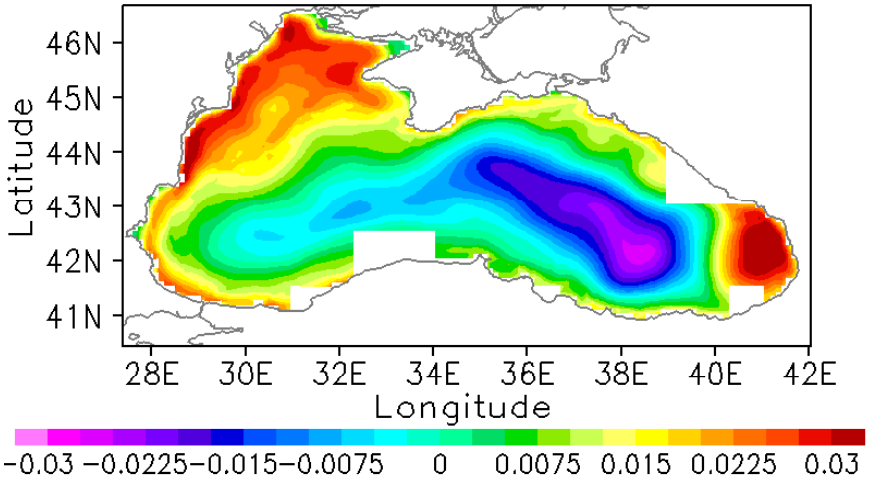
PC-2 2002-2008



D-EOF-2 Free Run 2002-2008



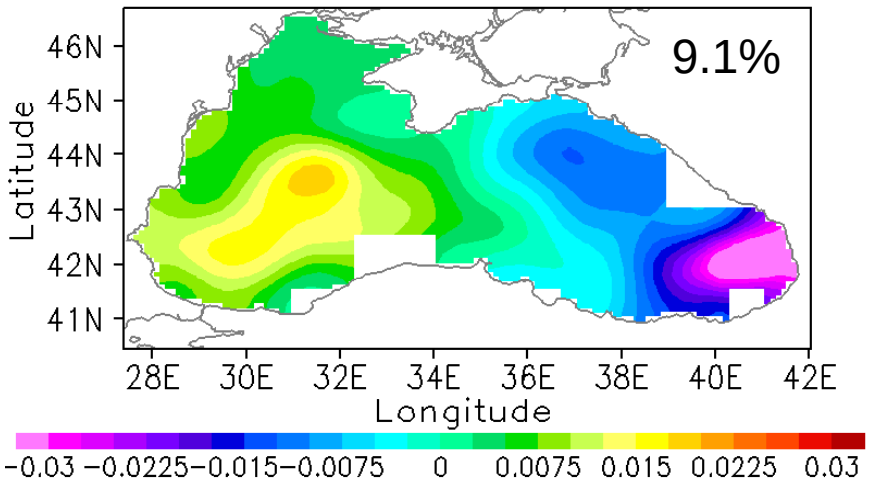
D-EOF-2 Assimilation Run 2002-2008



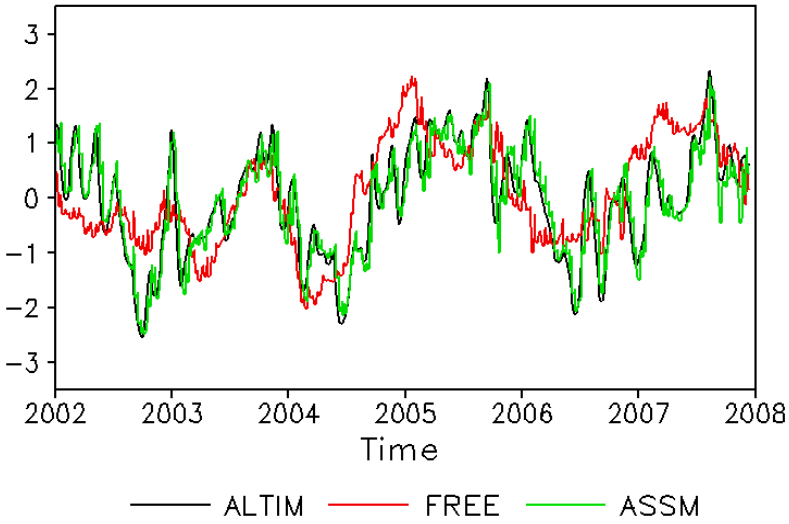
Comparison to Altimetry

Steric Sea Level Anomaly (3th mode)

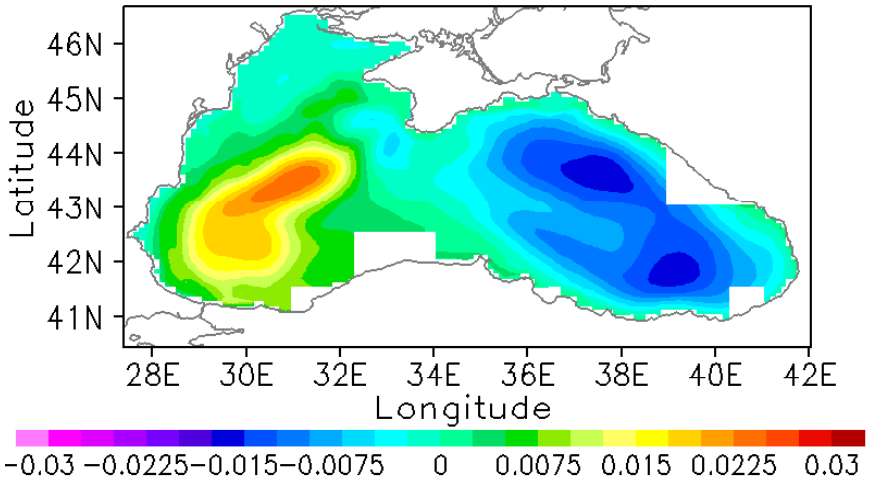
EOF-3 Aviso/Altimetry 2002-2008



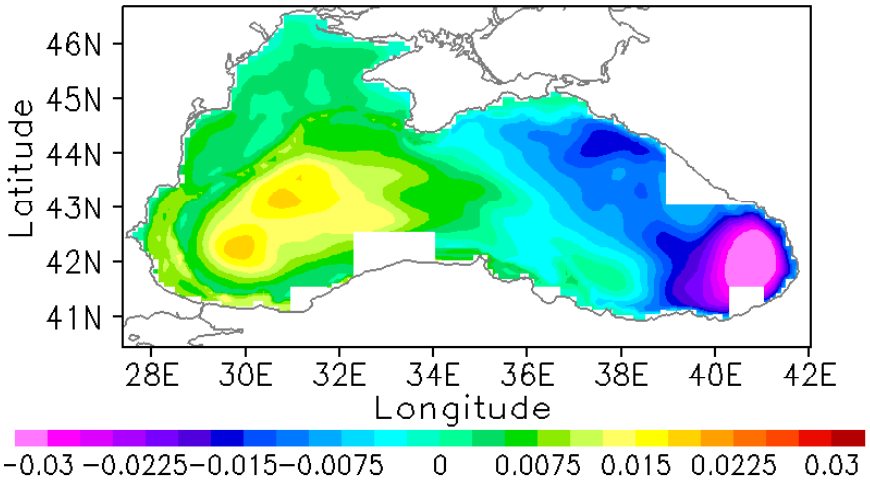
PC-3 2002-2008



D-EOF-3 Free Run 2002-2008

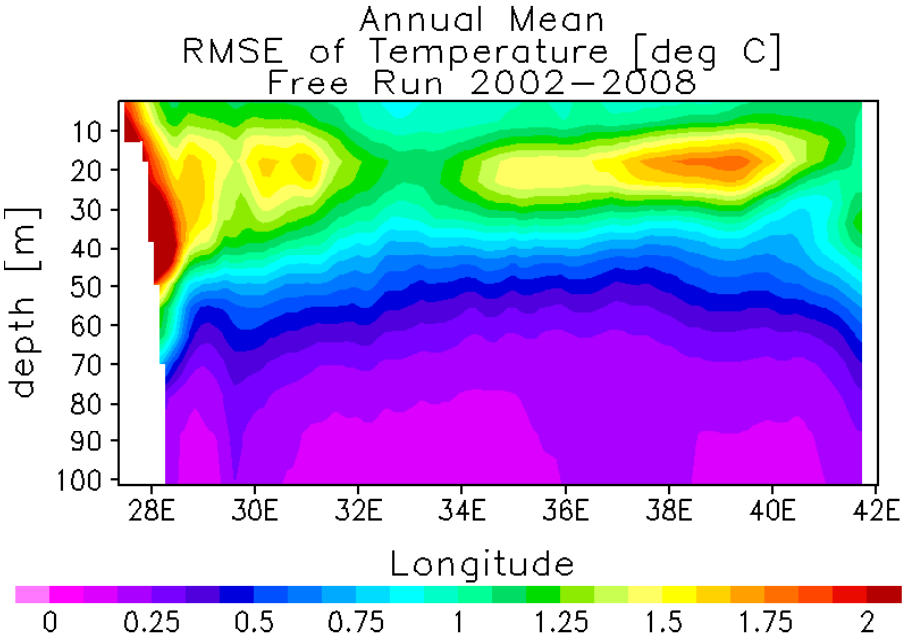


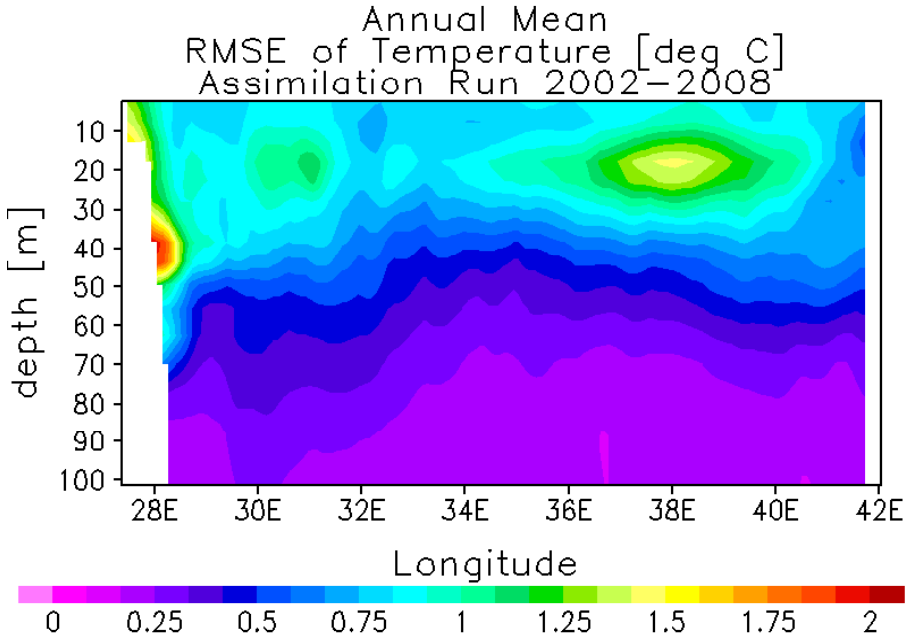
D-EOF-3 Assimilation Run 2002-2008

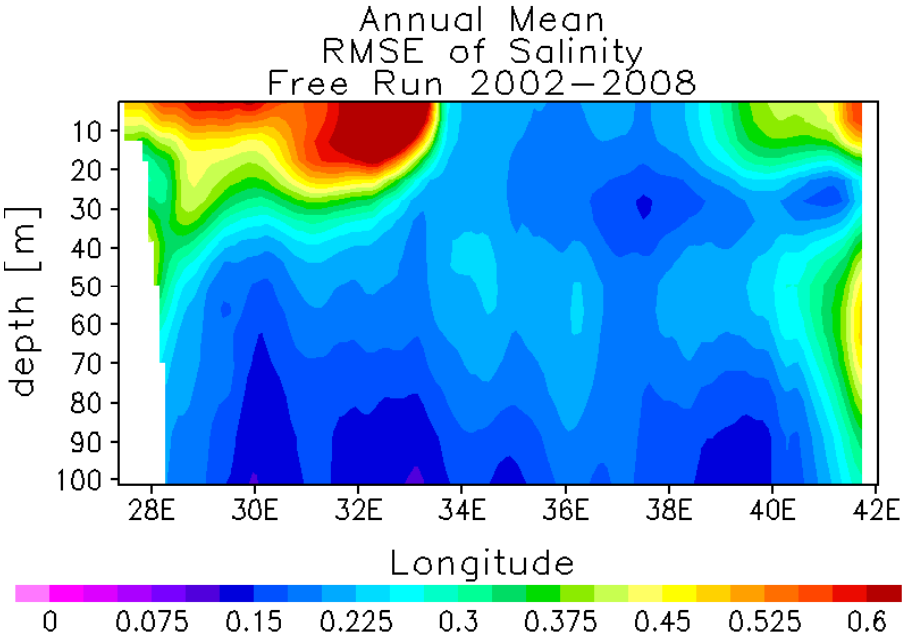


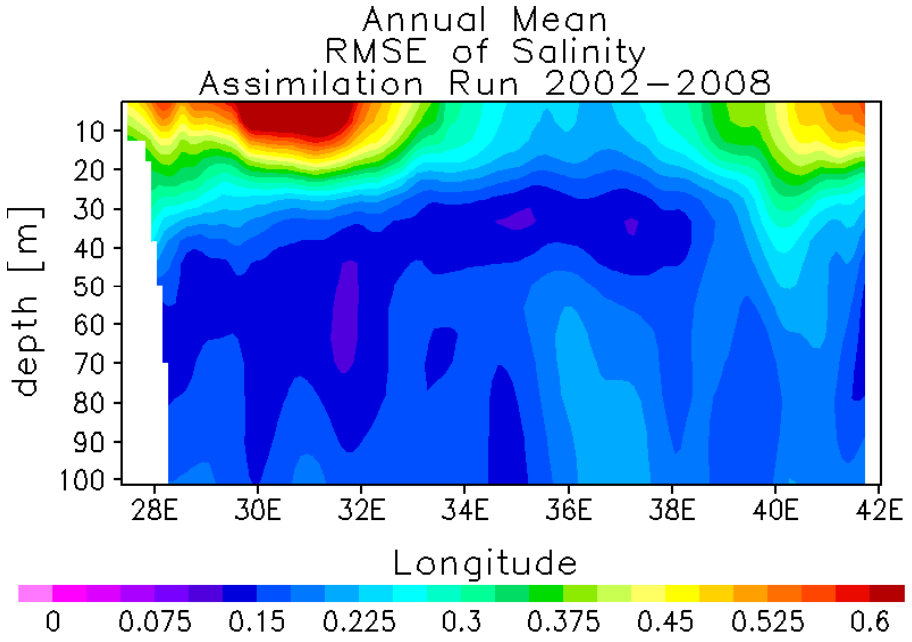
Comparison to Climatology

Mean year



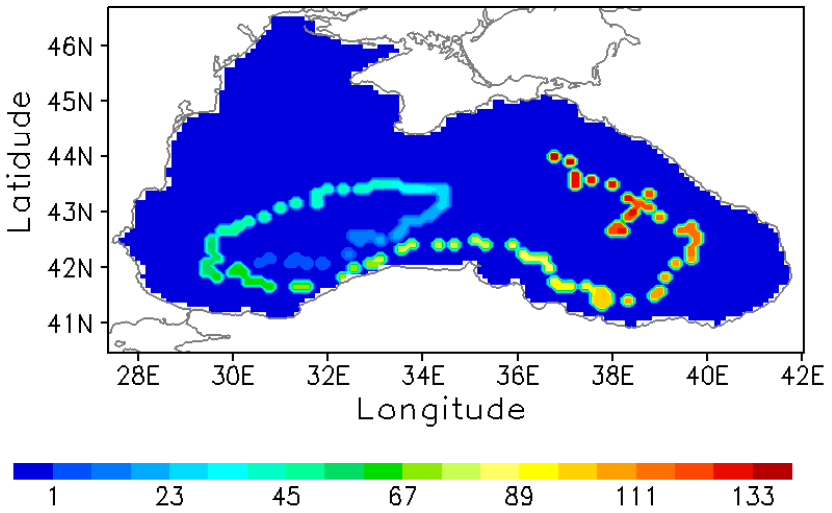




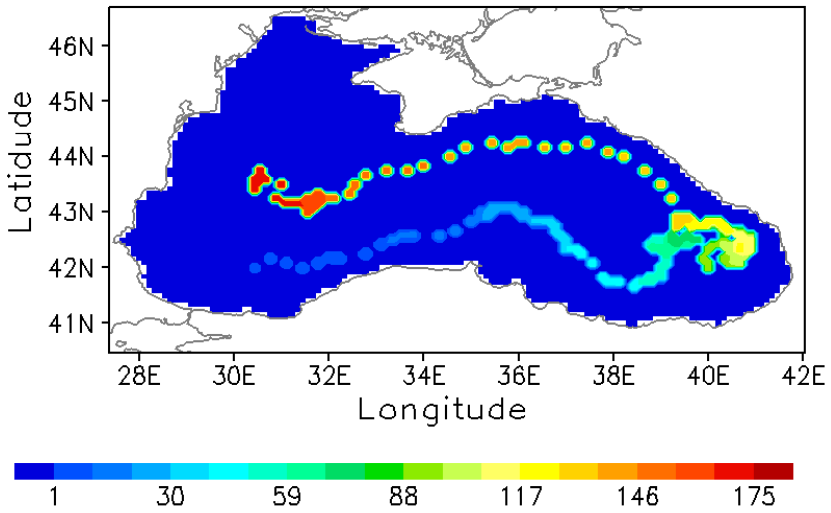


ARGO Observation

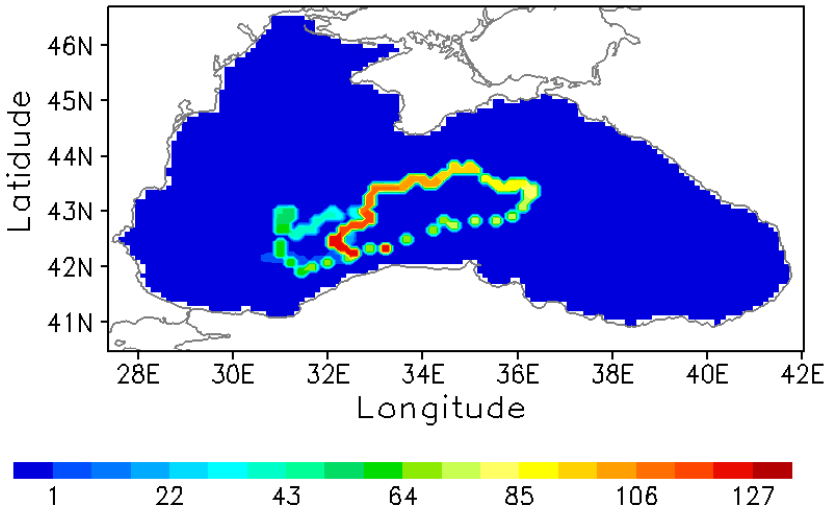
Mar 2005 – Dec 2007



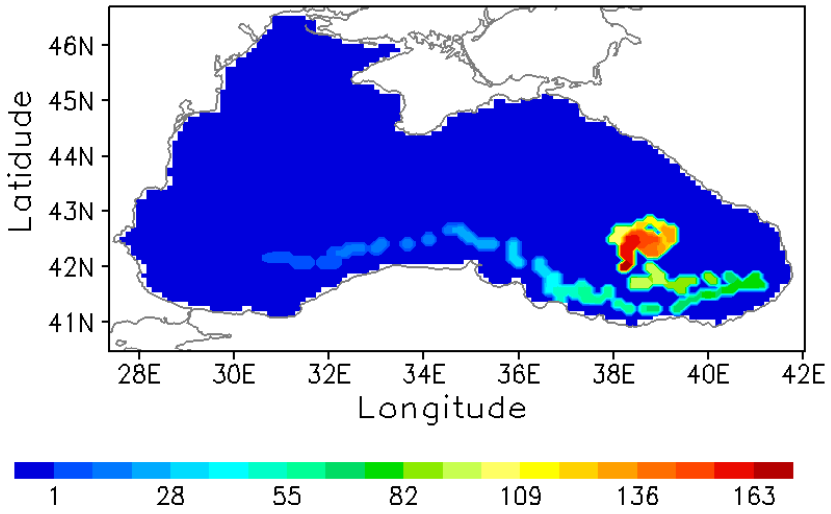
Mar 2005 – Oct 2008



Jul 2006 – Mar 2009



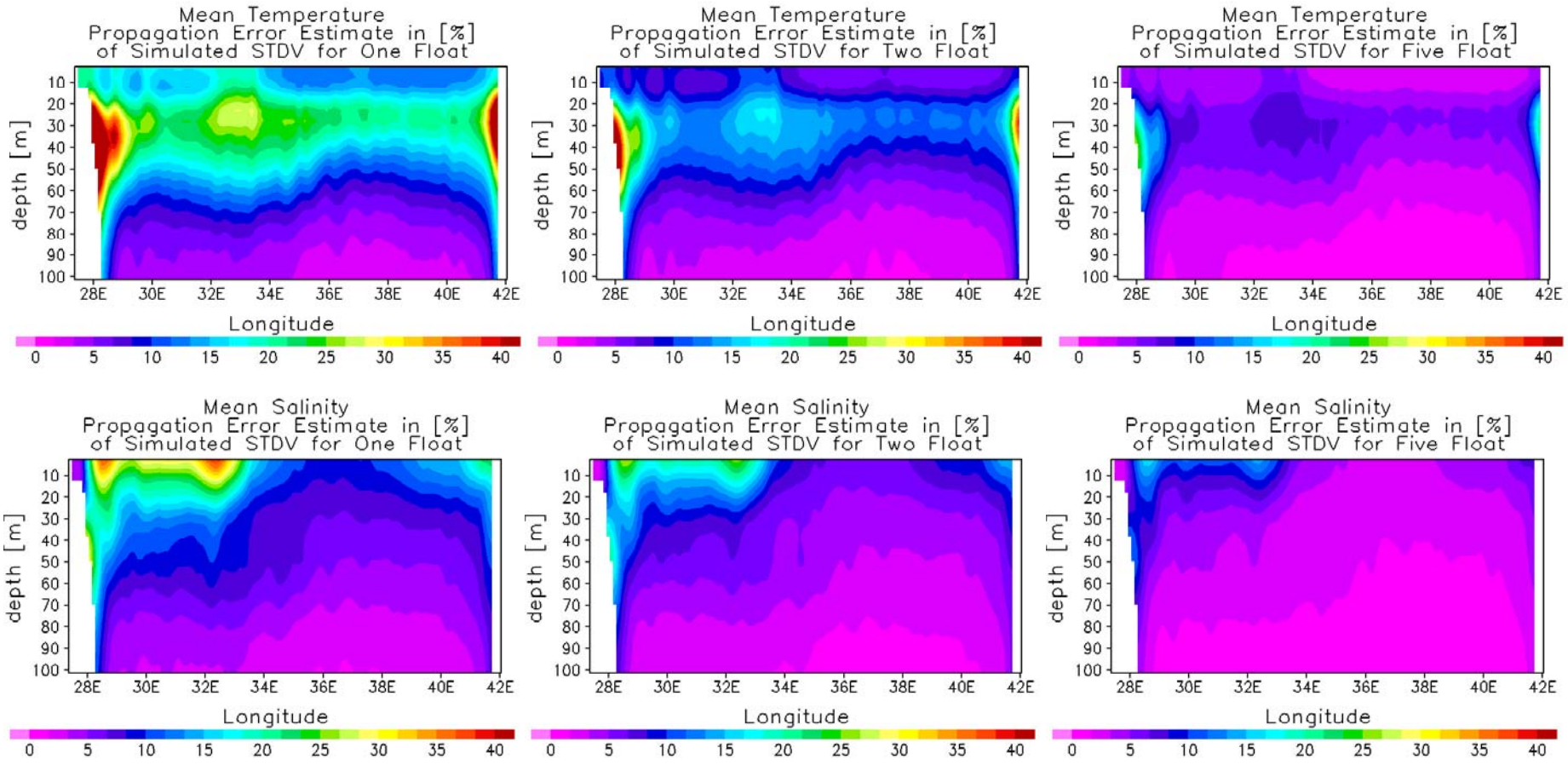
Jul 2006 – Dec 2009



Assimilation of Argo

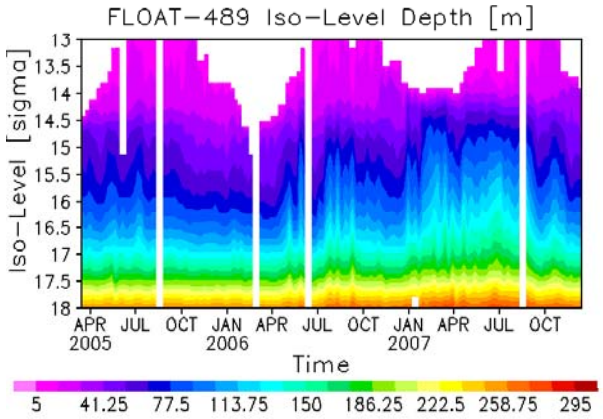
T/S Propagation Error Estimate

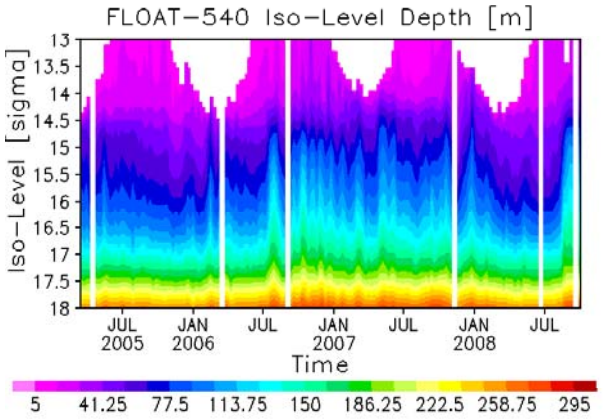
$$\Gamma_{t_i} = \sqrt{\frac{1}{m}\left(P(t_i) - P(t_i)H^T(HP(t_i)H^T + R)^{-1}HP(t_i)\right)}$$

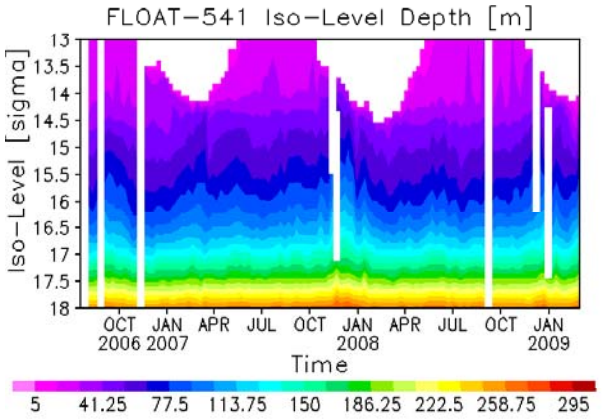


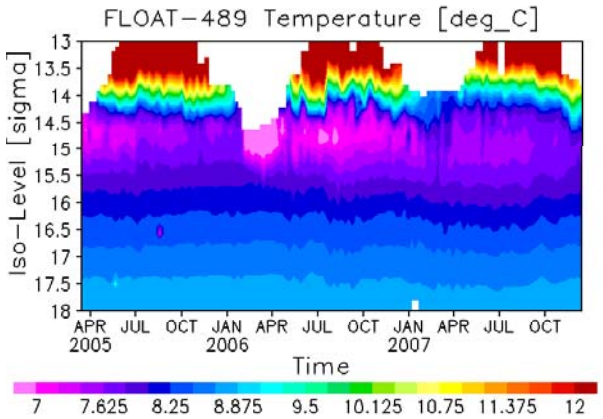
Analysis of ARGO Observation

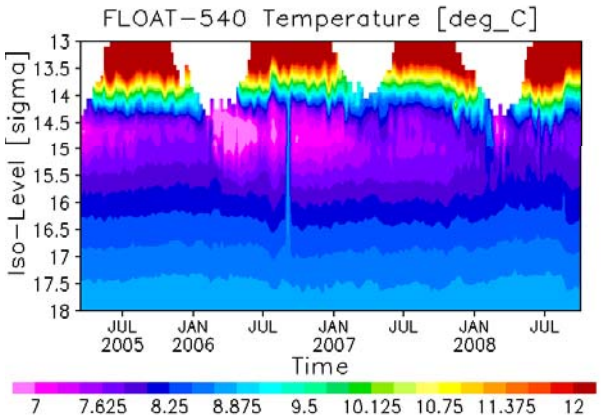
Iso-Level

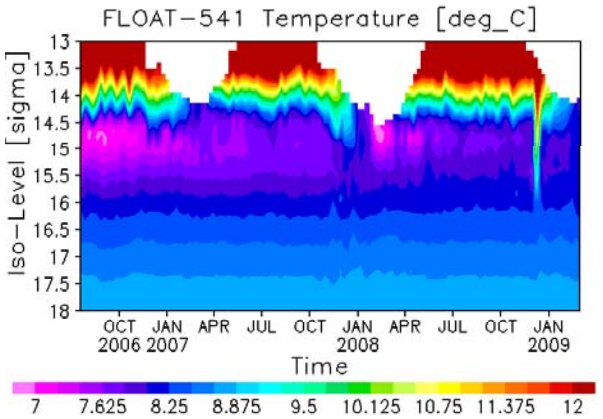


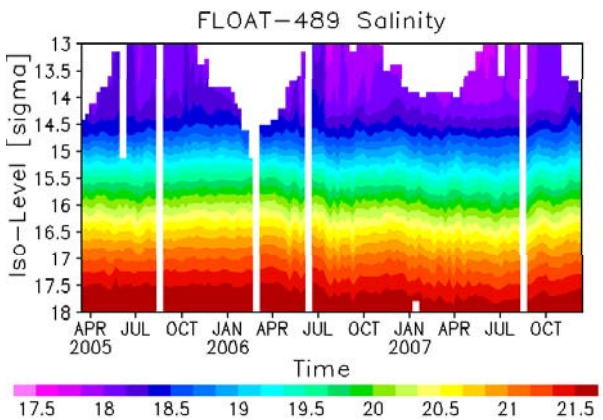


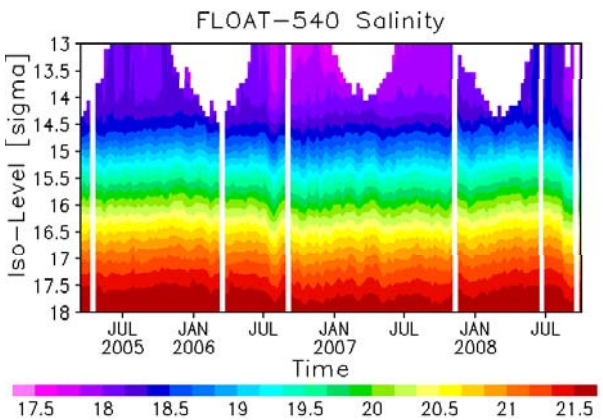


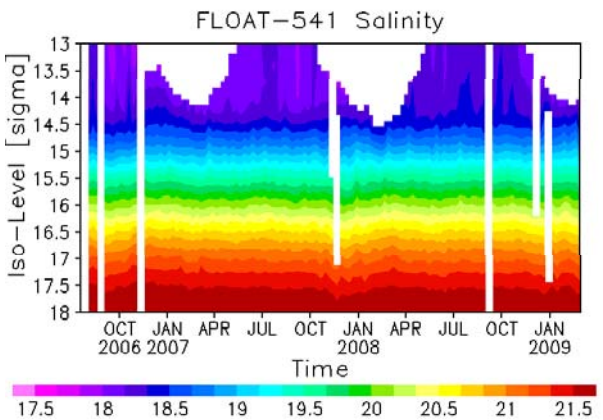






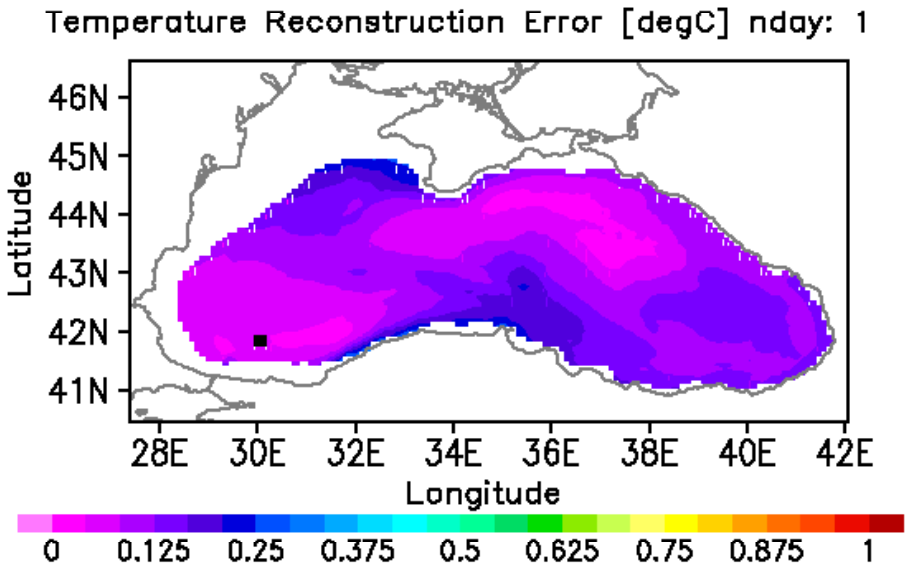


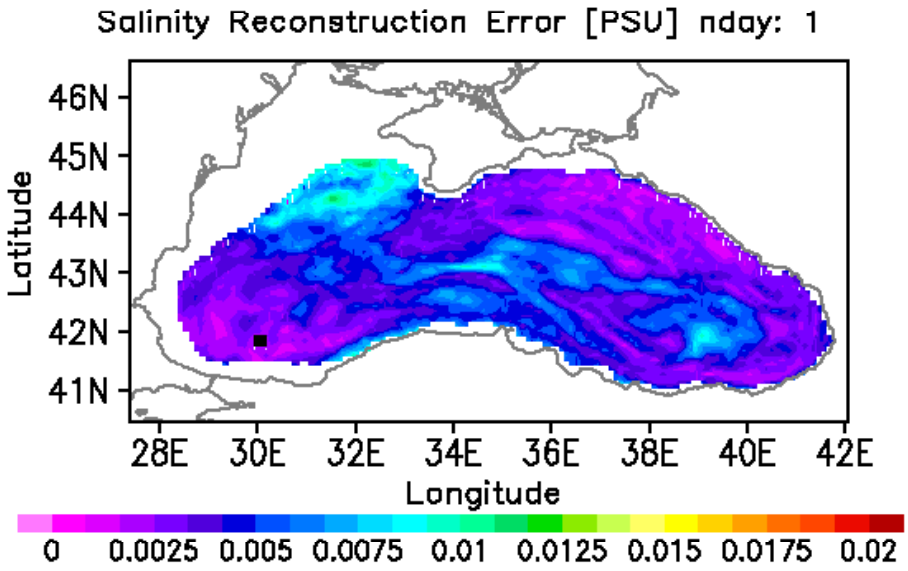


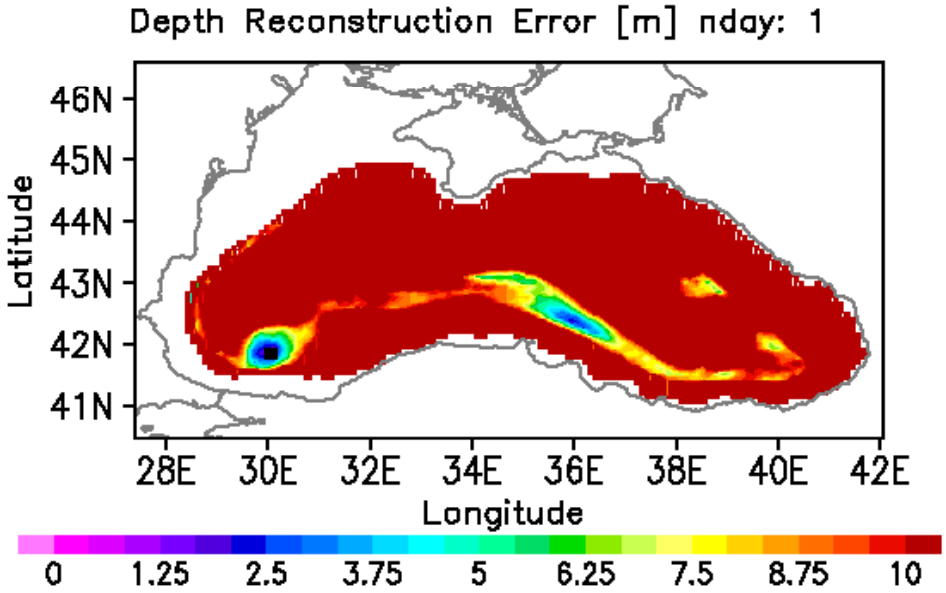


Assimilation of Argo

T/S Propagation Error Estimate on iso-levels







Conclusions

- Assimilation of SLA and SST observations is able to improve integrated steric heights
- Assimilation of SLA and SST observations has only a small impact on 3D salinity fields
- To further improve model state estimates via assimilation additional information about vertical characteristics is needed which may come form ARGO in-situ observations
- Assimilation of ARGO T/S measurements on z-levels do not harmonize with the assimilation of SLA and SST
- ARGO measurements in the Black Sea are sparse, therefore estimating the whole basin state seems not possible with an adequate accuracy
- Alternative assimilation approaches of may be more successful in making use of T/S information from ARGO

Deutsche Forschungsgemeinschaft DFG

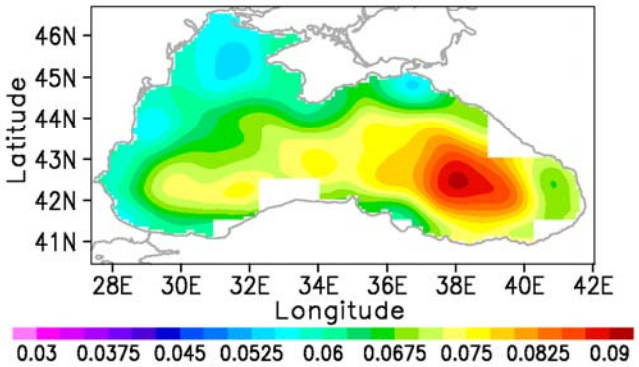
SESAME

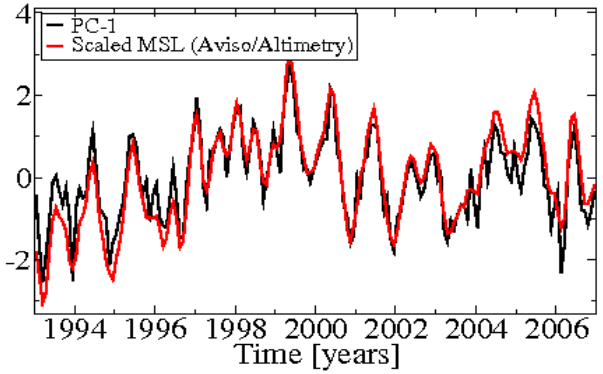
ICBM

Thank you for your attention.

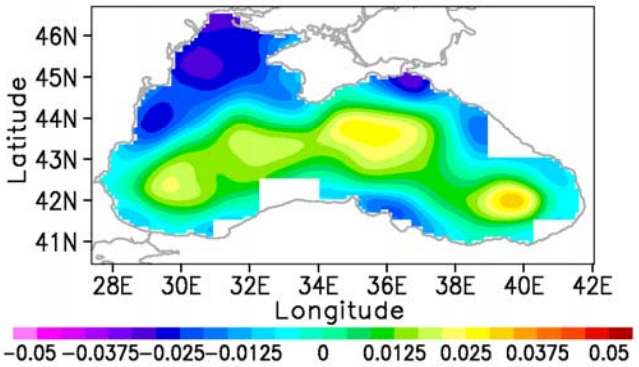
Analysis of Altimeter observation

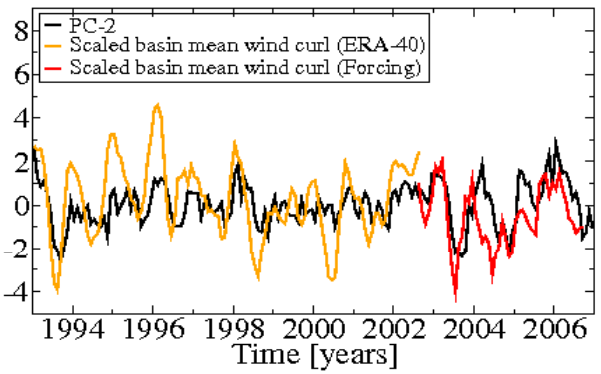
Mode 1





Mode 2





Mode 3