Inter-annual variability of exchange processes at the outer Black Sea shelf

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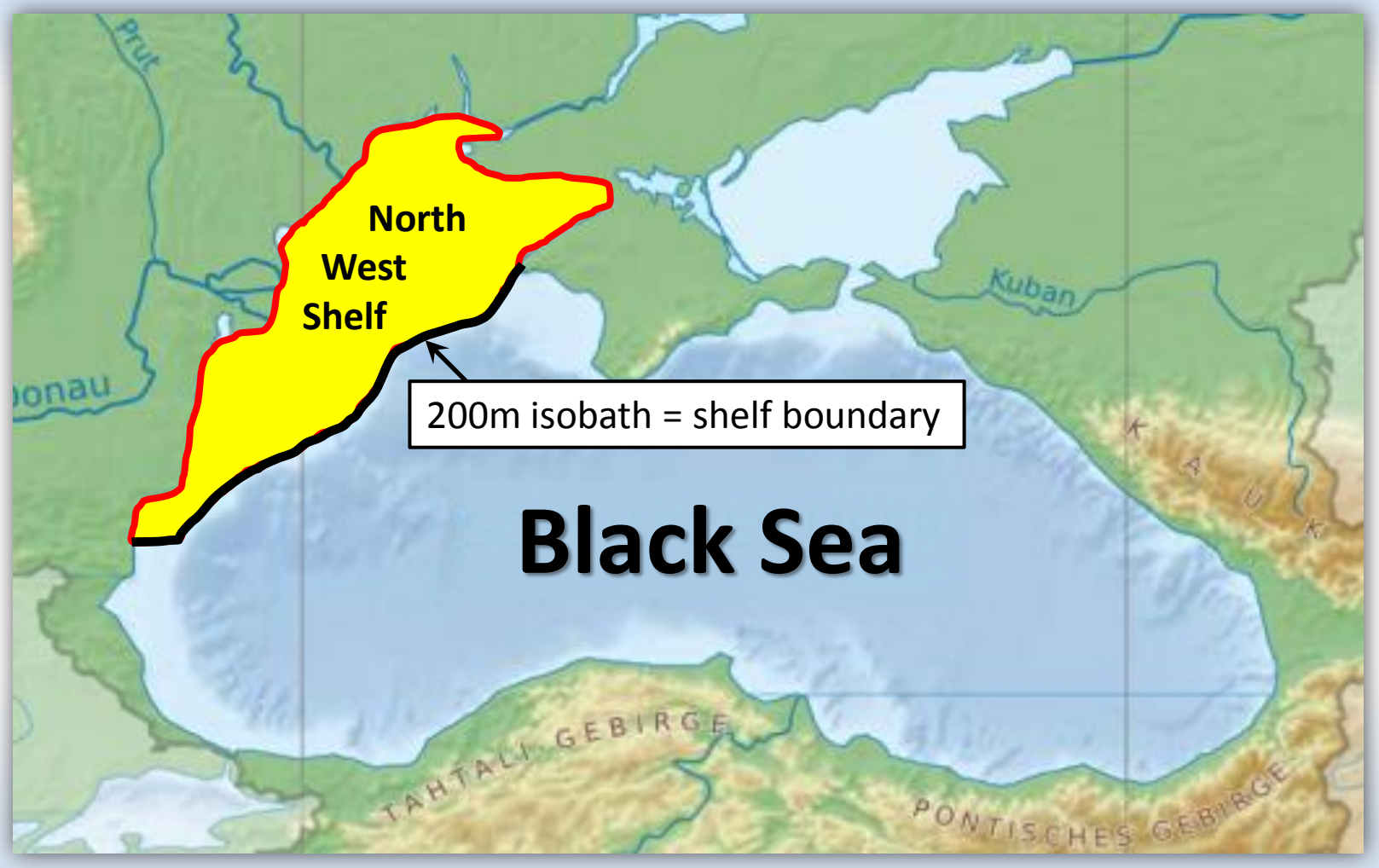
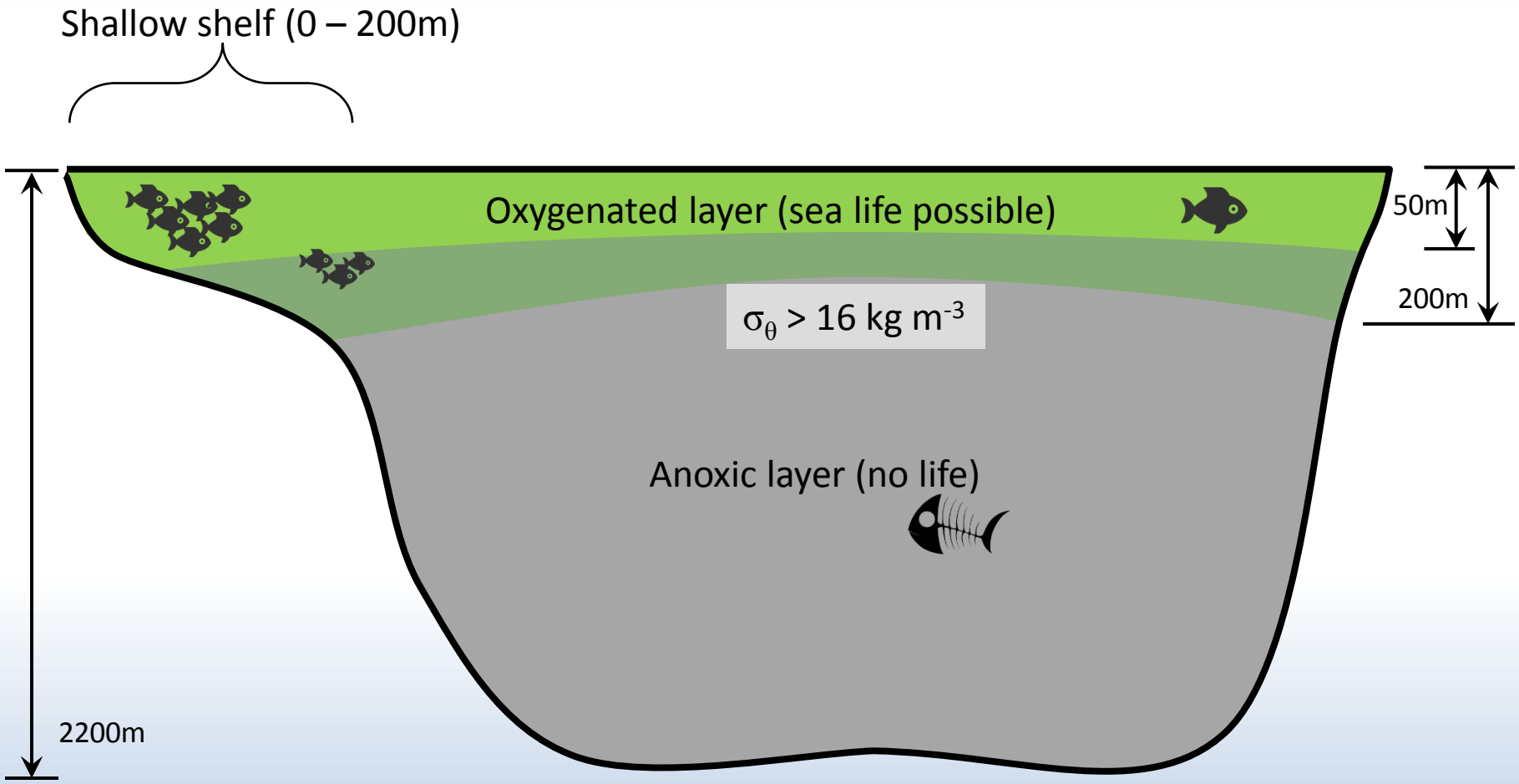
Black sea catchment map by Tentotwo (wikipedia)

Black Sea Shelf

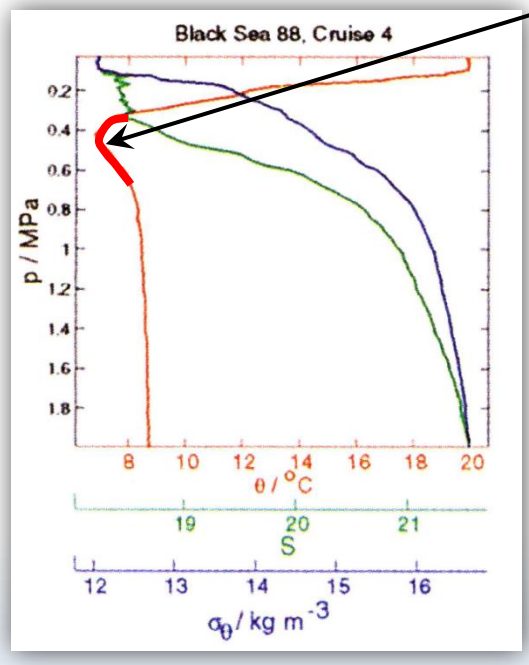


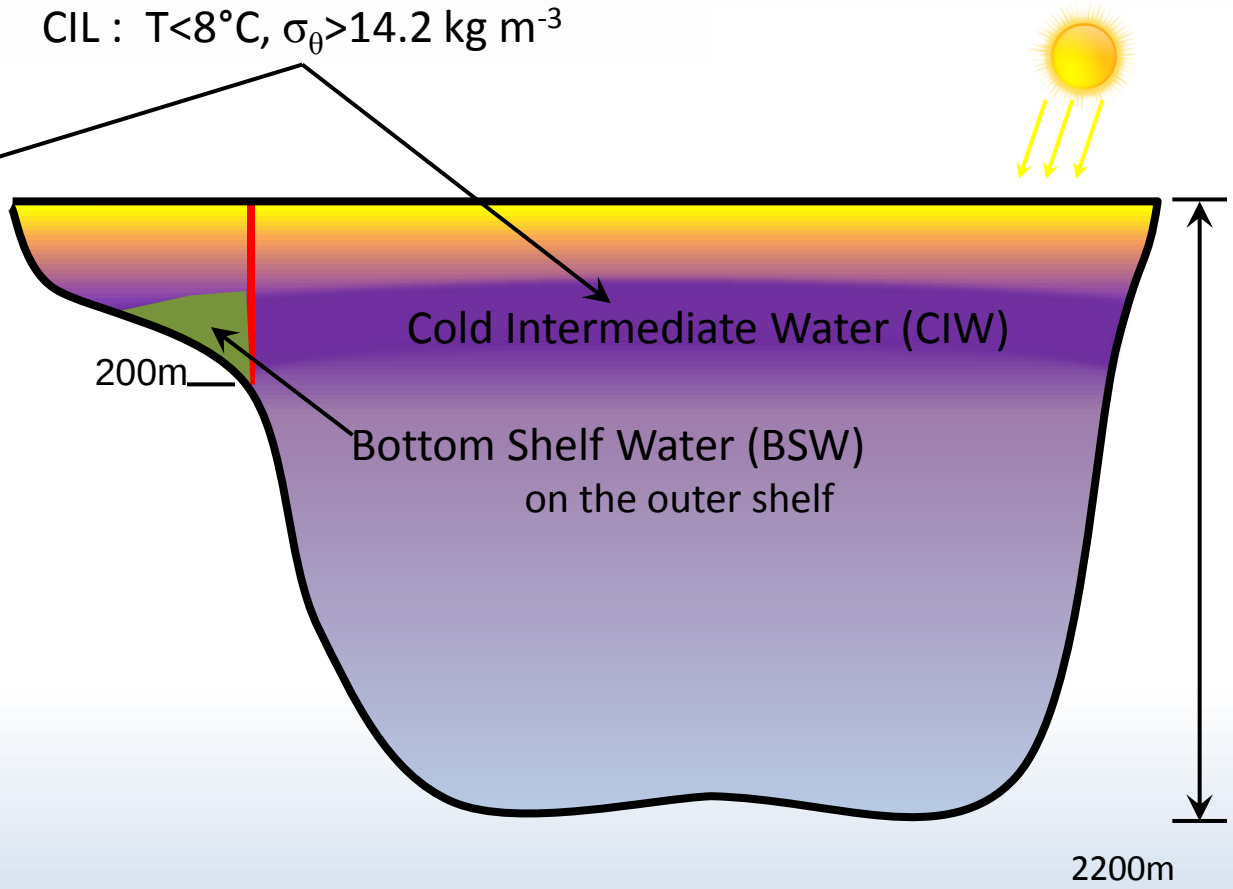
Black Sea Water column



Cold Intermediate Layer

CIL : T<8°C, σ_θ>14.2 kg m^{-3}

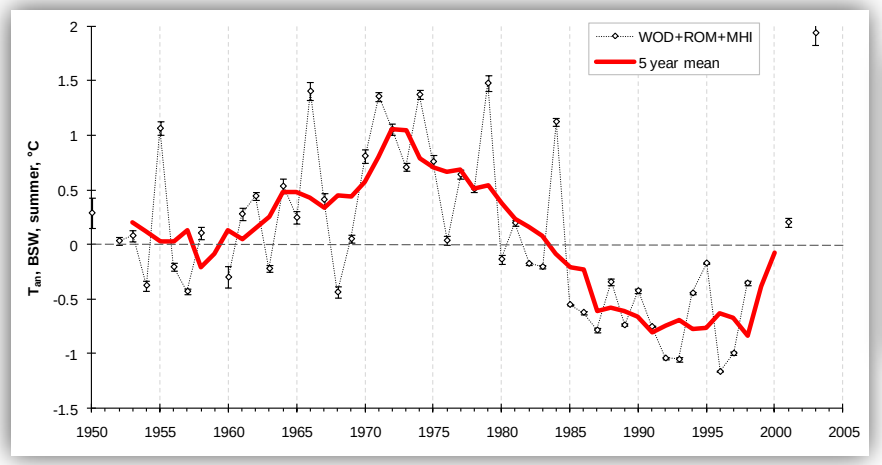


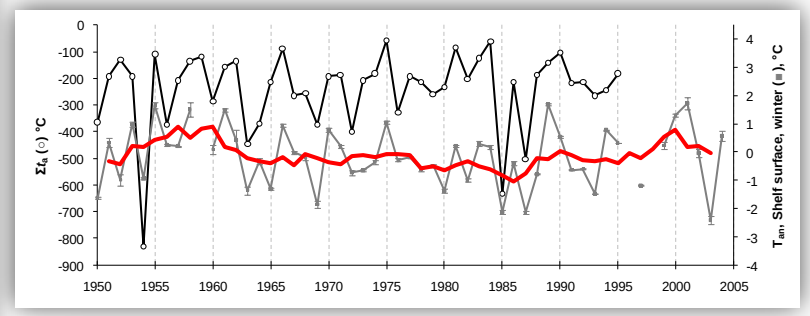


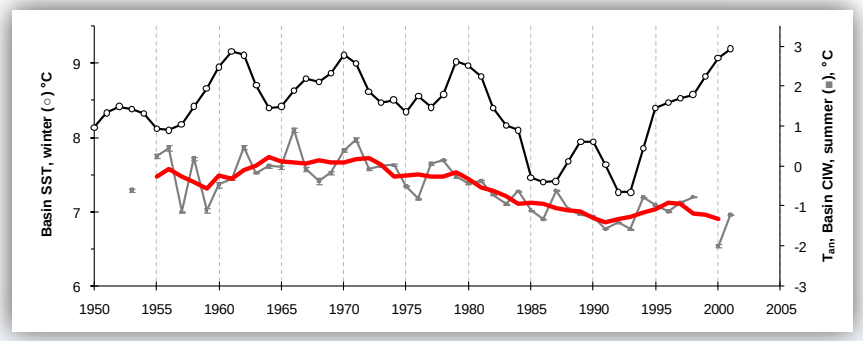
Gregg & Özsoy (1999) GRL **26**(13) 1869-1872

Shapiro *et al.* (2011)

"Seasonal and inter-annual temperature variability in the bottom waters over the western Black Sea shelf"





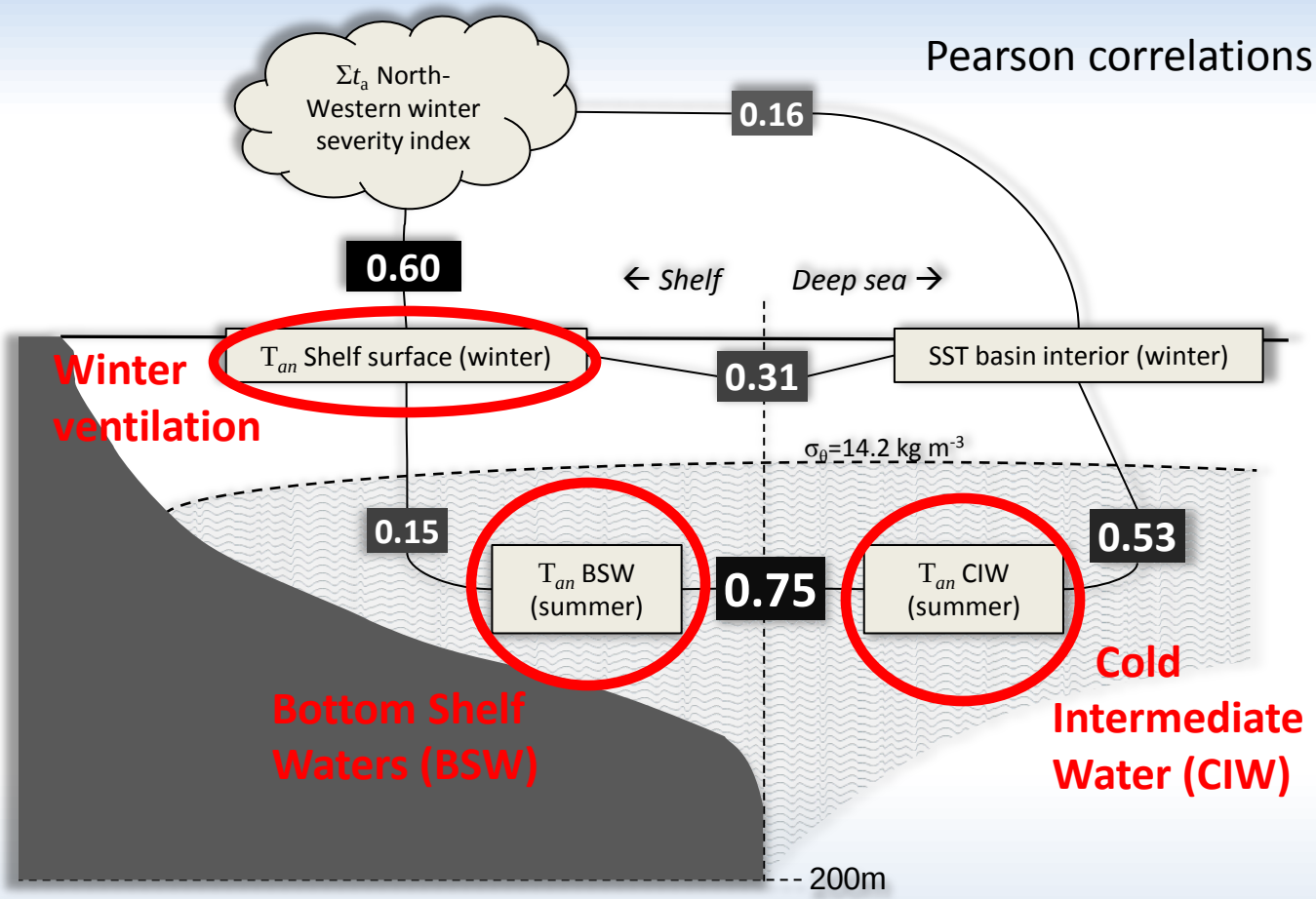


Long-term time series of temperature anomalies of 4 different water masses and atmospheric parameters

Extracted from **38726** stations (1950–2004)

Shapiro *et al.* (2011) *Ocean Science*, **7**, 585–596

Time series correlations



Shelf-deep sea exchanges are more important for ventilation of the bottom shelf waters than winter convection on the shelf

Shapiro *et al.* (2011) *Ocean Science*, **7**, 585–596

Model study

- BLS12 model based on NEMO v3.2

  $^{1}/_{12}$° resolution (≈6.5km), 170×92, 33 levels
- 34 model runs, each 1 year for 1979-2012
- Atmospheric forcing specific to each year

  ≈ 1 month to fully adjust to forcing
- Identical initial conditions (climate for 1 Jan)
- Simulated river inflow and Bosphorus outflow

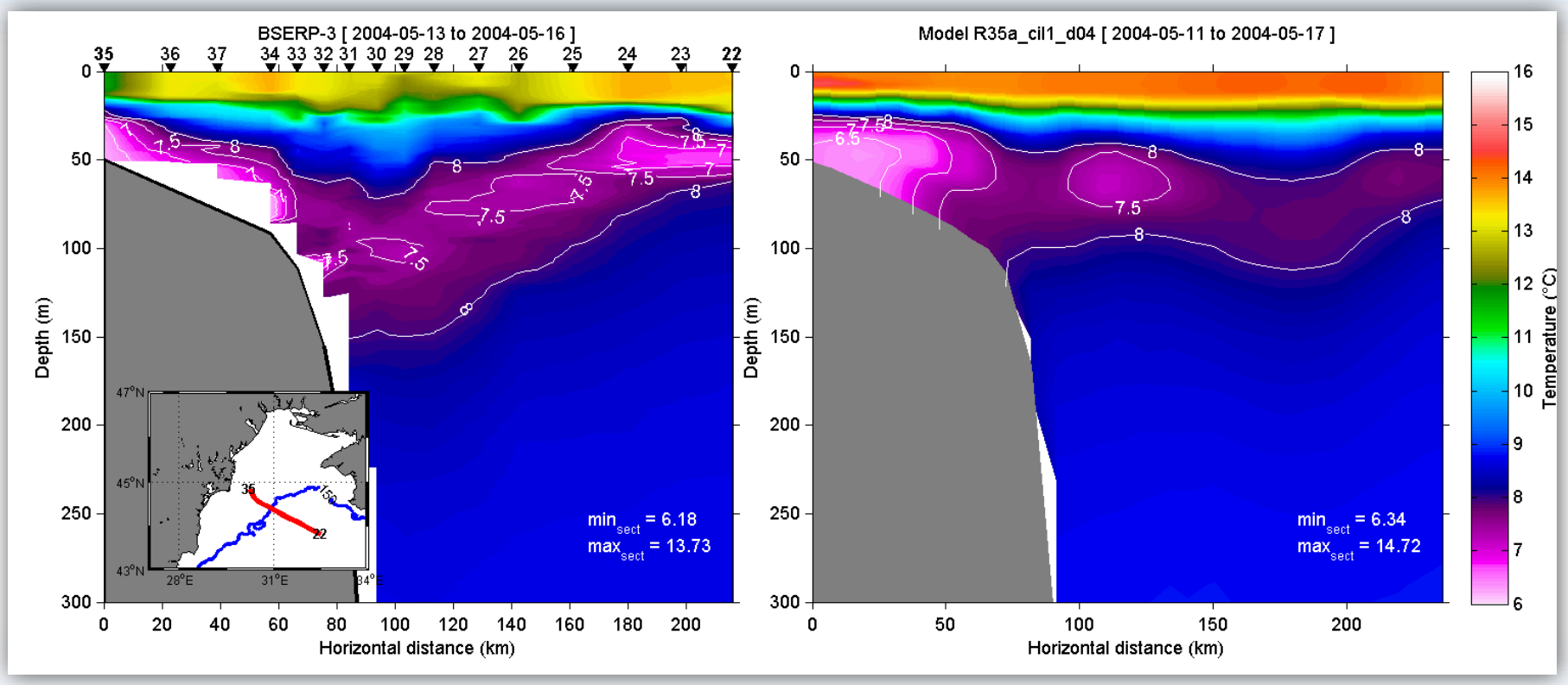
Aim

Using a 3D ocean circulation model:

- quantify the exchange of Cold Intermediate Water (CIW) between the open sea and the outer northwest Black Sea shelf

- assess its significance for the replenishment of Bottom Shelf Waters (BSW) on the outer shelf

Model validation



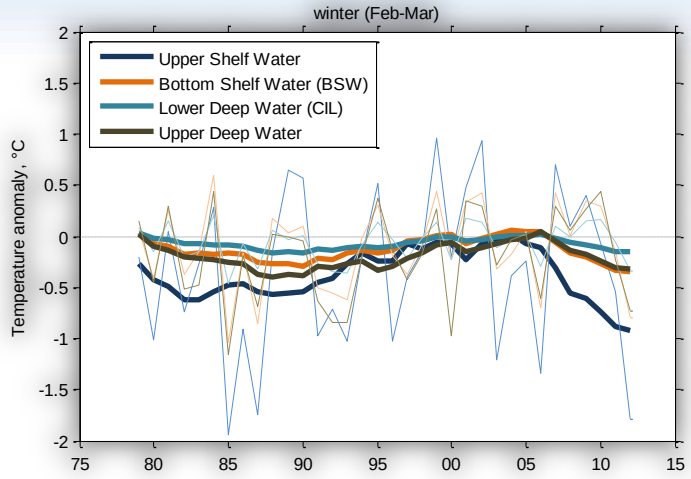
CTD observations

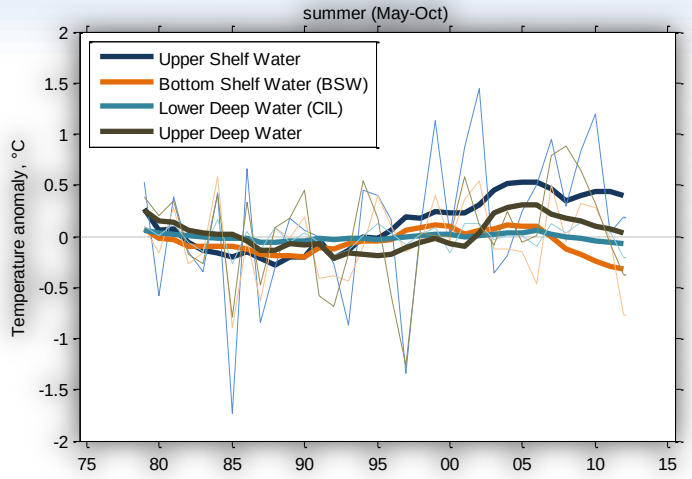
BSERP-3 cruise (2004)

Model

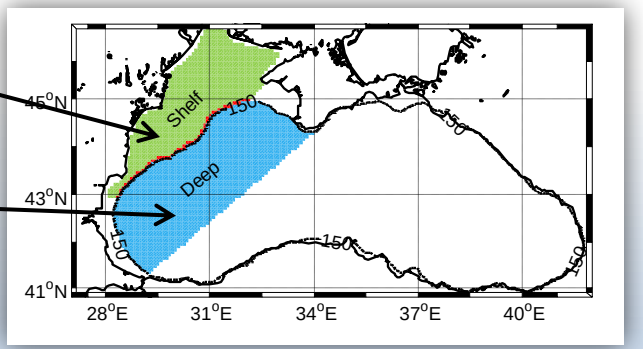
weekly mean

Time series of anomalies

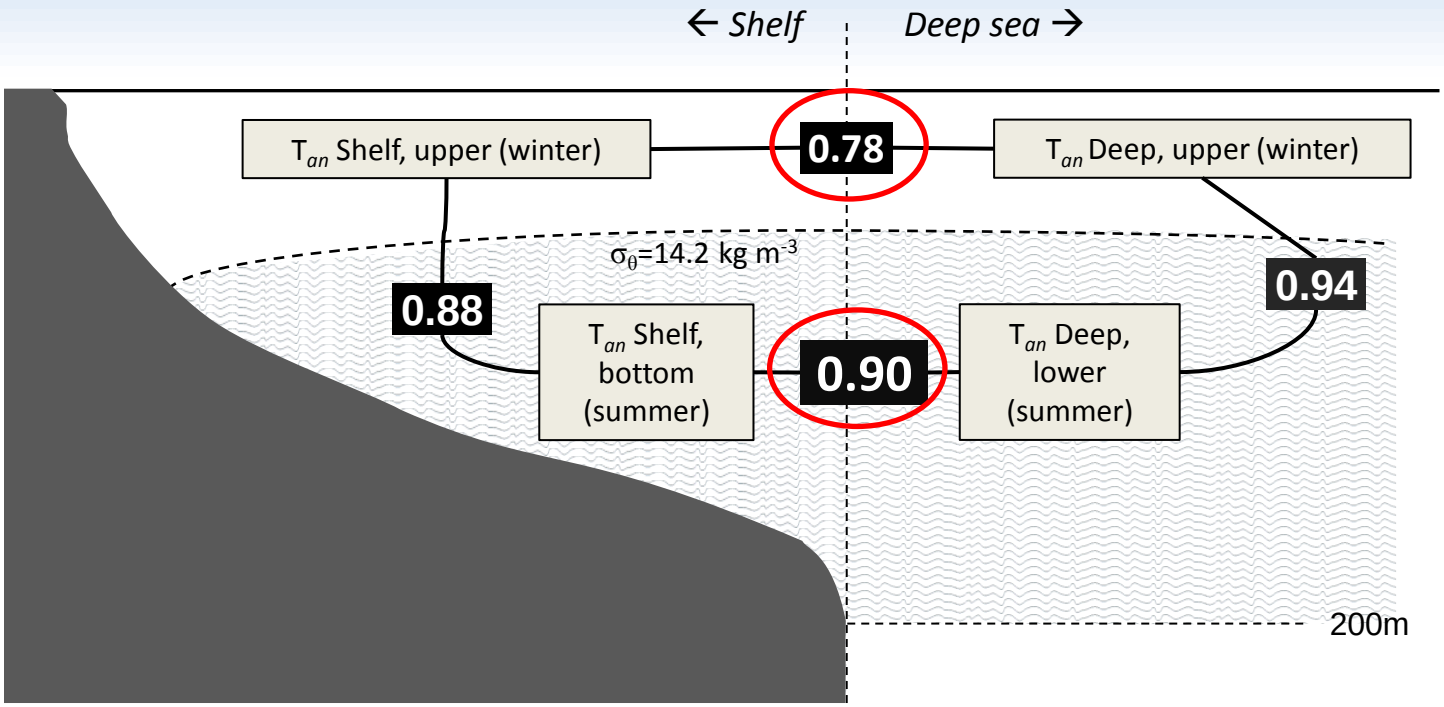




- Temperature anomaly time series from model data (34 years)
  - Bottom Shelf Water (BSW)
  - Upper Shelf Water
  - Lower Deep Water (CIL)
  - Upper Deep Water

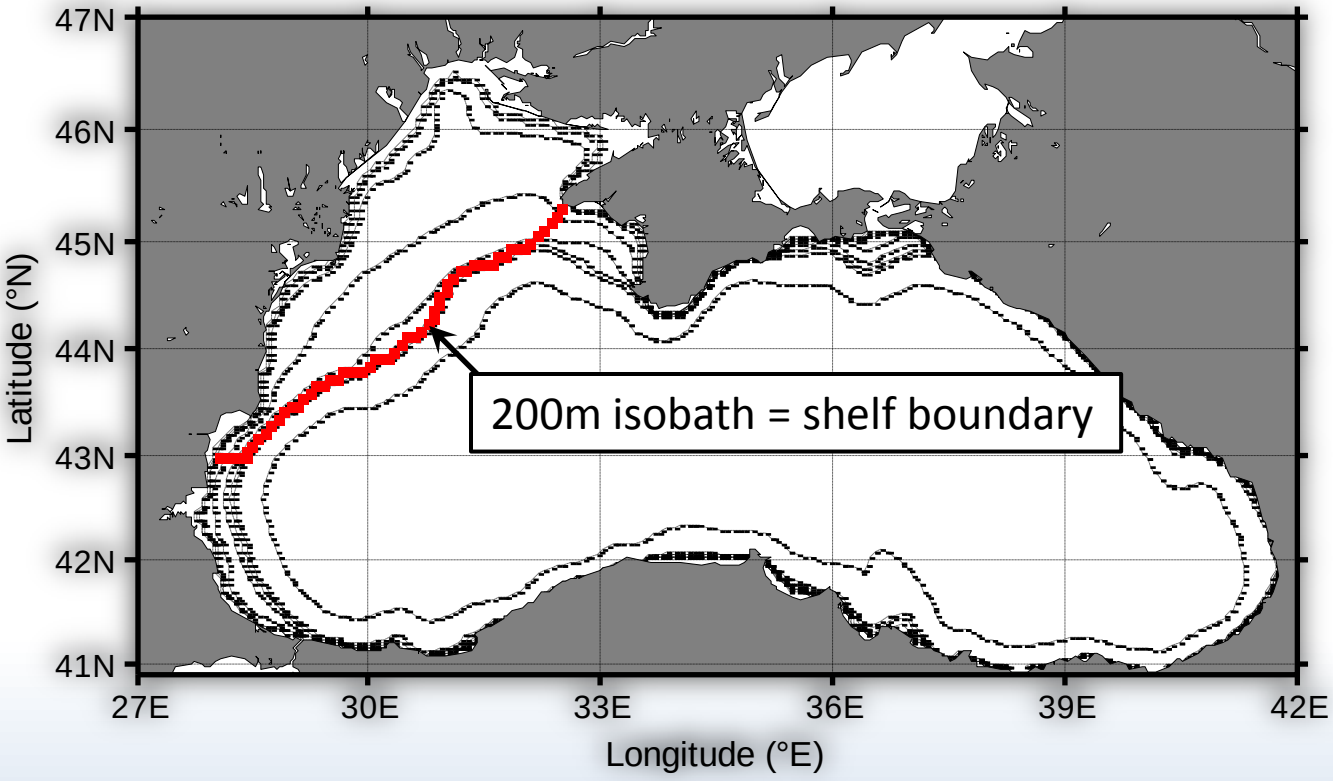


Correlations from model data

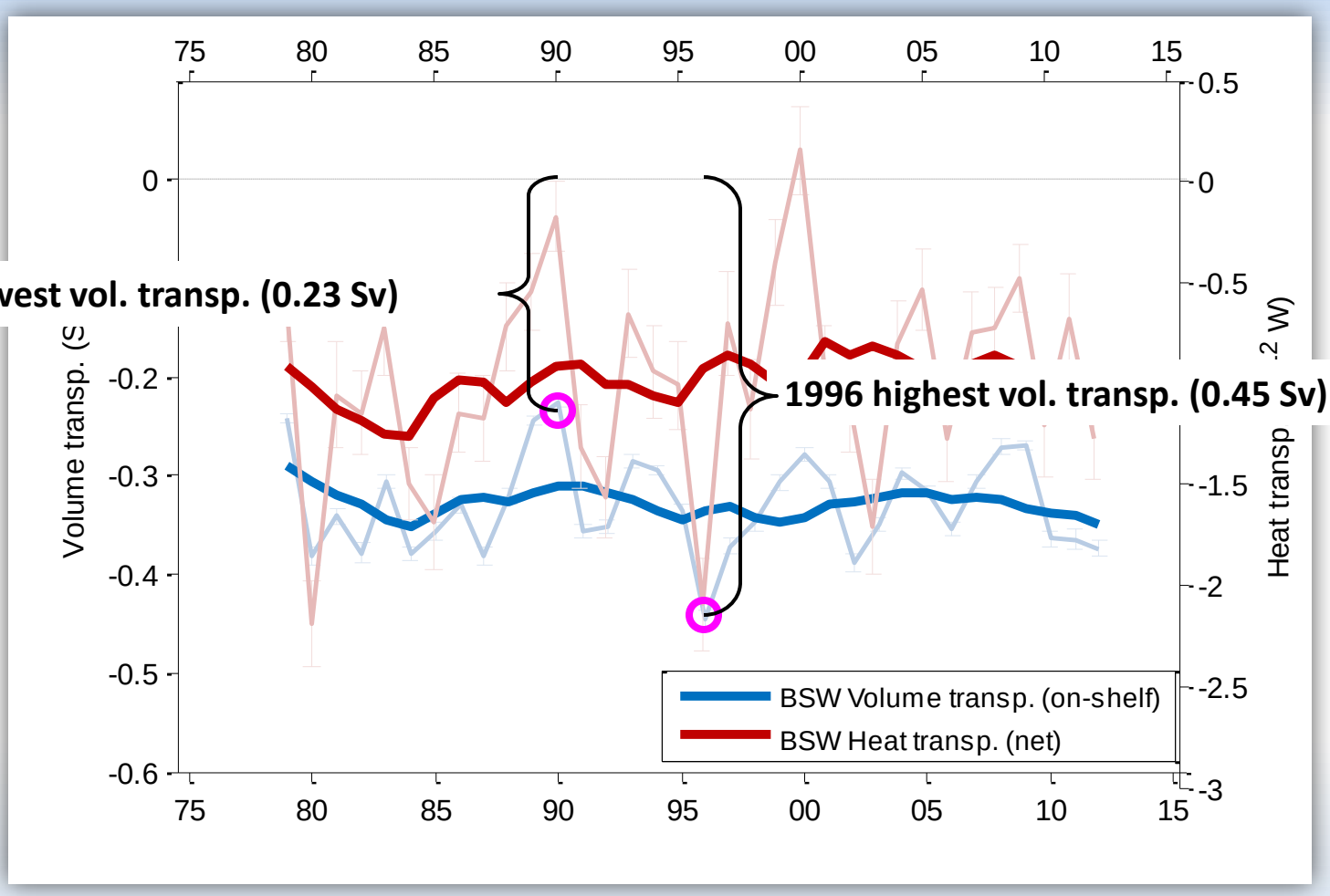


- Agreement with Shapiro *et al.* (2011)
- **Again, sub-pycnocline exchanges between shelf and deep sea are statistically more significant for ventilation of bottom waters on the outer shelf than convection in the previous winter**

Cross-shelf break exchanges



Cross-shelf break exchanges



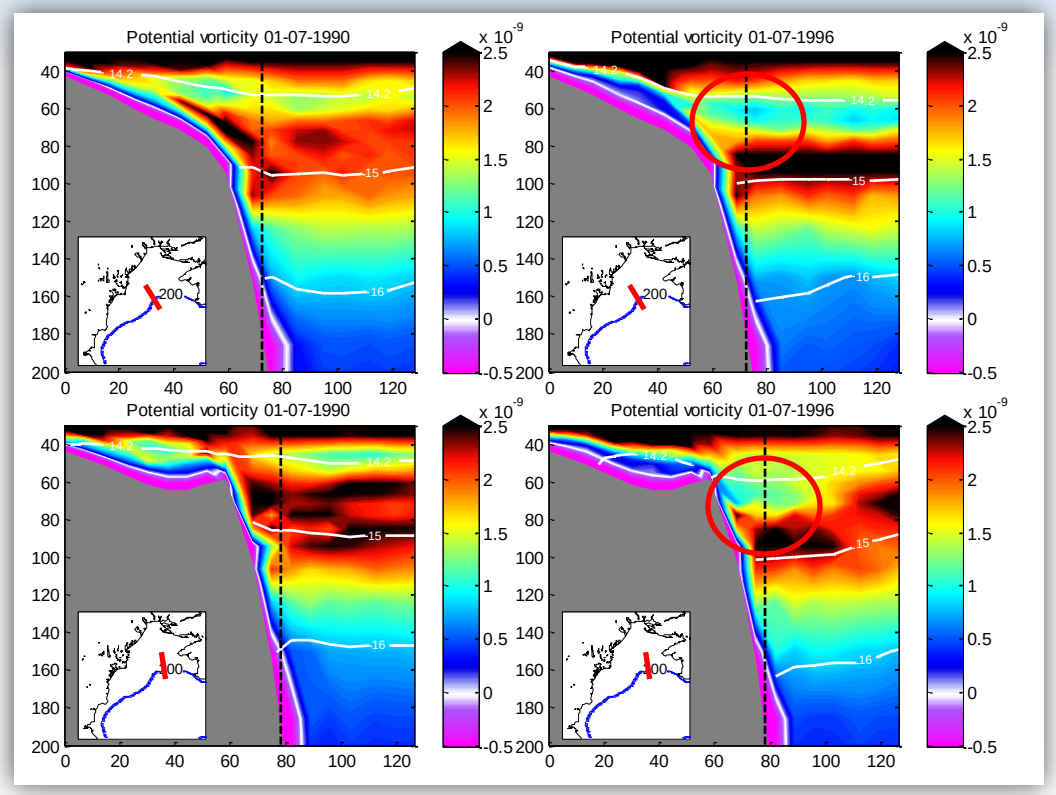
Shelf is generally colder than the deep basin

→ on-shelf transport brings warmer water from basin onto shelf

Potential vorticity

$$\mathrm{PV} = \frac{1}{\rho}\left(\frac{dv}{dx} - \frac{du}{dy} + f\right)\frac{d\sigma_\theta}{dz}$$

Low volume transport



High volume transport

Gradient in potential vorticity at shelf break → **barrier to exchanges** *(low volume transport)*

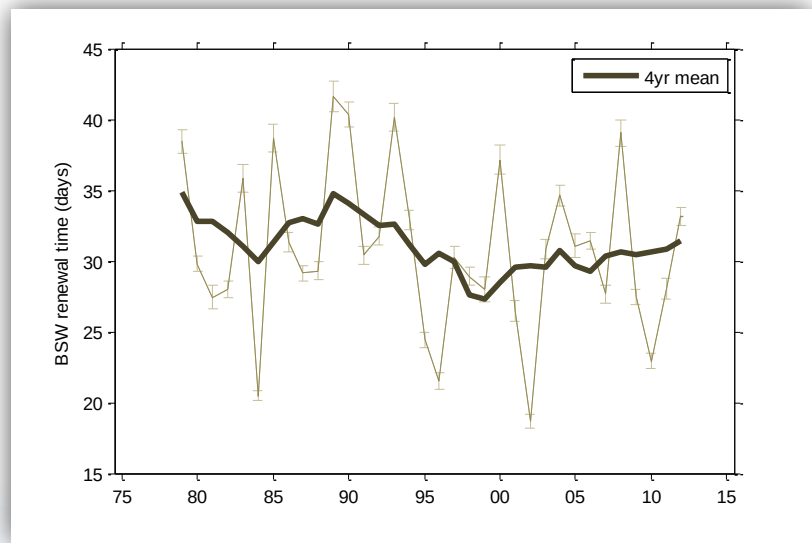
Channel of constant potential vorticity across shelf break → **conduit for exchanges** *(high volume transport)*

Conclusions

- on-shelf volume transport of CIW varies from 0.23 Sv (in 1990) → 0.45 Sv (in 1996)
- In years with high values of volume transport
  - a ‘channel’ of constant PV connects BSW and CIL
  - conduit for waters to move across the shelf break
- In the years of reduced transport
  - a PV ‘barrier’, i.e. a band of significant PV gradient along the shelf break, so exchanges are inhibited

Open question

- Renewal time of BSW is **31 days** on average
- During the warm season there appears to be efficient exchange between bottom waters on the outer shelf and the CIL in the deep sea



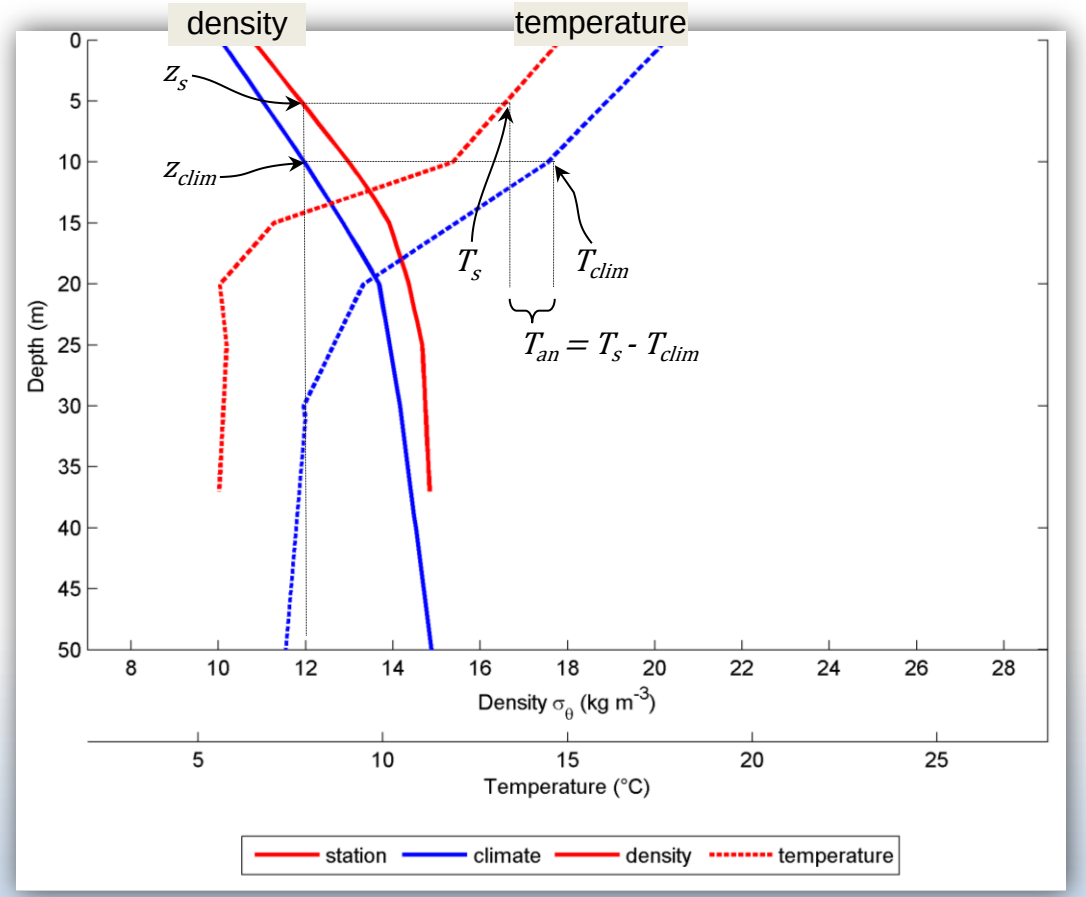
- **But dead zones exist!**
- **If there are significant exchanges, why is there hypoxia in bottom waters?**

Thank you

Black Sea coast at Alupka, photo by Fred Wobus, 2009

Temperature anomalies

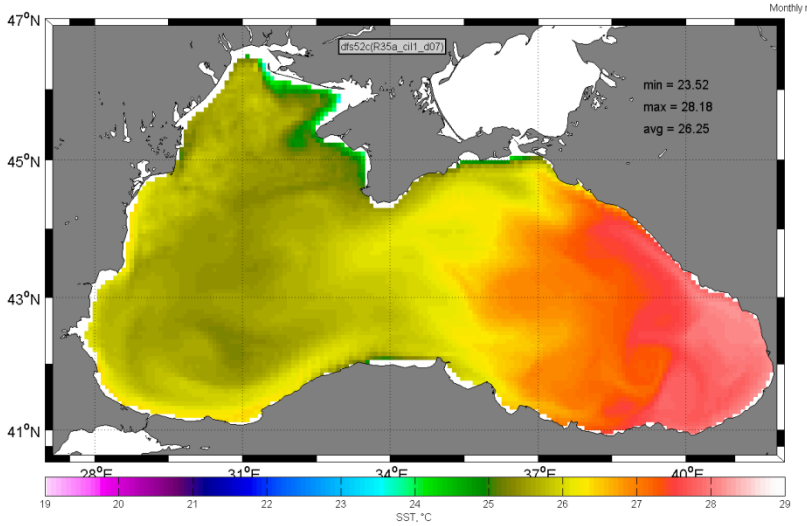
$$T_{an}(x, y, \sigma_\theta, t) = Ts(x, y, \sigma_\theta, t) - T_{clim}(x, y, \sigma_\theta, t)$$



T_{an} = Temp. difference between station temp T_s at a given density and climatic temp T_{clim} at point of water column of same density

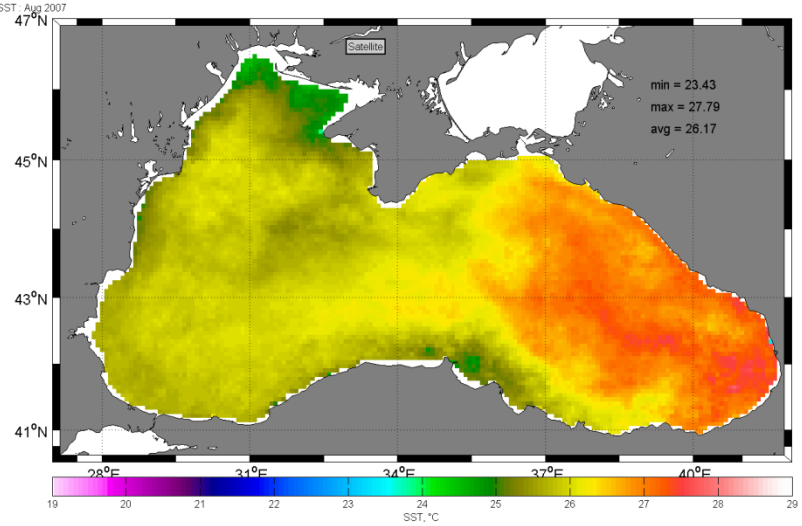
Absolute temp varies regionally, but anomalies are correlated over large distances (up to ≈1200km)

Satellite SST



Model

monthly mean



Satellite

monthly mean

SST anomaly time series