LONG-TERM VARIABILITY OF THE BLACK SEA DYNAMICS DERIVED FROM MODELLING

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OBJECTIVES:

The overall objective of the WP4 PERSEUS project is the development of scientific tools to evaluate the SES environmental status by engaging existing and upgraded remotely operated monitoring and modelling capabilities.

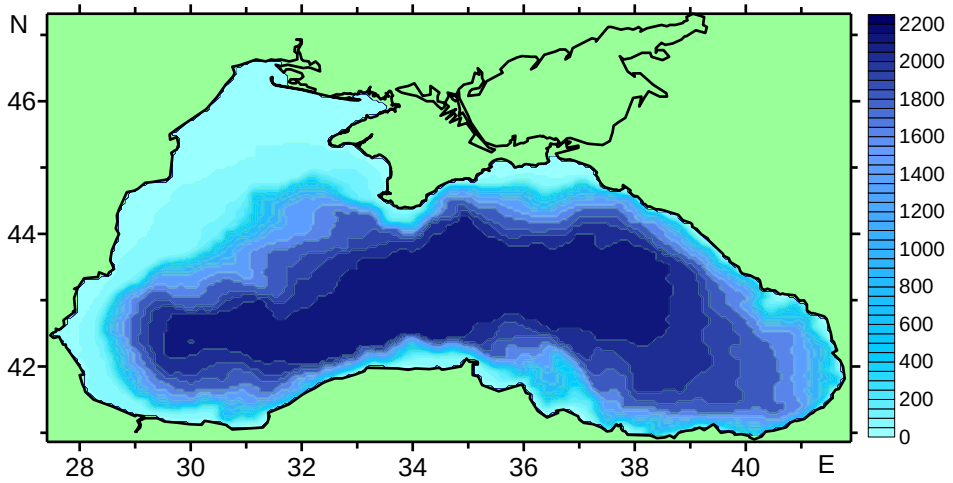
• Execute test runs (pertinent to the 20th century) that will define the correctness of the model

• Assess the model quality trough validation procedures against available reference observations

• Long-term simulations of the Black Sea dynamics (for the first two decades of the 21st century) as basis for ecological modelling

Black Sea Circulation Model

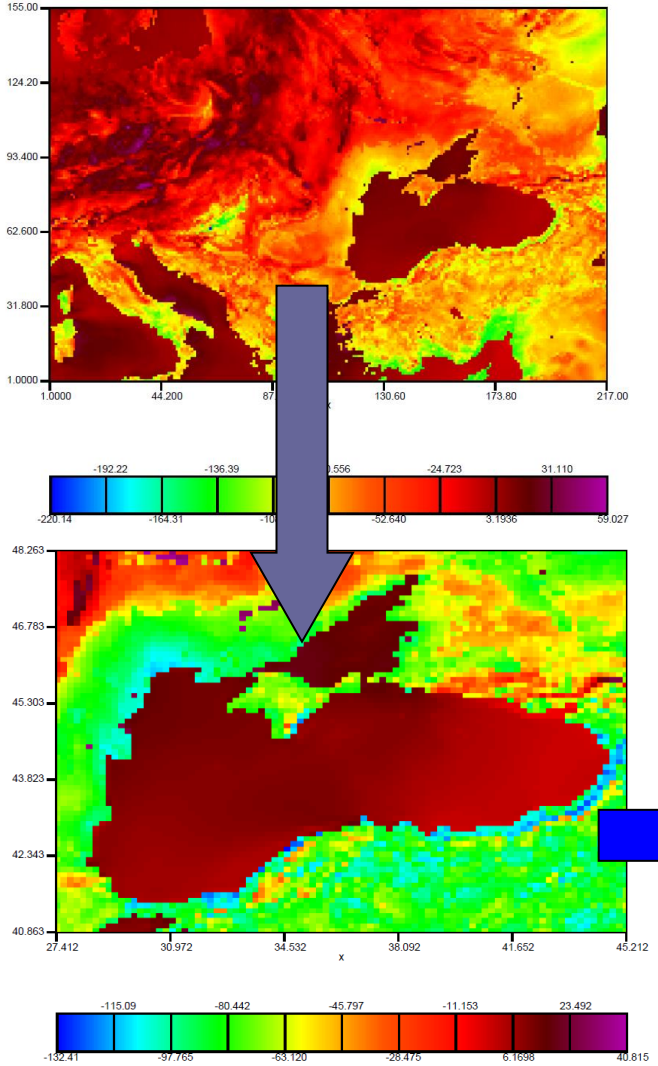
- Based on the model of the Black Sea circulation developed in MHI (Demyshev and Korotaev, 1992)
- Approximation of the traditional primitive equations on C-grid.
- Horizontal space resolution: dx=dy=4.8km (238x132 grid poits)
- 40 z-levels compressed towards the sea surface
- Vertical mixing processes are described by 2.5-level Mellor-Yamada turbulence model
- Climatic monthly-mean rivers and straits discharges



The model area and bathymetry

Black Sea Atmospheric Surface Forcing Data

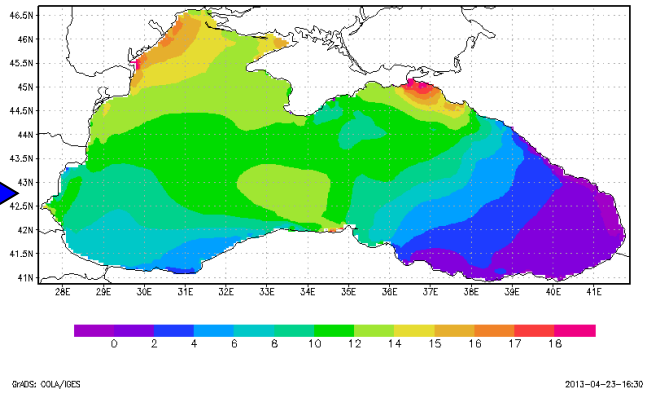
Atmospheric forcing prepared by CMCC (provided by the regional climate model COSMO-CLM) was downloaded from FTP server (ftp.cmcc.it/PERSEUS/) and interpolated on the grid of the Black sea circulation model.



The atmospheric forcing data have a spatial resolution of 14 km and a daily temporal resolution.

The list of the main parameters used in the circulation model

- ***Total precipitation (accumulated over 6 hours)***
- ***Accumulated flux of surface moisture***
- ***Sensible heat flux (surface)***
- ***Latent heat flux (surface)***
- ***Zonal wind in 10m***
- ***Meridional wind in 10m***
- ***Surface albedo (shortwave radiation)***
- ***Average solar radiation budget (surface)***
- ***Average thermal radiation budget (surface)***



Validation of the Results

Physical Reanalysis of the Black Sea Dynamics 1971-1993(Knysh et al., 2012)

Reanalysis of the Black Sea dynamics for 1971–1993 was performed by assimilating the temperature and salinity profiles into the Black Sea circulation model. Three to ten monthly hydrographic surveys were conducted during 1971-1993 with irregular coverage both in space and time. The optimal interpolation was applied to prepare monthly temperature and salinity arrays on the model grid.

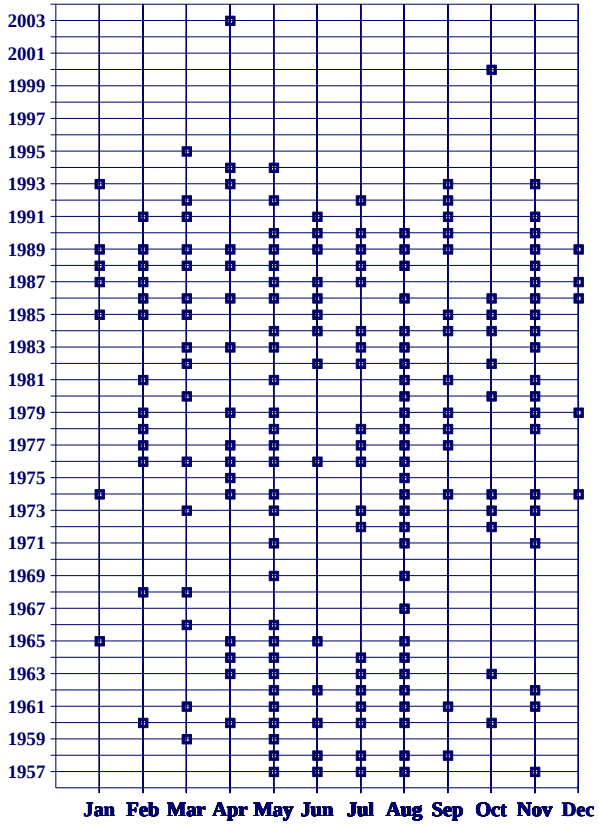
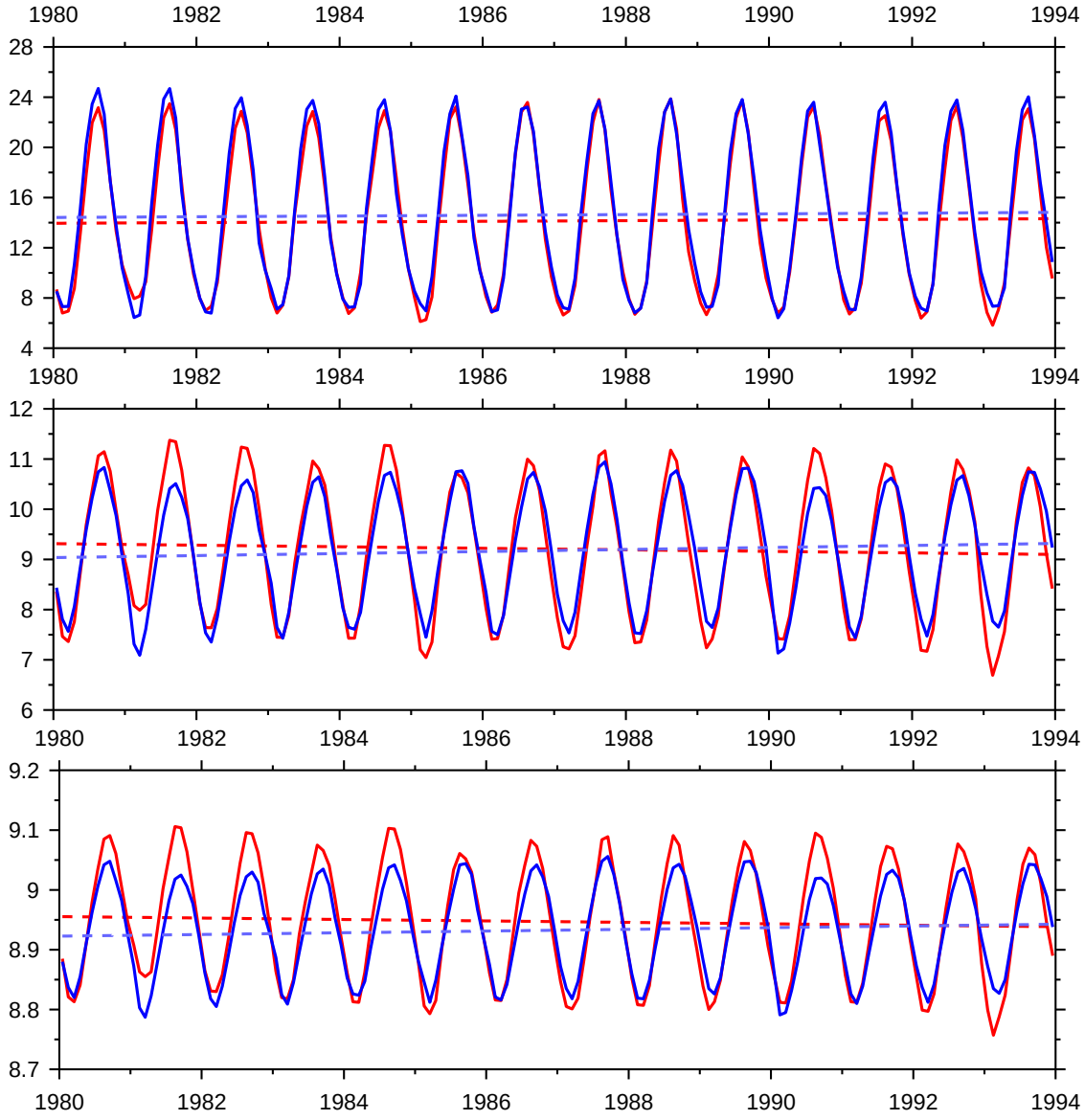


Diagram illustrating distribution in time hydrographic surveys in the Black Sea from 1957 to 2003 years.

Evolution of the basin-averaged monthly-mean temperature

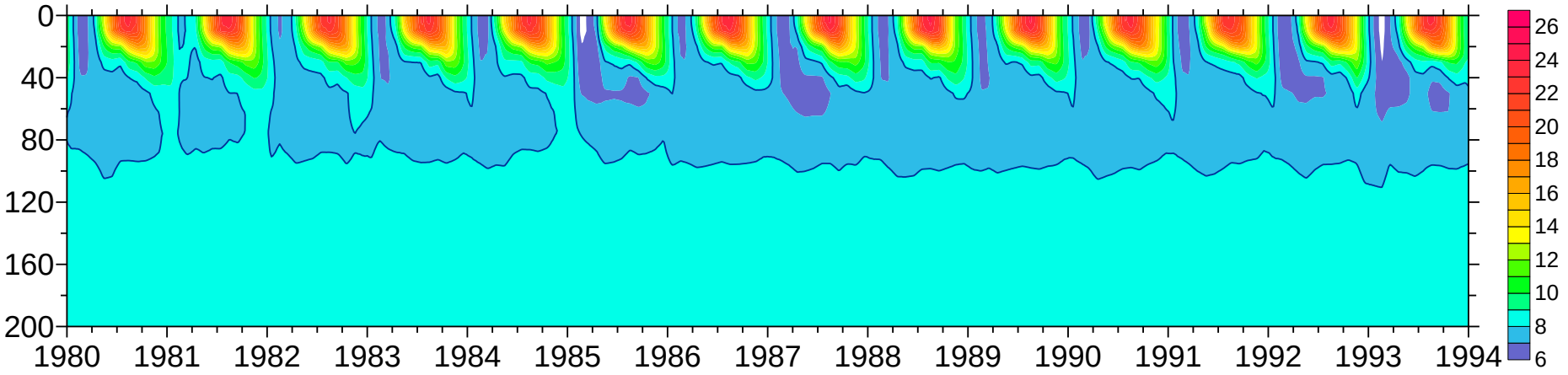


Surface temperature (°C)

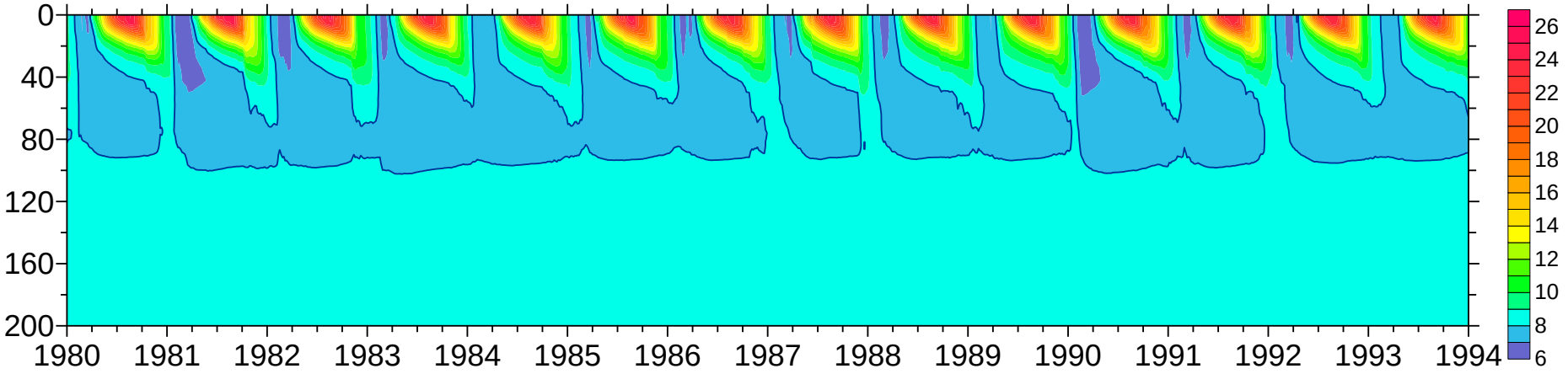
Temperature in the upper 100m layer (°C)

Volume-mean temperature(°C)

Evolution of the basin-averaged temperature in the upper 200m layer

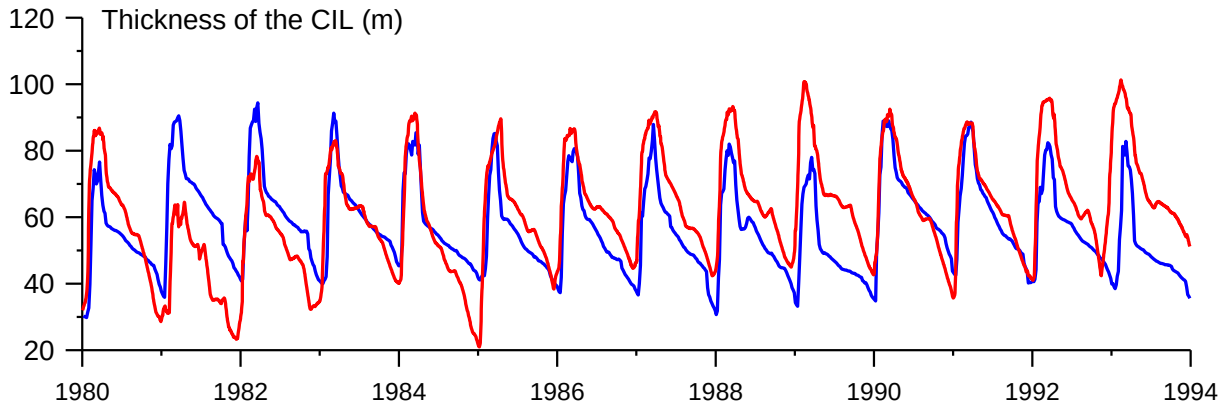


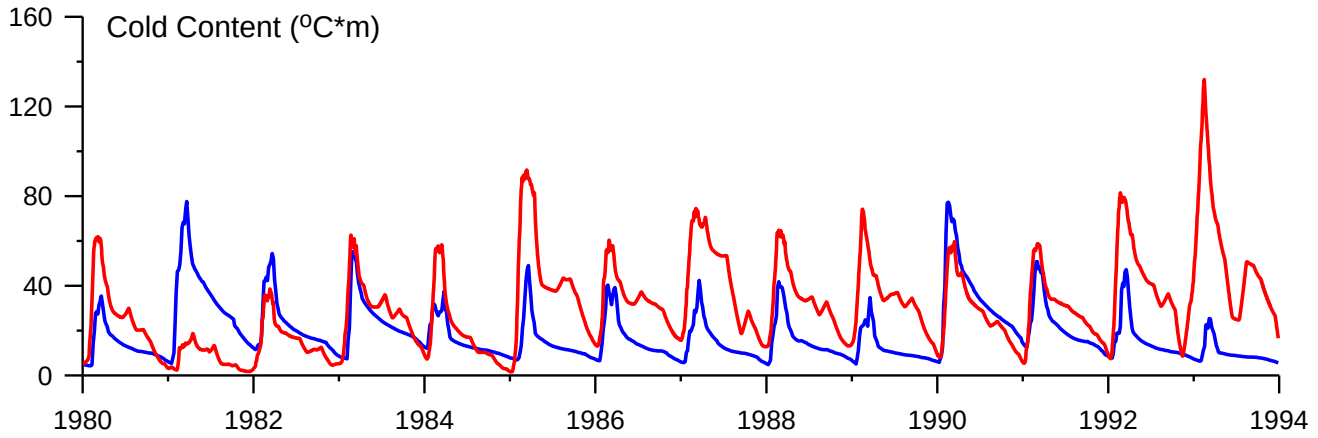
Reanalysis



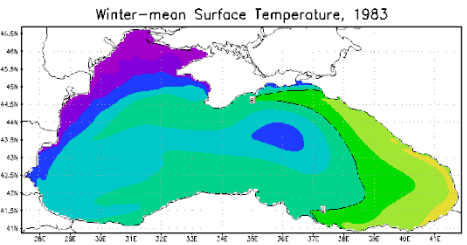
Hindcast

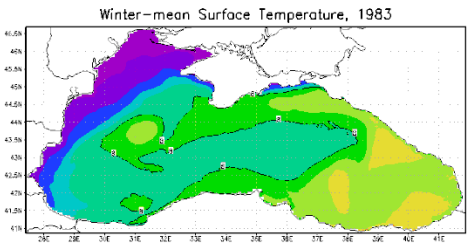
Evolution of the cold intermediate layer (CIL) characteristics

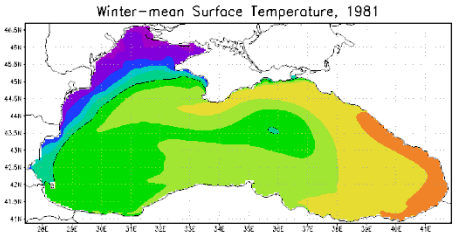


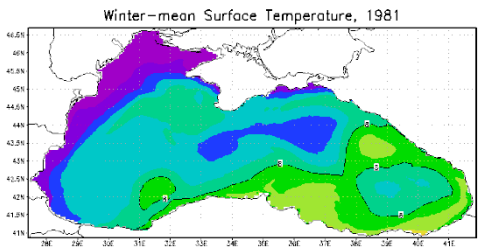


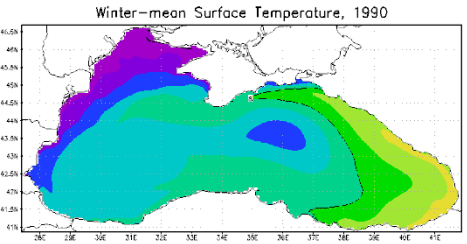
Winter-mean surface temperature

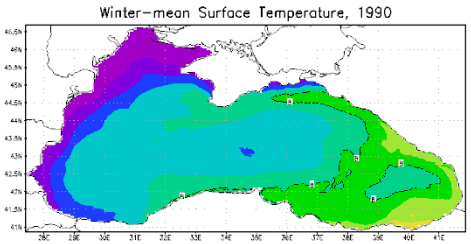


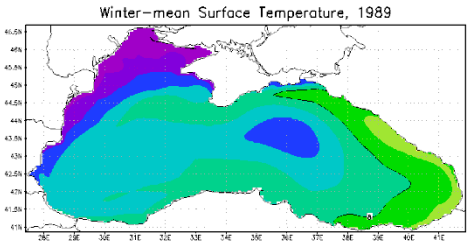


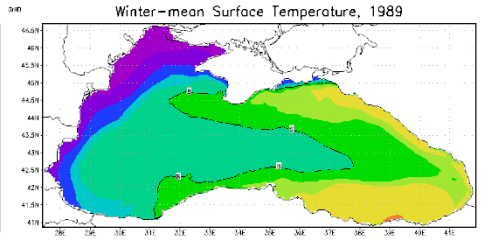


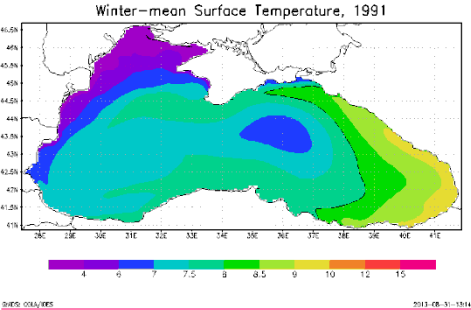


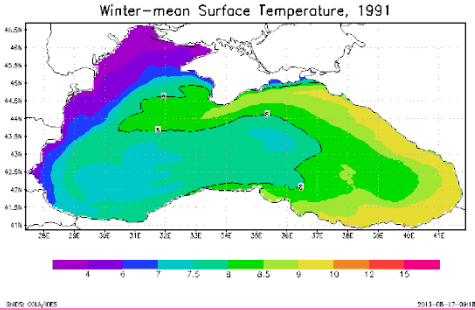


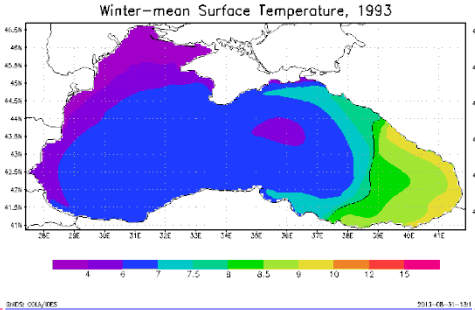


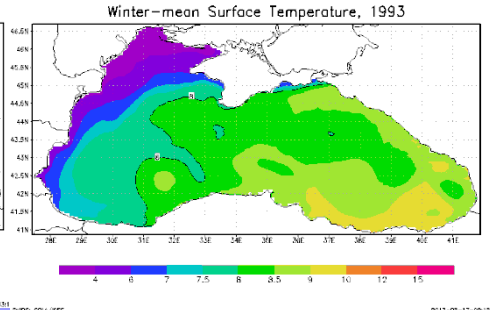






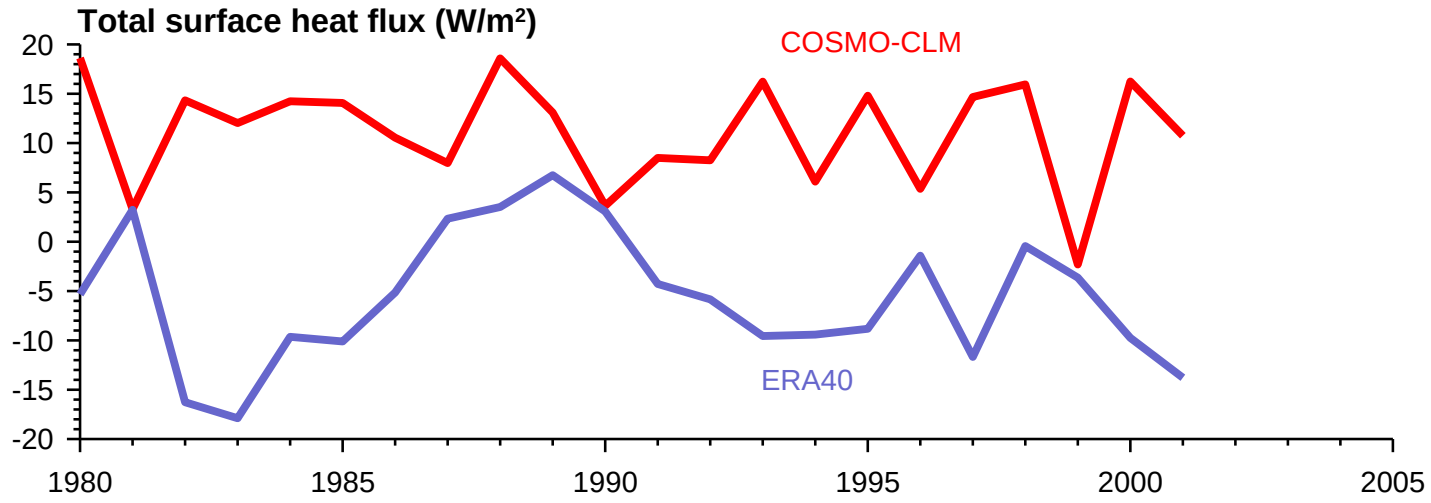


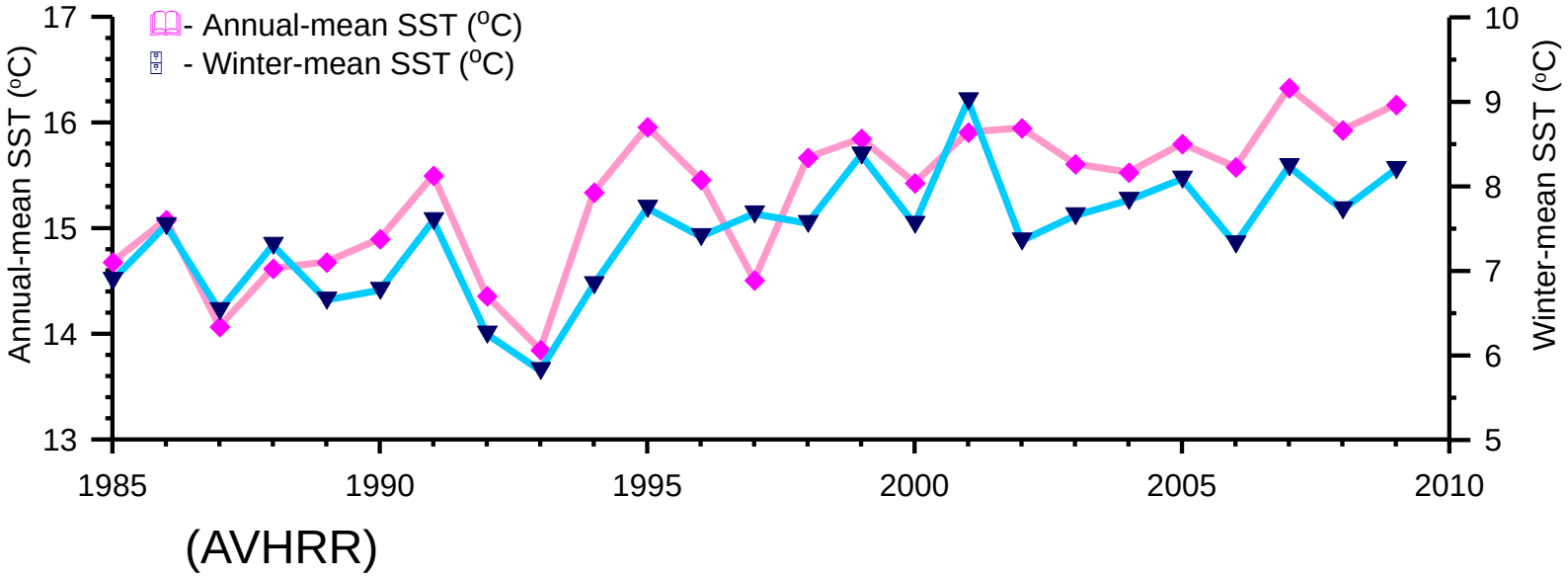




Reanalysis **Hindcast** **Reanalysis** **Hindcast**

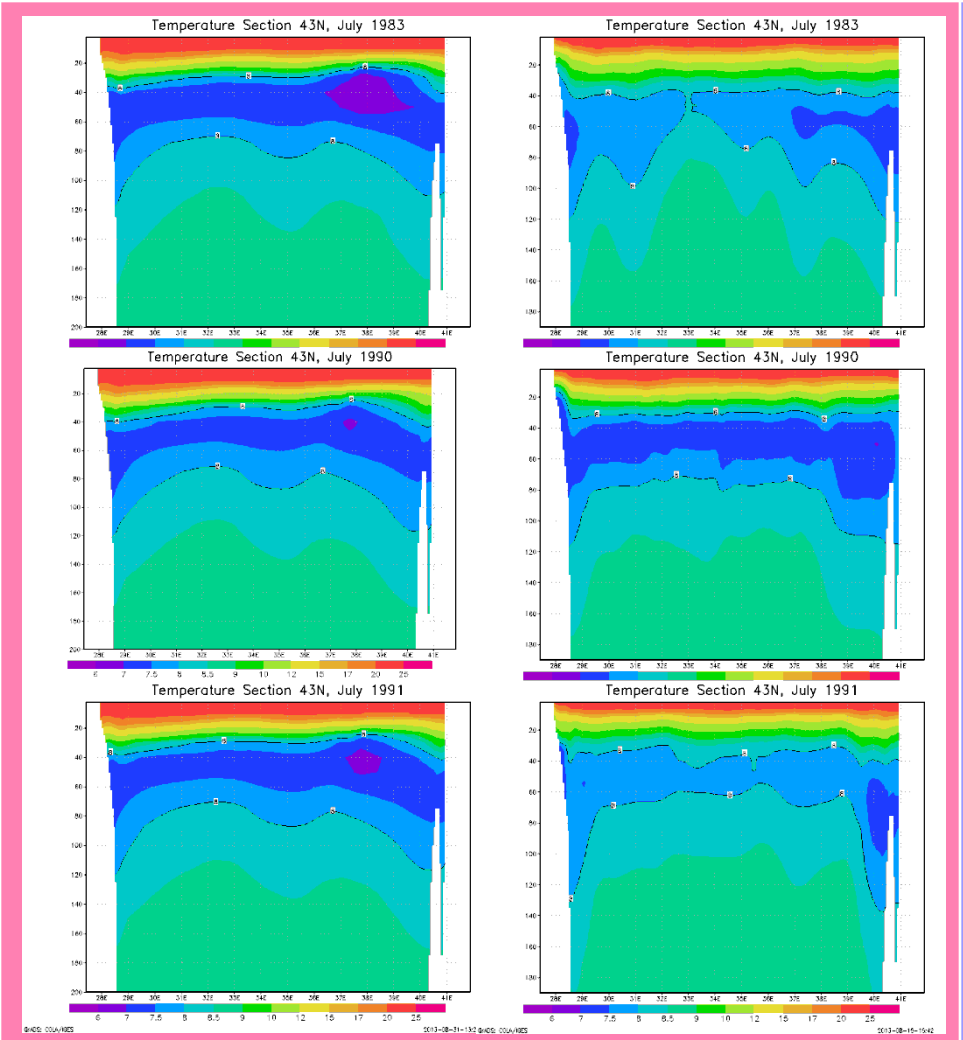
Annual-mean surface het fluxes



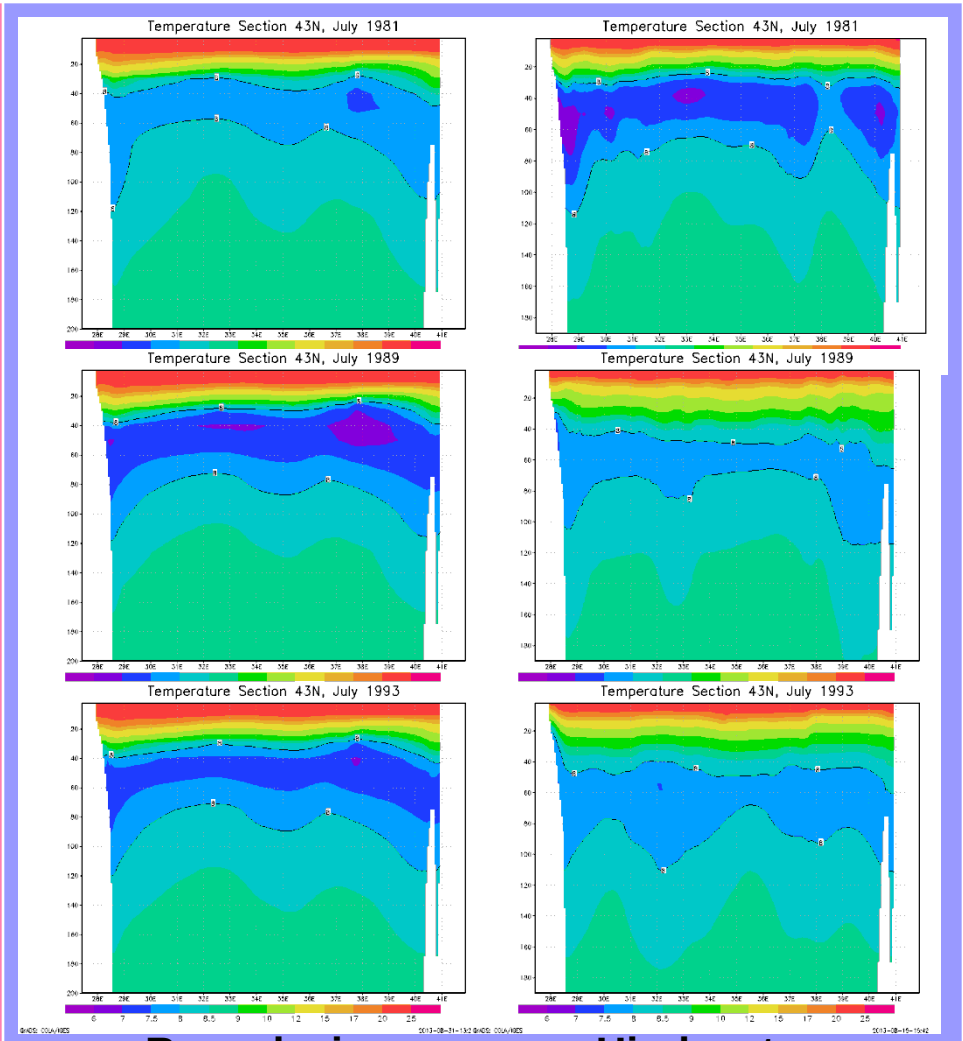


(AVHRR)

Summer temperature zonal cross section along 43N

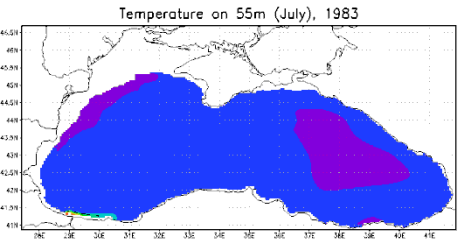


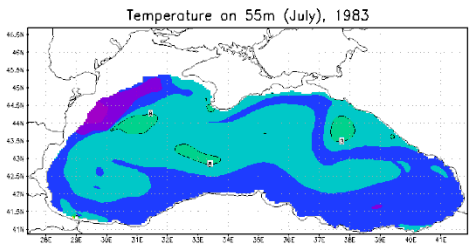
Reanalysis **Hindcast**

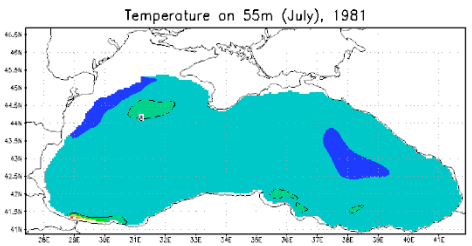


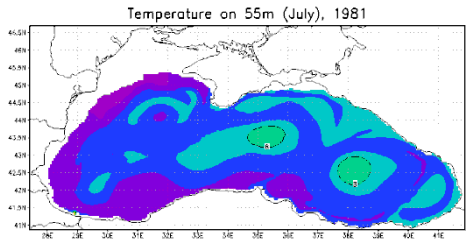
Reanalysis **Hindcast**

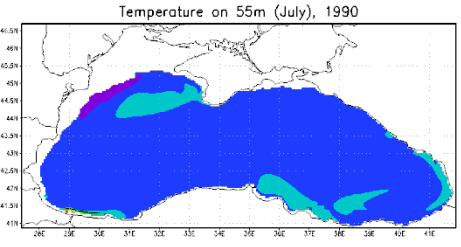
Summer temperature distribution on 55m horizon

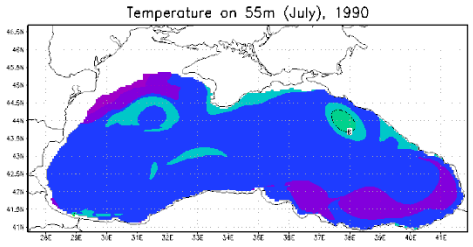


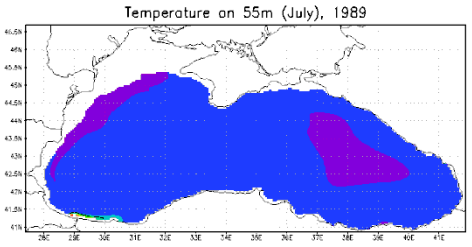


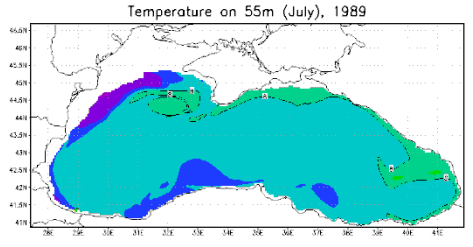


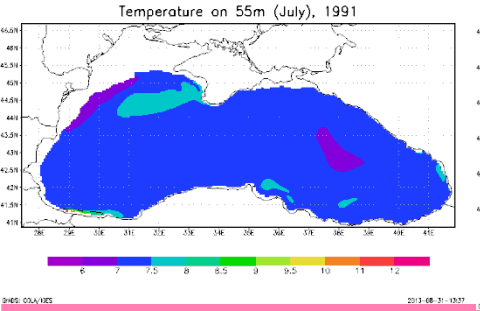


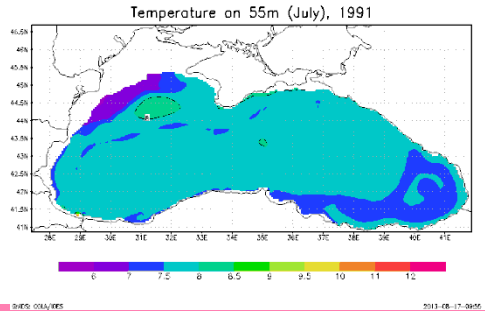


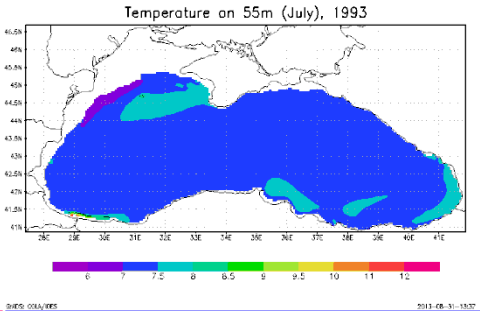


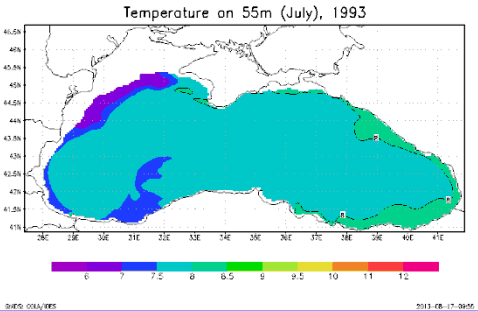






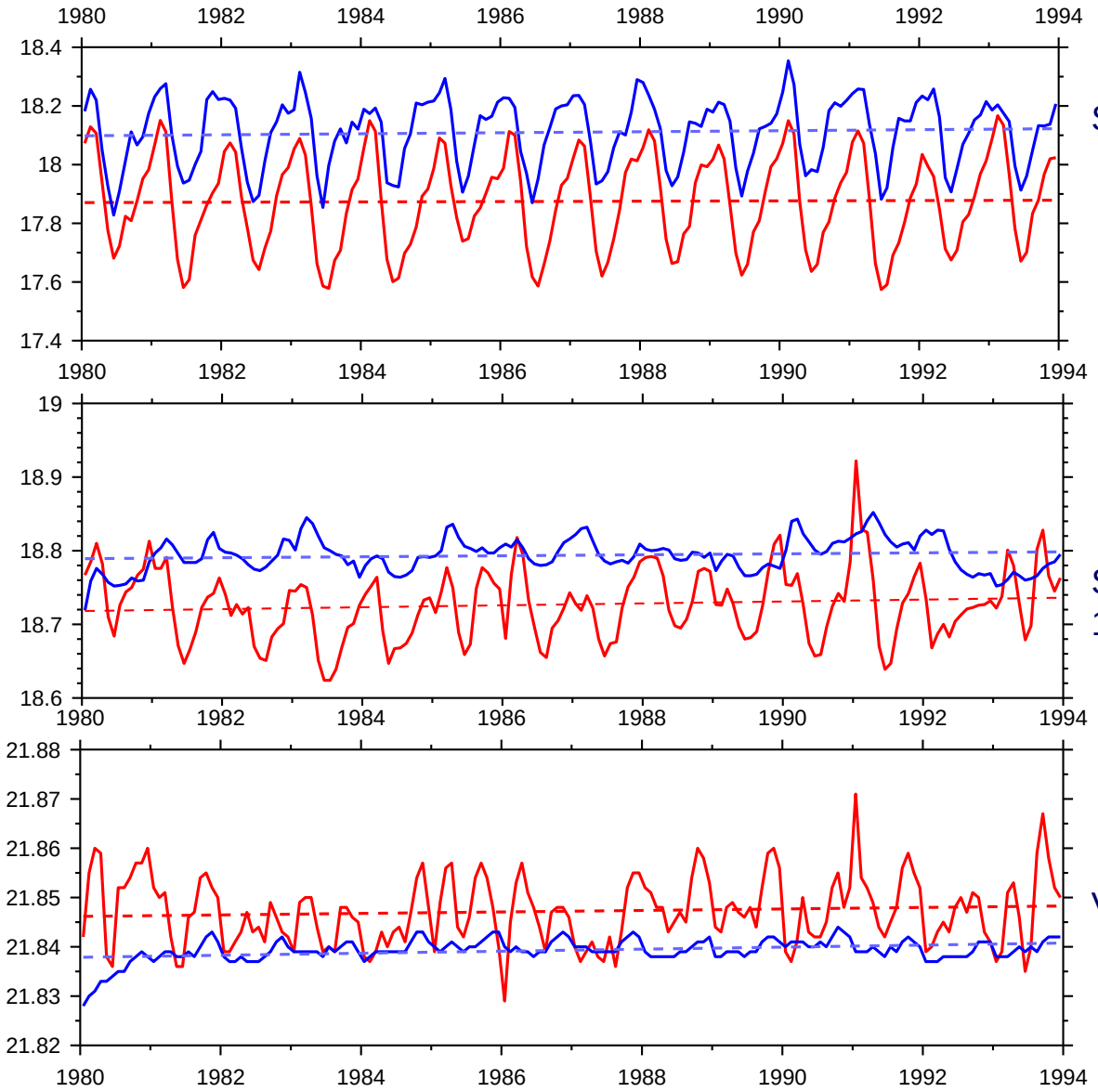






Reanalysis **Hindcast** **Reanalysis** **Hindcast**

Evolution of the basin-averaged monthly-mean salinity

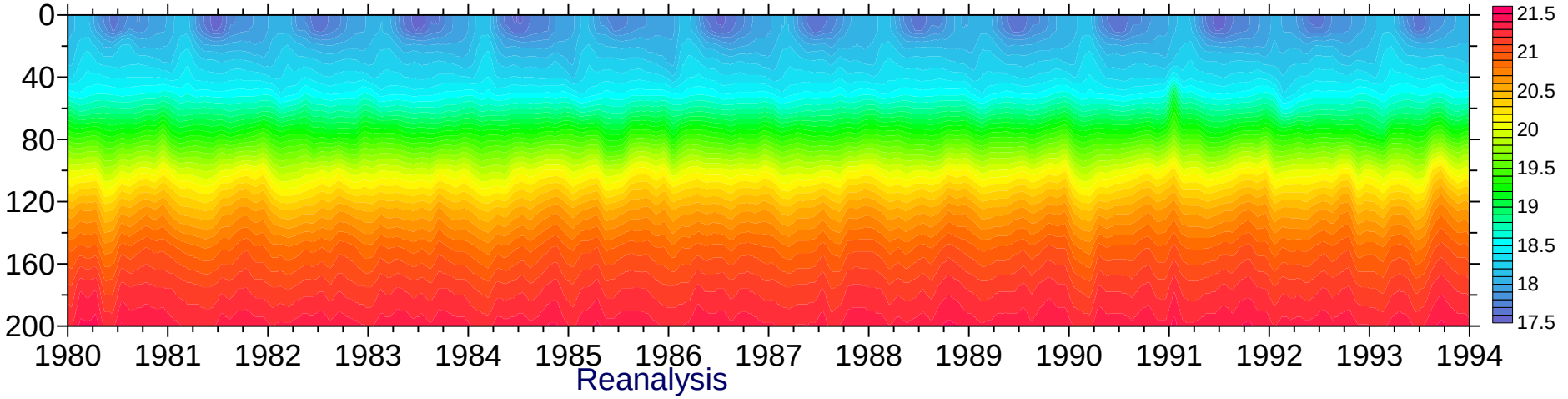


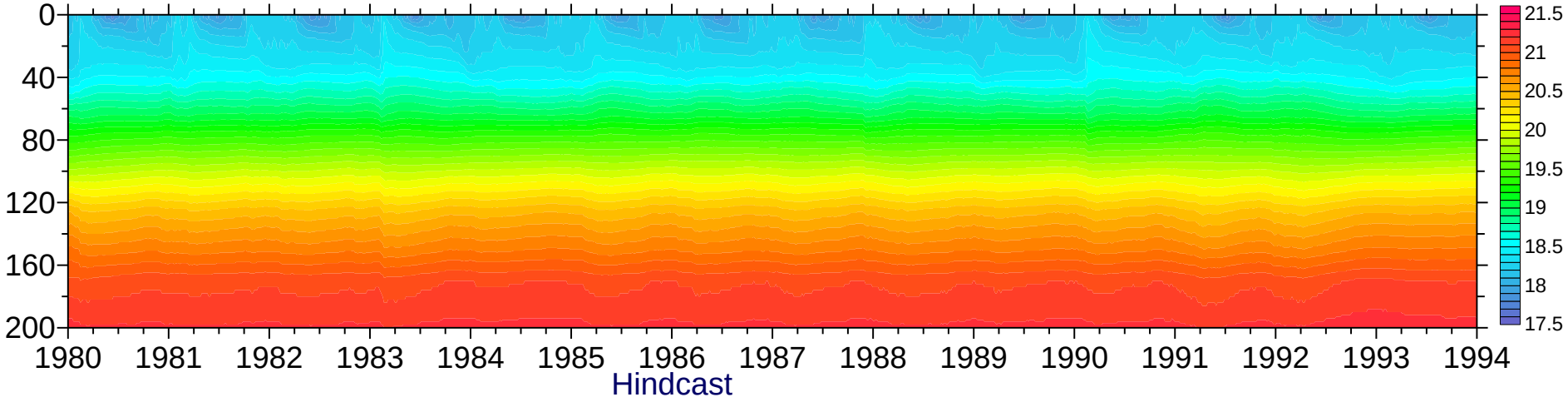
Surface salinity (psu)

Salinity in the upper 100m layer (psu)

Volume-mean salinity

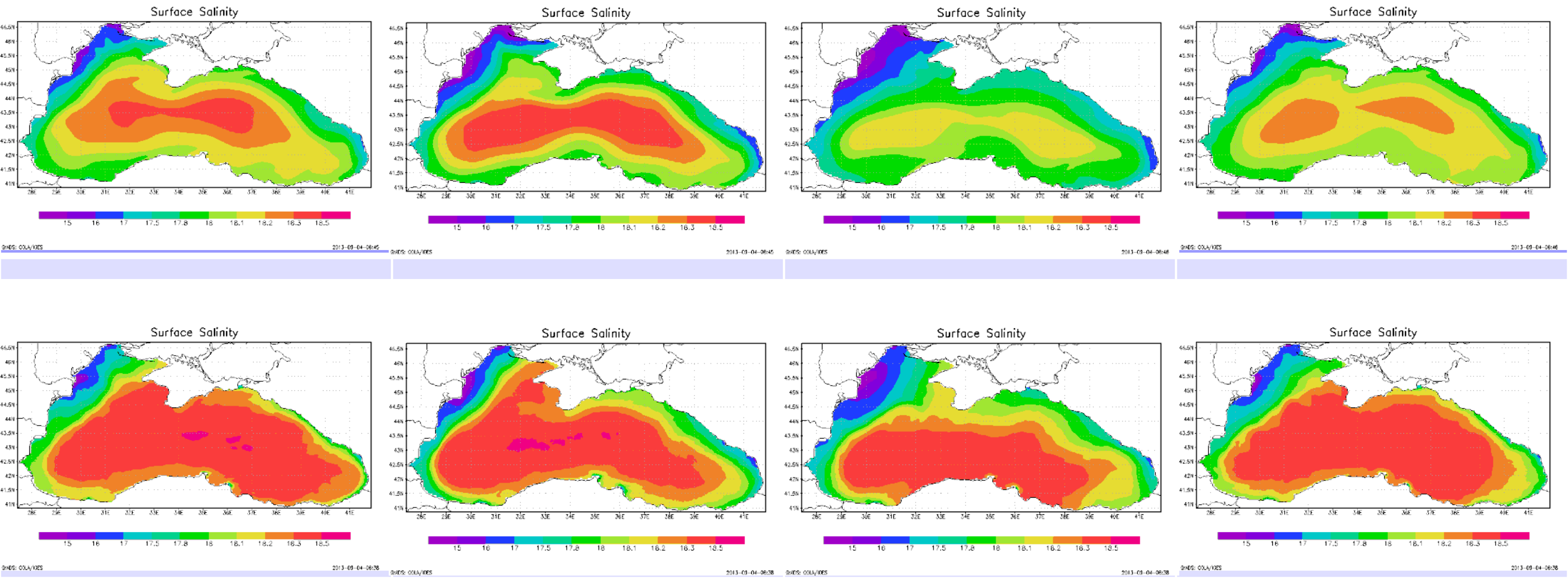
Evolution of the basin-averaged salinity in the upper 200m layer





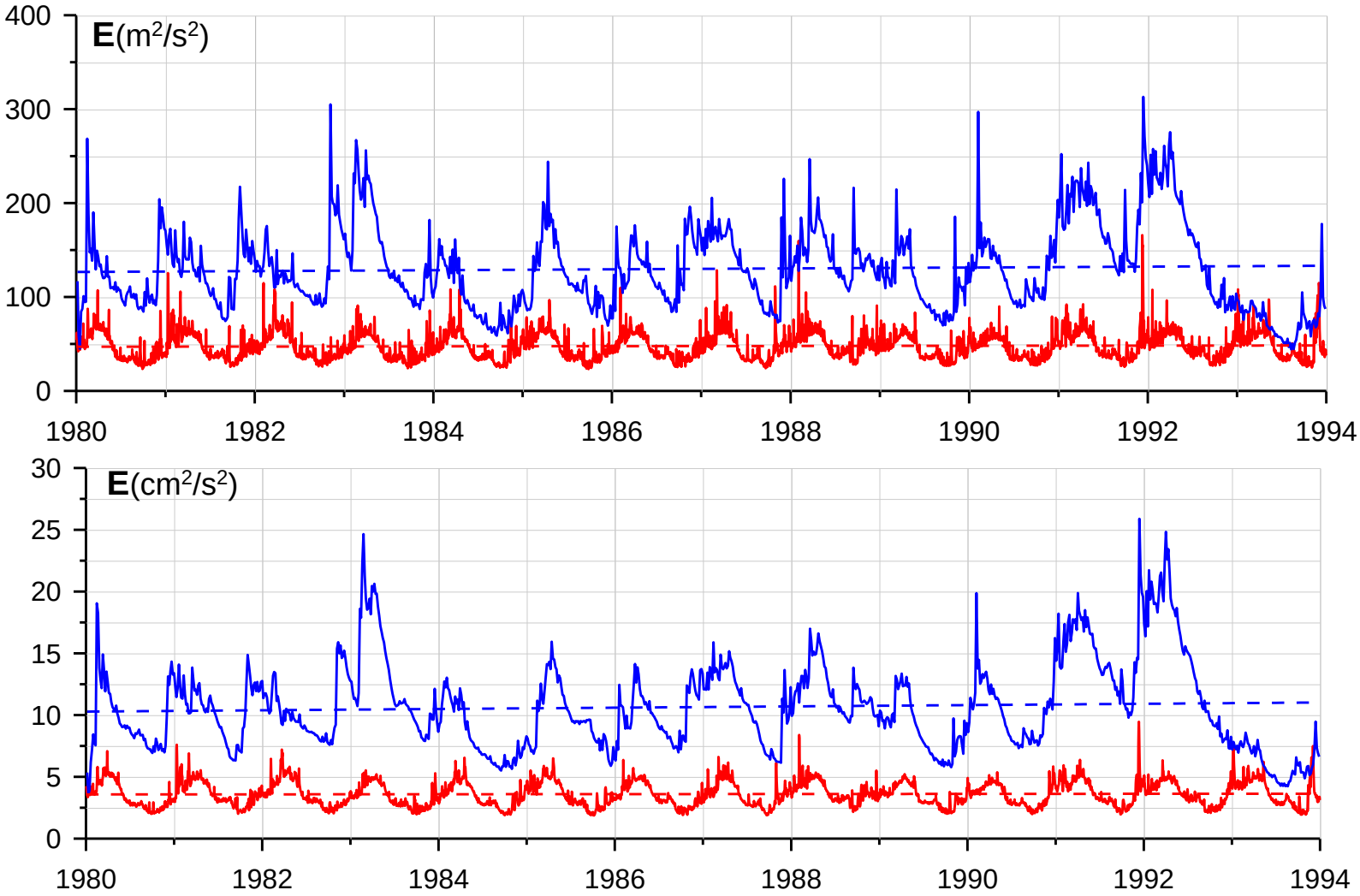
Surface salinity distribution

(Climate based on 14 year data sets)



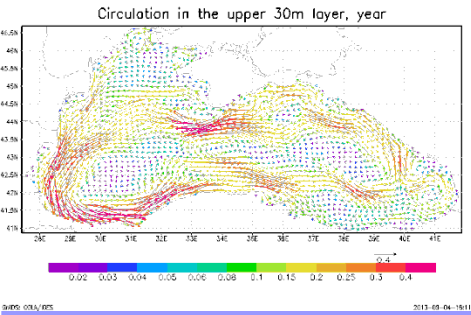
winter **spring** **summer** **autumn**

Currents

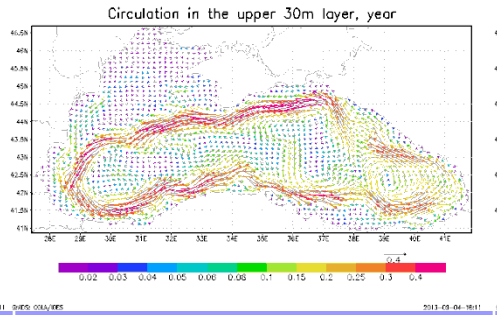


Mean kinetic energy in the upper 30m layer (upper) and total volume (lower)

Current snapshots



19.01.1986



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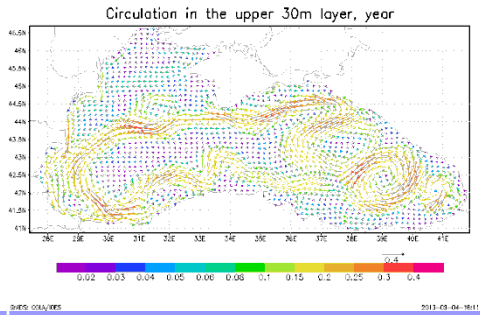

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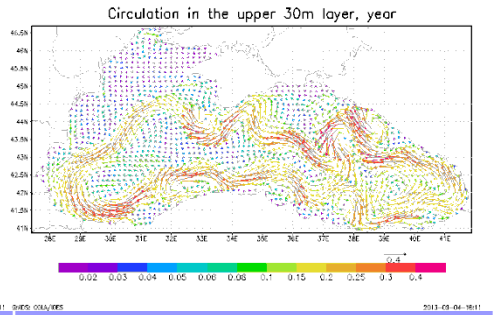

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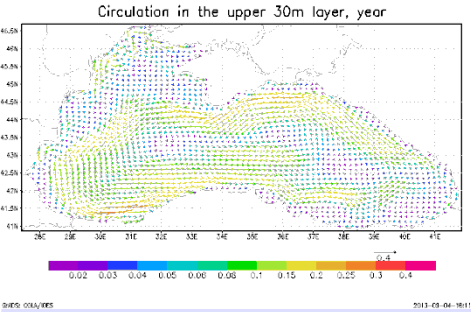
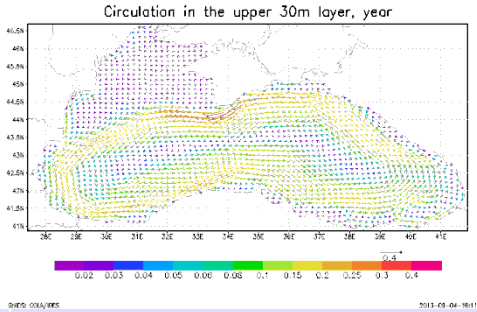
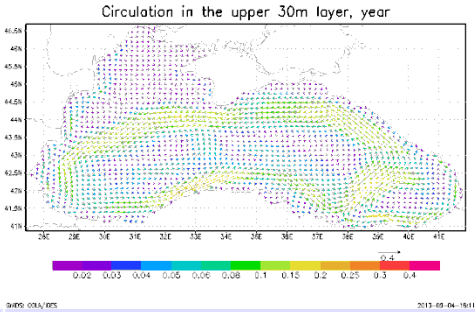
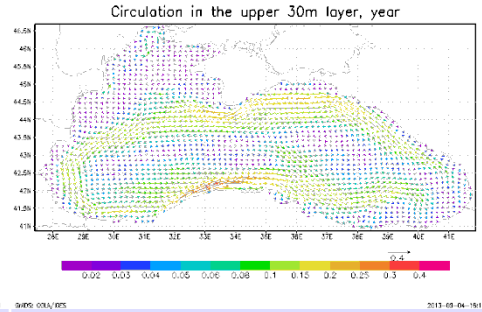
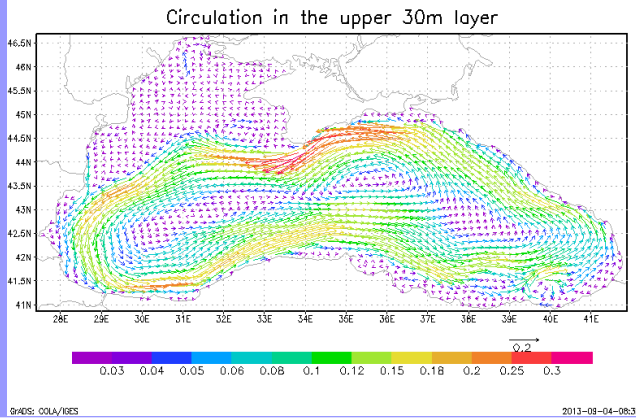


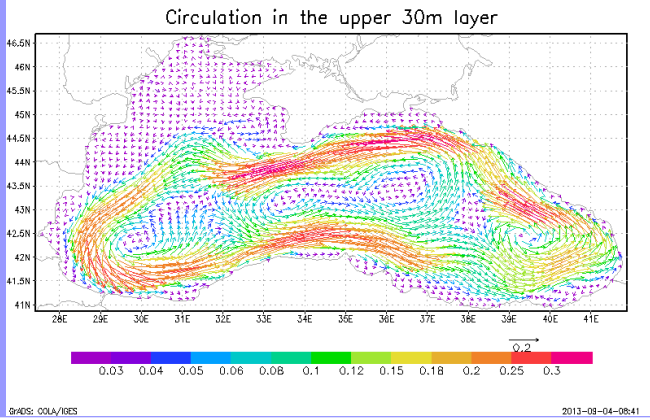


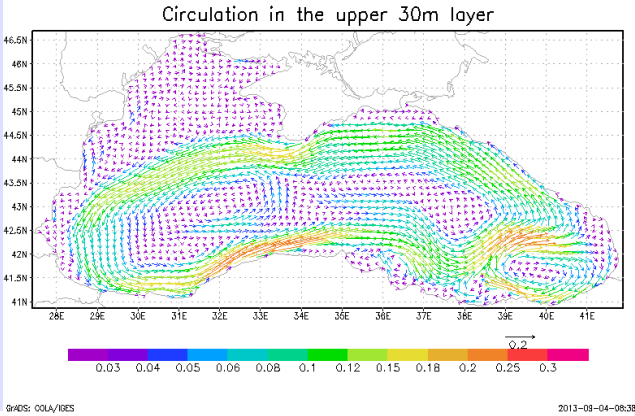


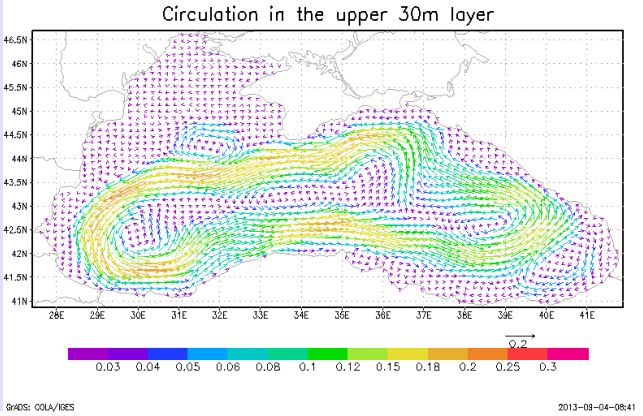


Climatic currents in the upper 30m layer



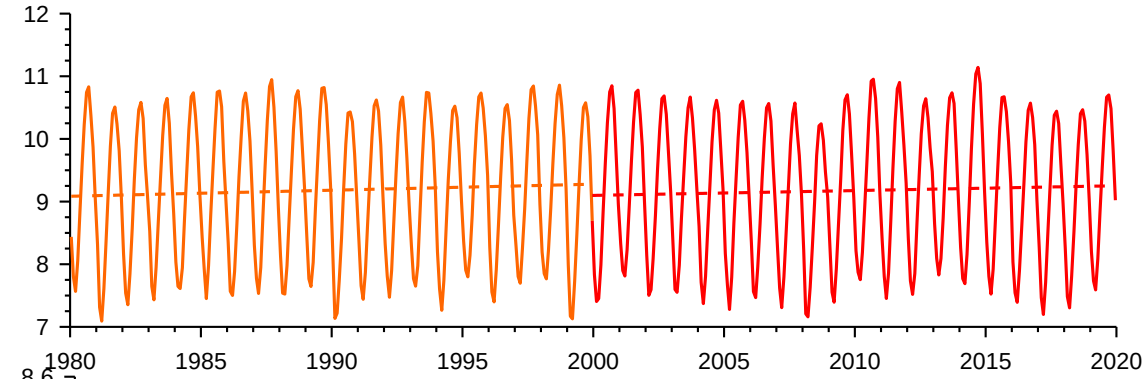




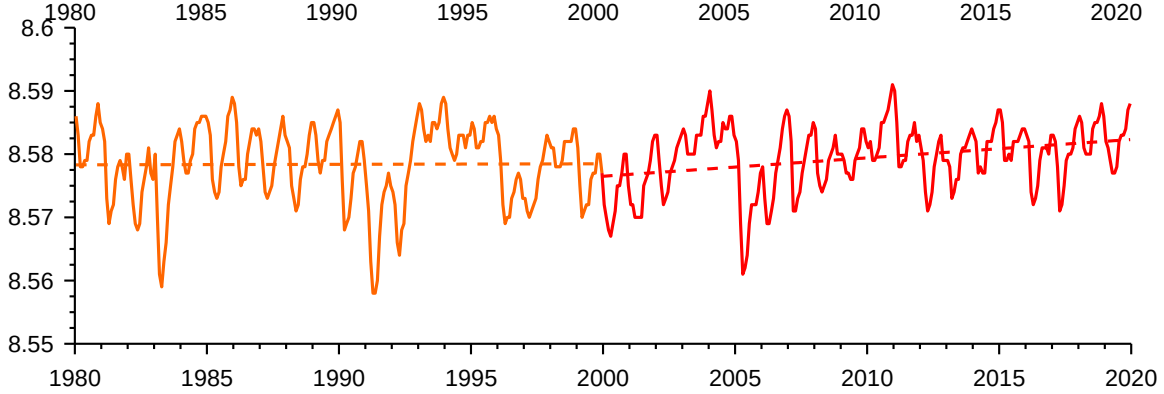


Reanalysis **Hindcast**

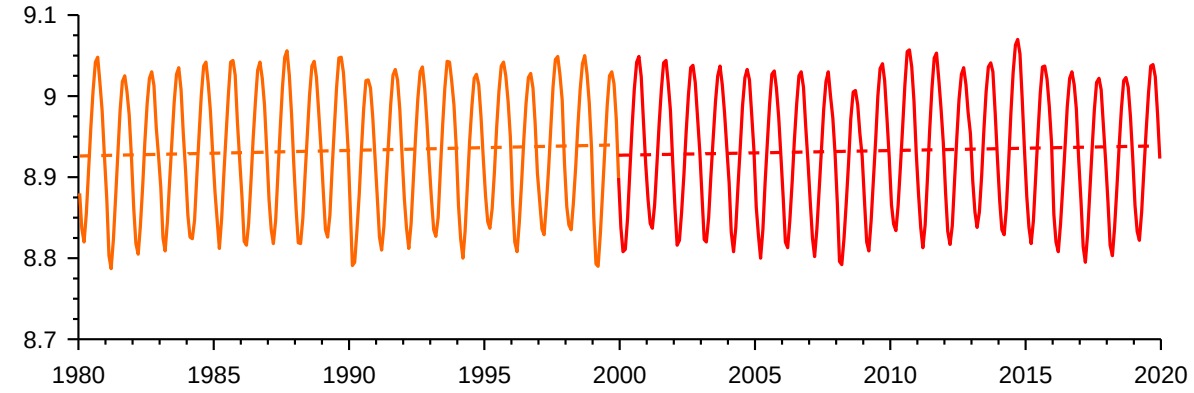
Long-term evolution of the basin-averaged temperature in different layers



0-100m

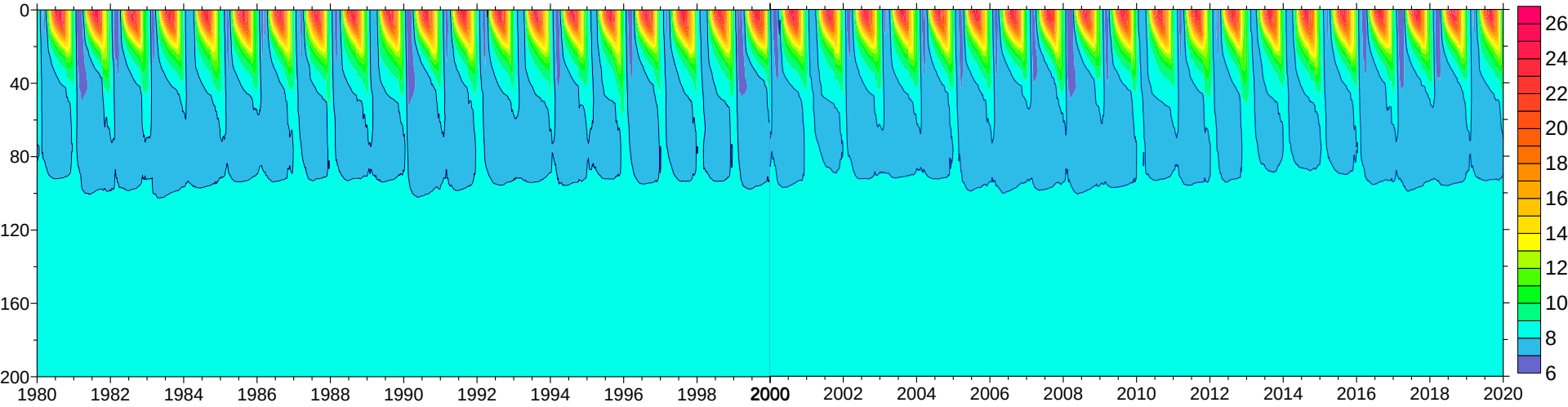


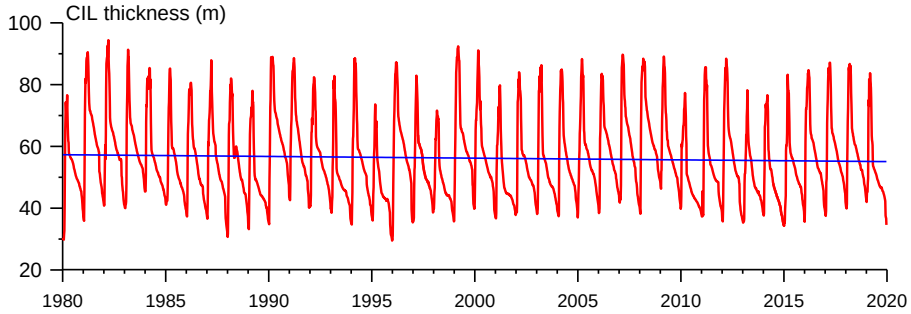
100-300m

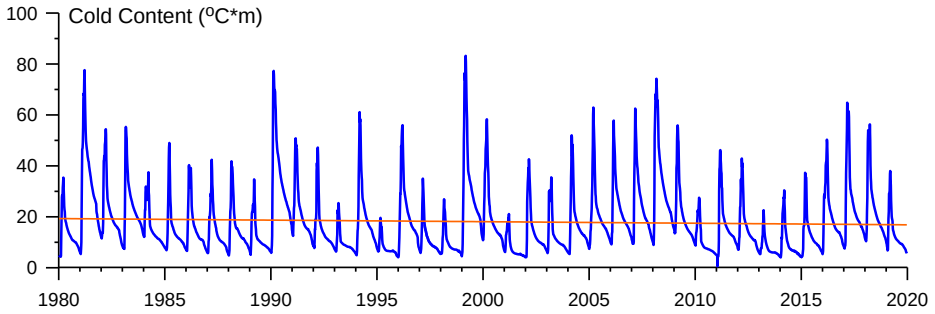


Total volume

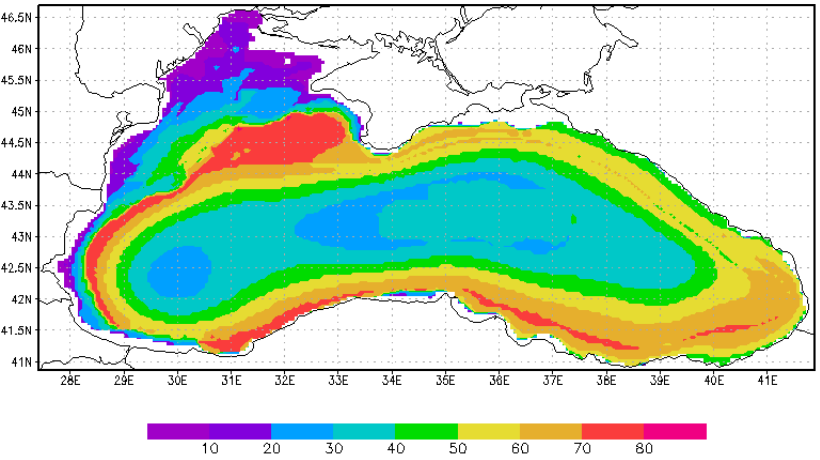
Subsurface indication of warming

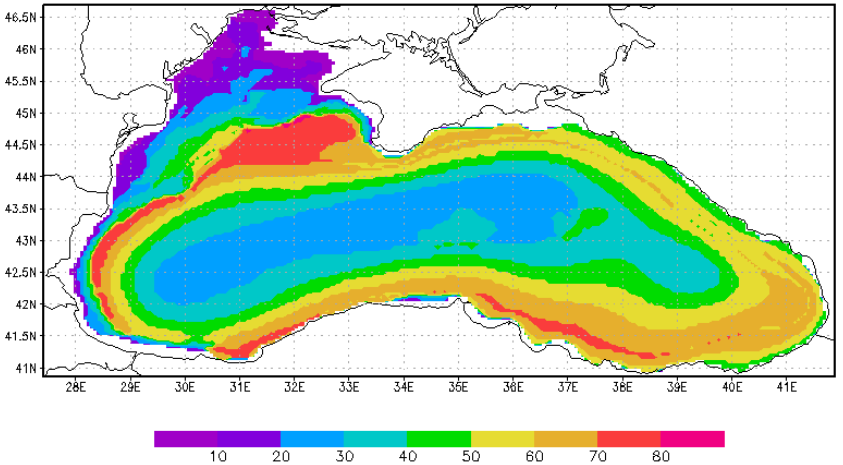


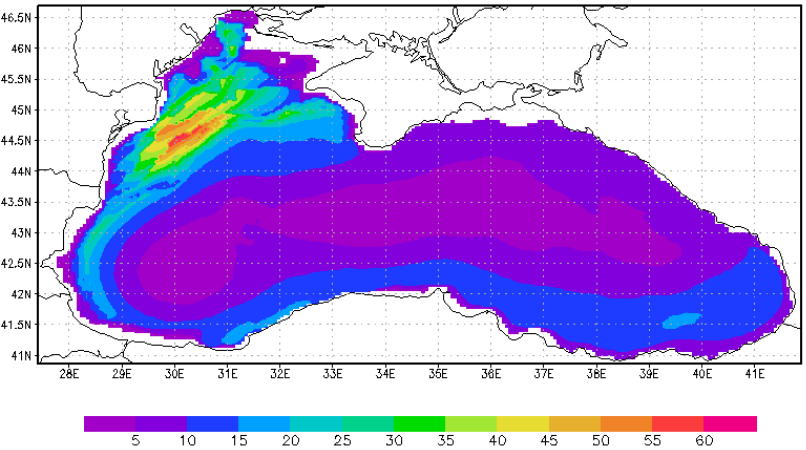


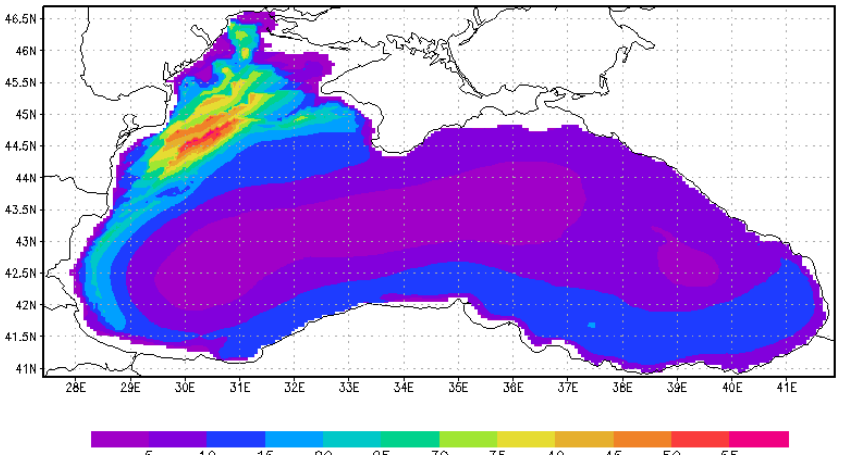


Mean CIL thickness and cold content





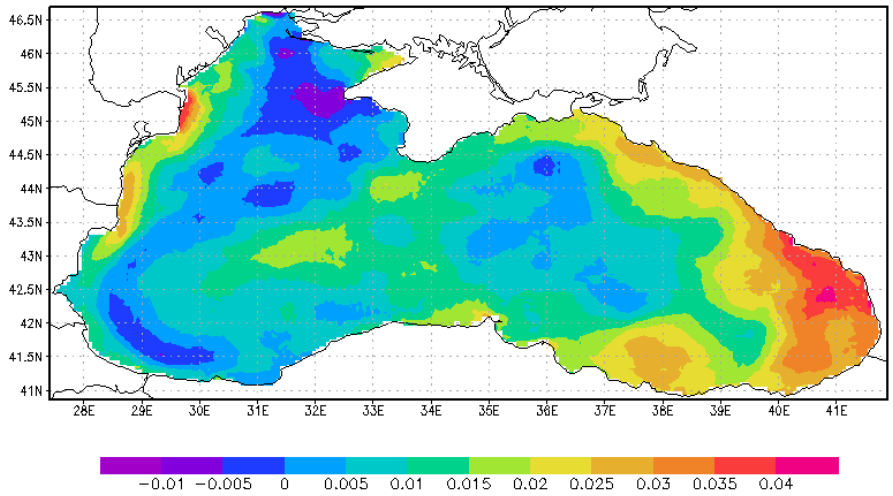




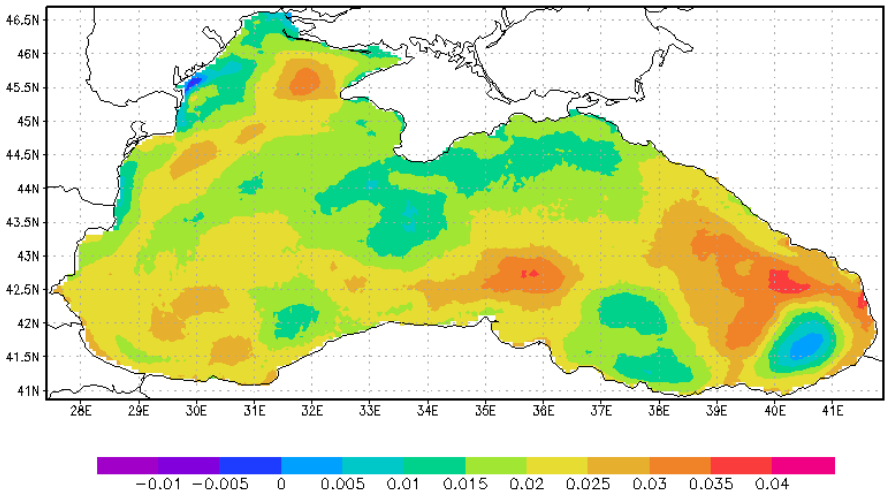
1980 – 2000

2000 – 2020

Temperature trend maps

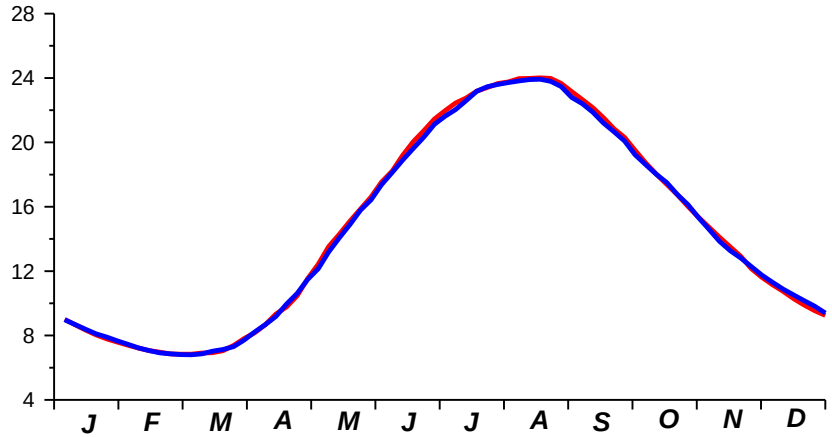


1980 – 2000



2000 – 2020

Temperature season cycles for two time periods
(red line corresponds to 1980-2000, blue – 2000-2020)



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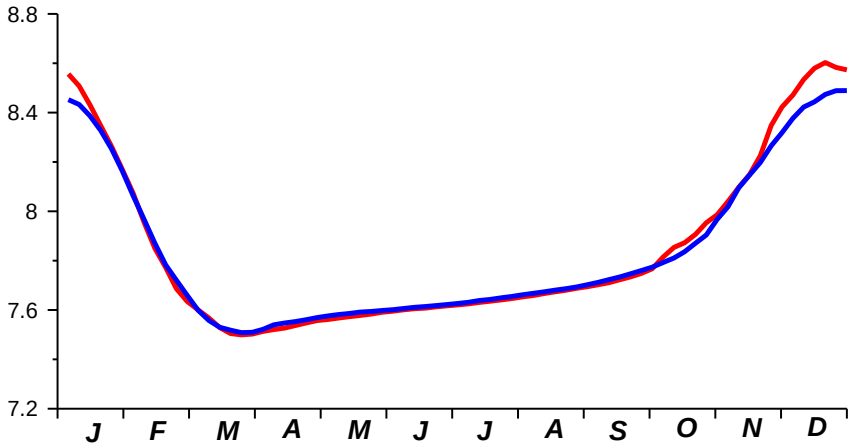

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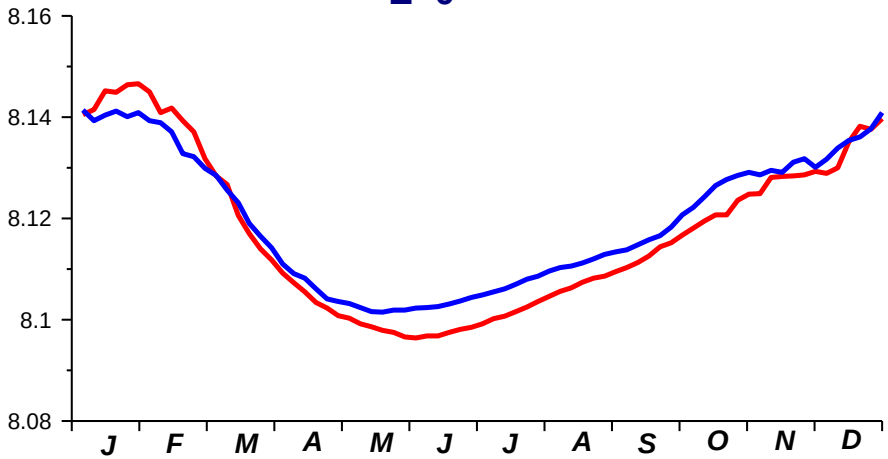

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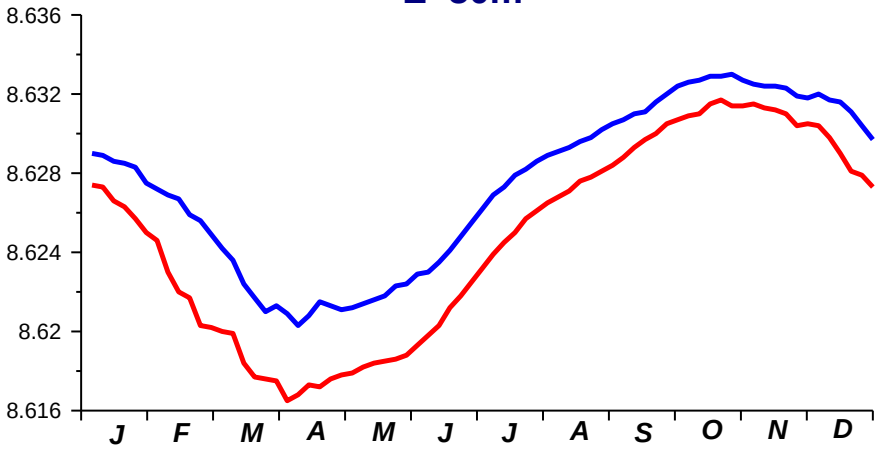
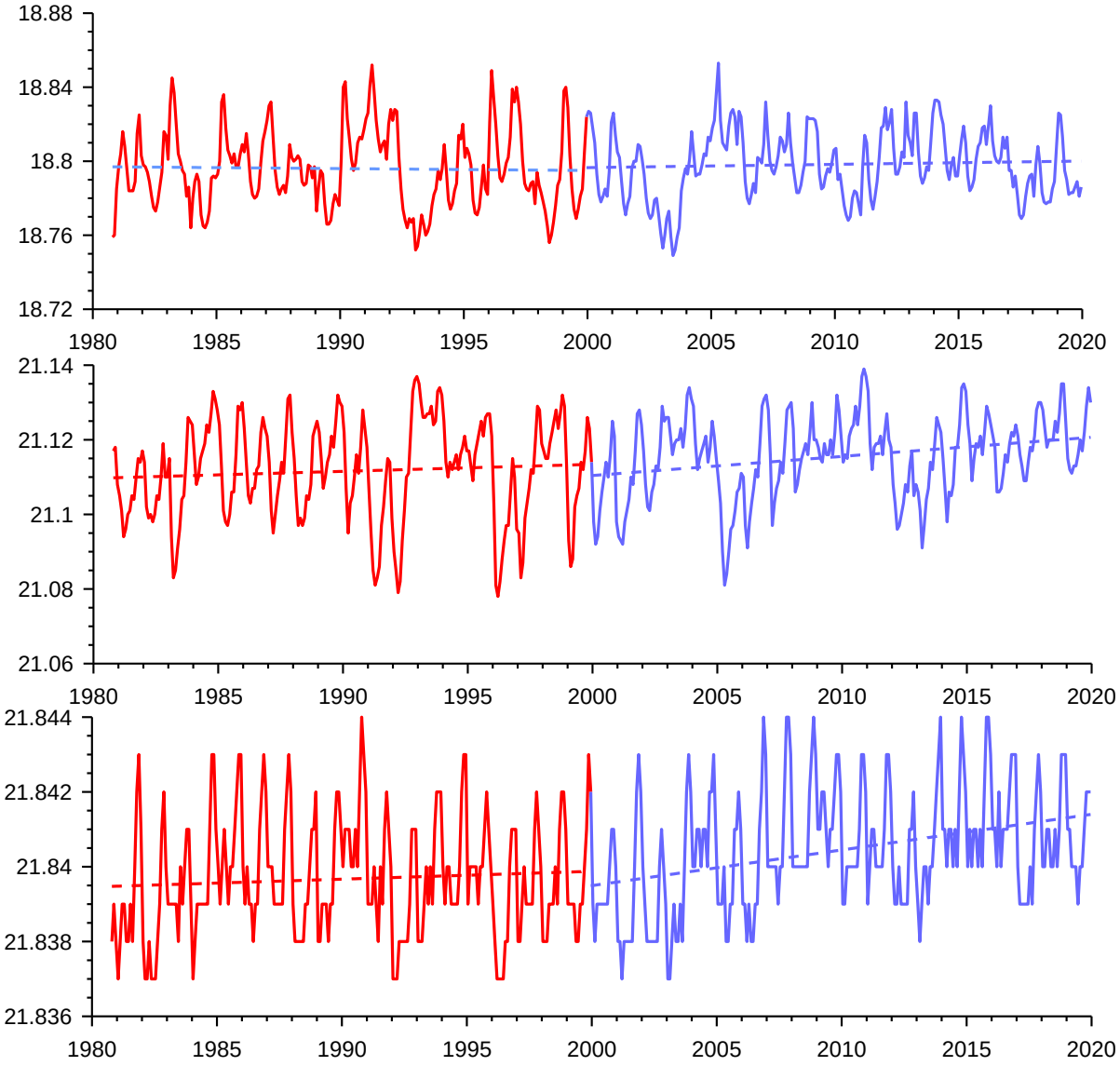


Z=200m

Long-term evolution of the basin-averaged salinity in different layers

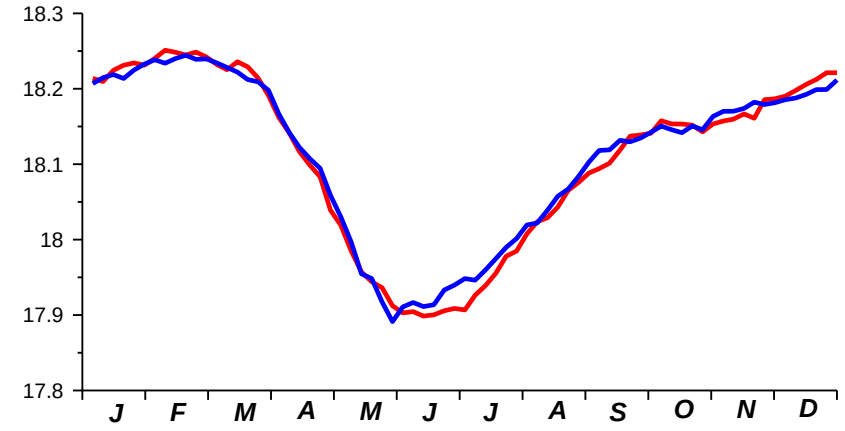


0-100m

100-300m

Total volume

Salinity season cycles for two time periods
(red line corresponds to 1980-2000, blue – 2000-2020)



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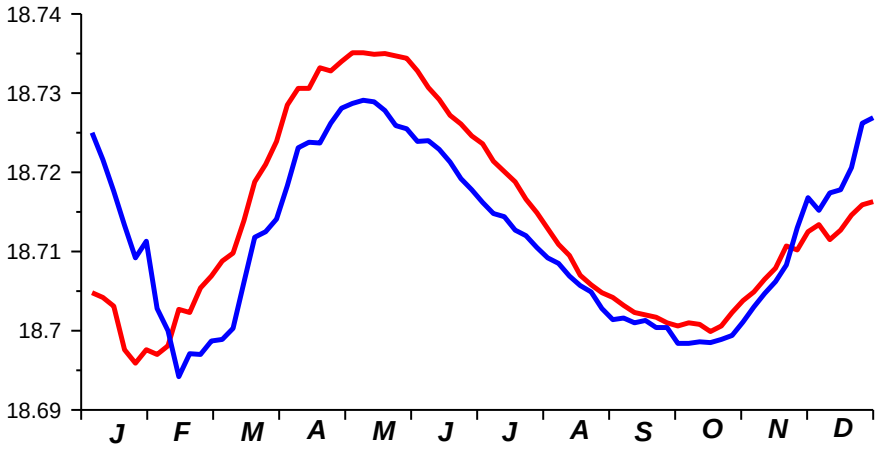

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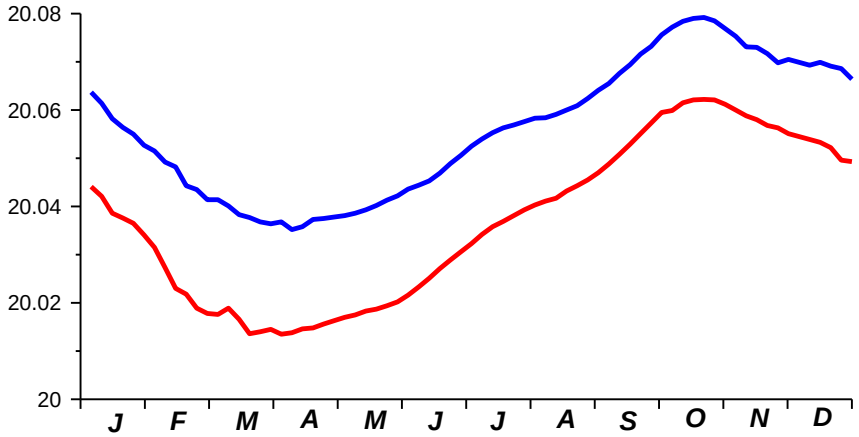

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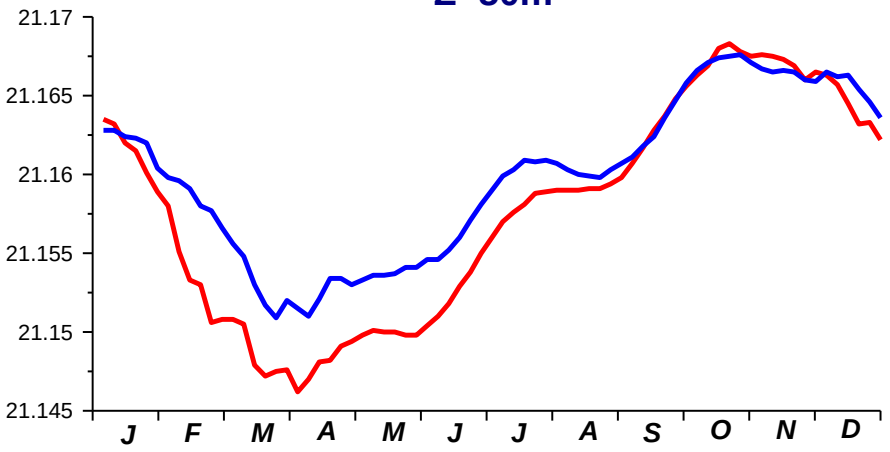
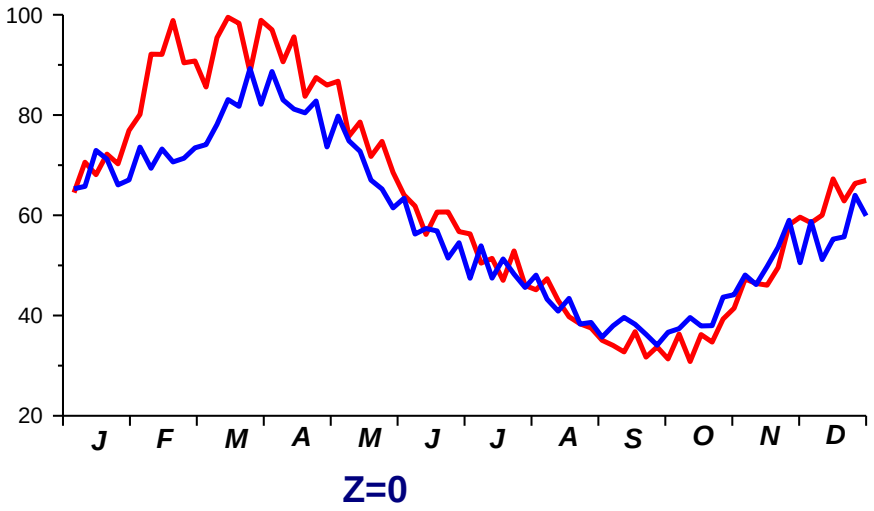


Z=200m

Kinetic energy season cycles for two time periods (cm^2/s^2)

(red line corresponds to 1980-2000, blue – 2000-2020)



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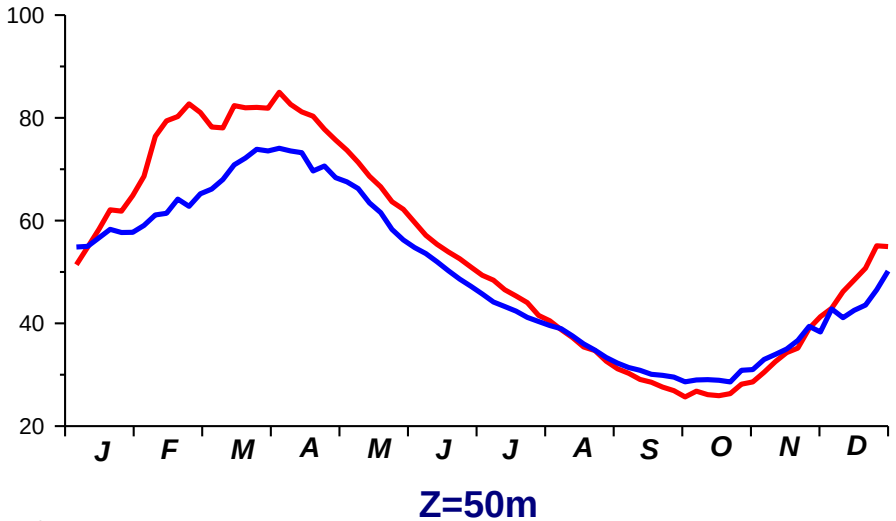

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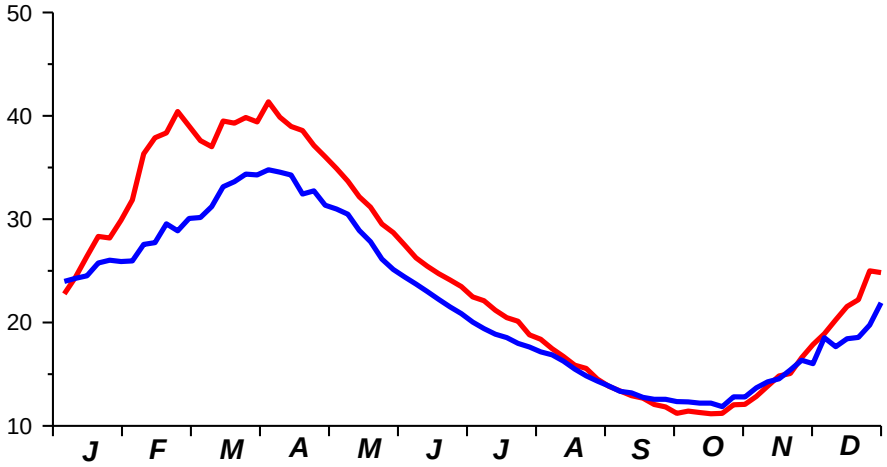

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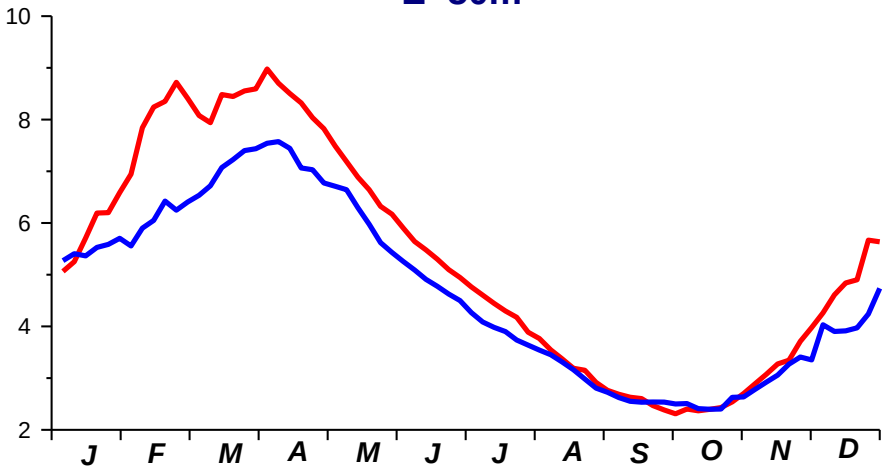

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Summary and conclusions

- *The circulation model has been applied to investigate a long-term evolution of the Black Sea dynamics, driving by COSMO-CLM atmospheric forcing. The work included as present day simulation (1980 – 2012) and a future projection (2013 – 2020).*

- *Results of simulation were compared with hydrographical fields which were obtained in Black Sea physical reanalysis (1971 – 1993). This comparison showed, that extreme values of temperature in the upper layer during seasonal cycle (winter and summer) are underestimated in hindcast results as compared with reanalysis. Hindcast salinity in the upper layer is generally larger. On the other hand current fields are described in results of modelling more realistic as the include mesoscale variability.*

- *Analysis of four decade evolution demonstrated warming of the Black Sea surface waters and growth of its salinity. In general the model describes evolution of the Black Sea dynamics (seasonal and long-term) sufficiently well.*

- *Physical fields obtained as results of the simulation can be used as input parameters in low trophic level model of the Black Sea ecosystem.*