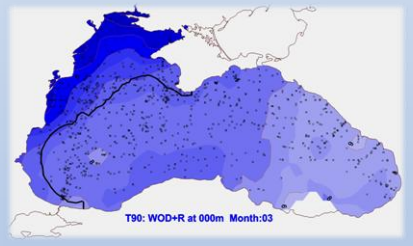
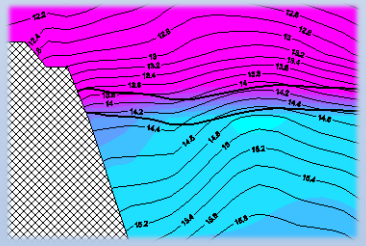






Interannual Temperature Variability in the Benthic Boundary Layer over the Black Sea Shelf

Fred Wobus, PhD student (UoP)
G.I. Shapiro (UoP), D.L. Aleynik (SAMS)

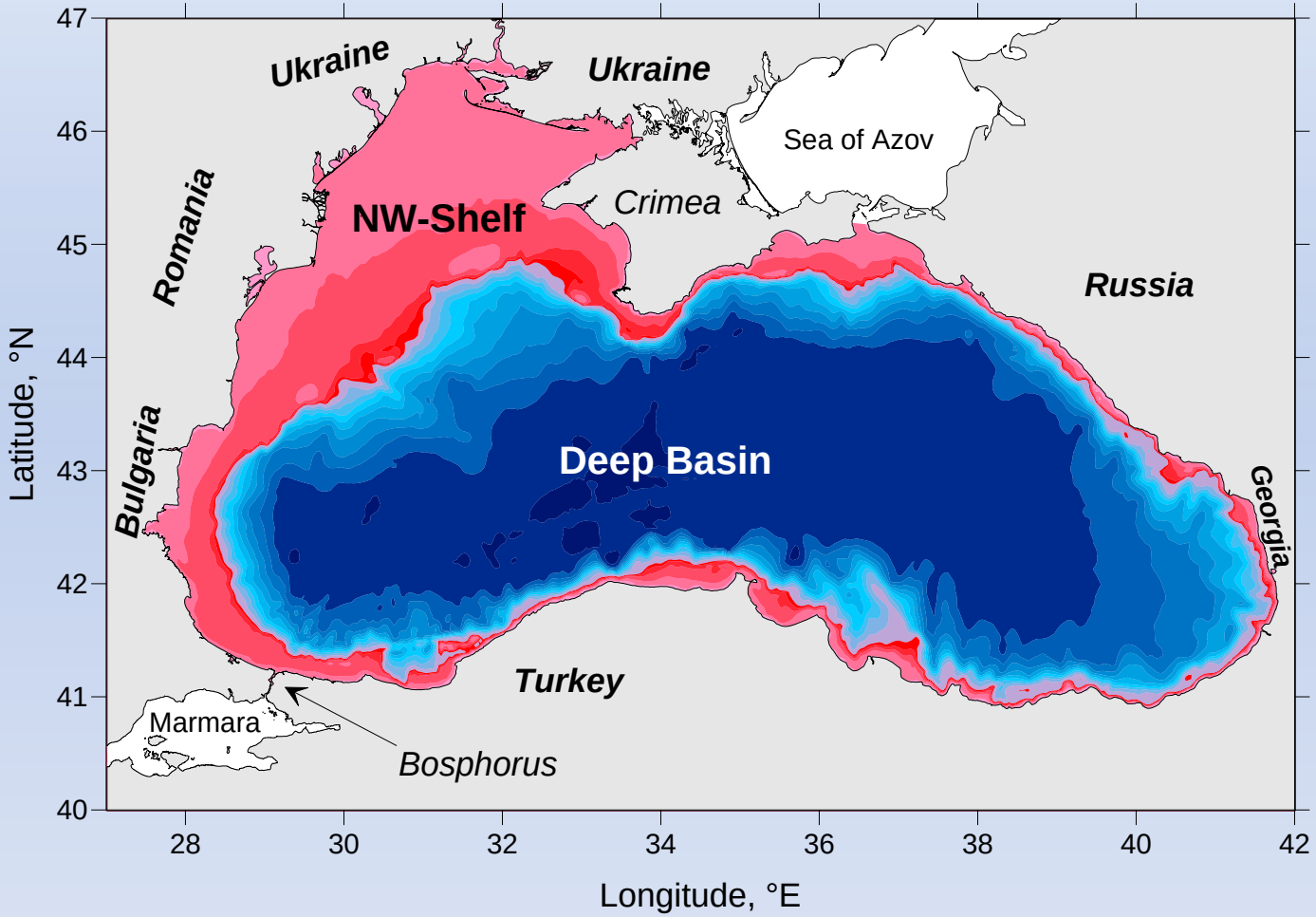
Postgraduate Society Conference
18th March 2010

The Black Sea

- Area: 414,000 km^2 (*), Depth: 2,245 m
- Drainage basin: 2M km^2, 160M people, 23 countries
- Environmental collapse
  - Since 1970s
  - *"Toilet bowl for half of Europe"* (Wash. Post)
- Anthropogenic causes
- Changes in physical environment

(*) almost twice as large as Great Britain!

Black Sea Bathymetry



Shelf (0 – 200 m), **Slope** (200 – 2000 m), **Deep Basin** (> 2000 m)

Data from ETOPO2 (NGDC, 2006)

Black Sea Oceanography

- Largely isolated from World Ocean
  - Bosphorus inflow
- Density stratification
  - Avg. salinity of 18/22 PSU
  - Permanent pycnocline
- Thermal stratification
  - Cold Intermediate Layer
  - < 8°C at 50-90m
- Chemical stratification
  - Anoxic below 100-200m

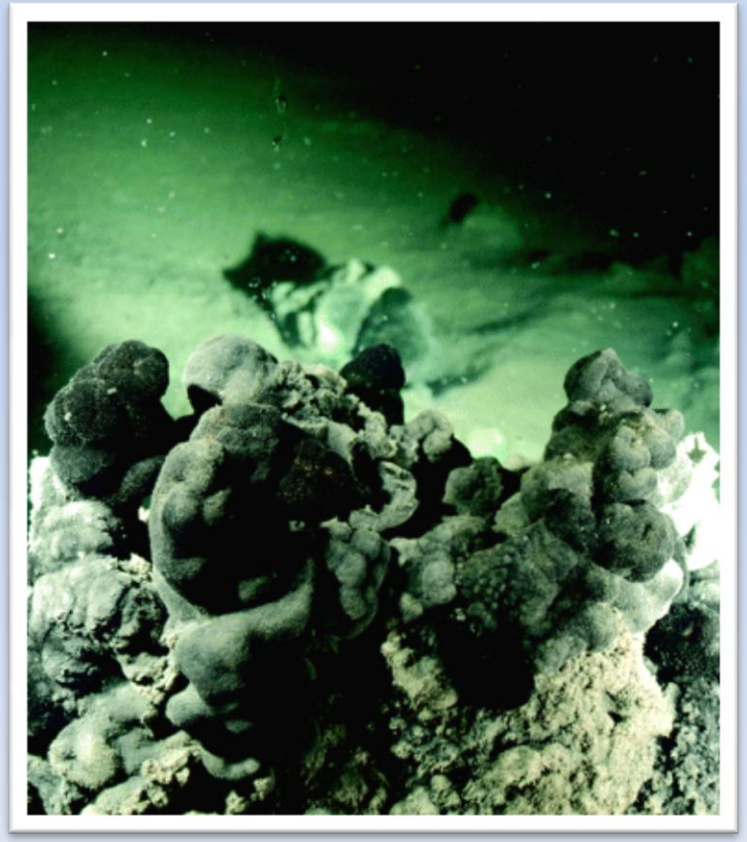


Image: © American Society for Microbiology (2005)

Aims

- Assess the long-term variability of the physical state in the shelf bottom layer
- Identify areas of the shelf bottom where water masses are isolated from effects of surface processes
- Quantify the role of horizontal exchanges in the ventilation of near-bottom water masses

Motivation

- Density layers align with oxygen availability
  - Benthic ecosystem depends on O_2
- We use the near-bottom temperature as indicators for physical conditions in the benthic boundary layer on the shelf
- Near-bottom temperature is directly related to the volume of cold water formation

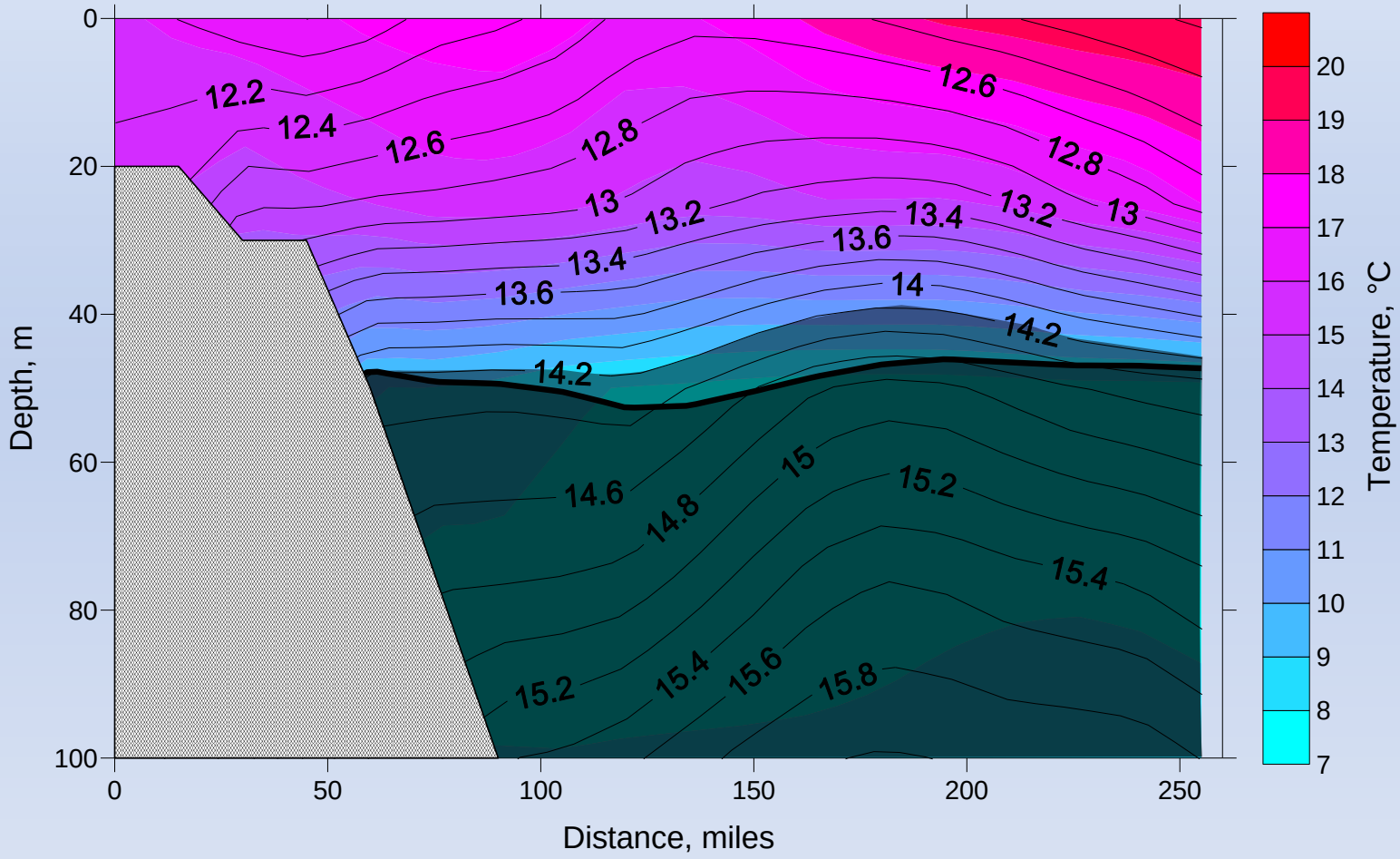
Benthic Boundary Layer (BBL)

- Winter mixing overturns water column
  - against potential energy of stratified water column
- Surface-applied energy required ~ 10 KJ/m^2.

$$W_{mix} = g\left[z_1 \int_{z_1}^{0} \sigma_\theta(z)\, dz - 2 \int_{z_1}^{0} \sigma_\theta(z) z\, dz\right]$$

- Energy penetrates down to density level σ_θ=14.2 kg m^{-3} → density boundary of BBL
  - Denser waters remain unmixed during winter

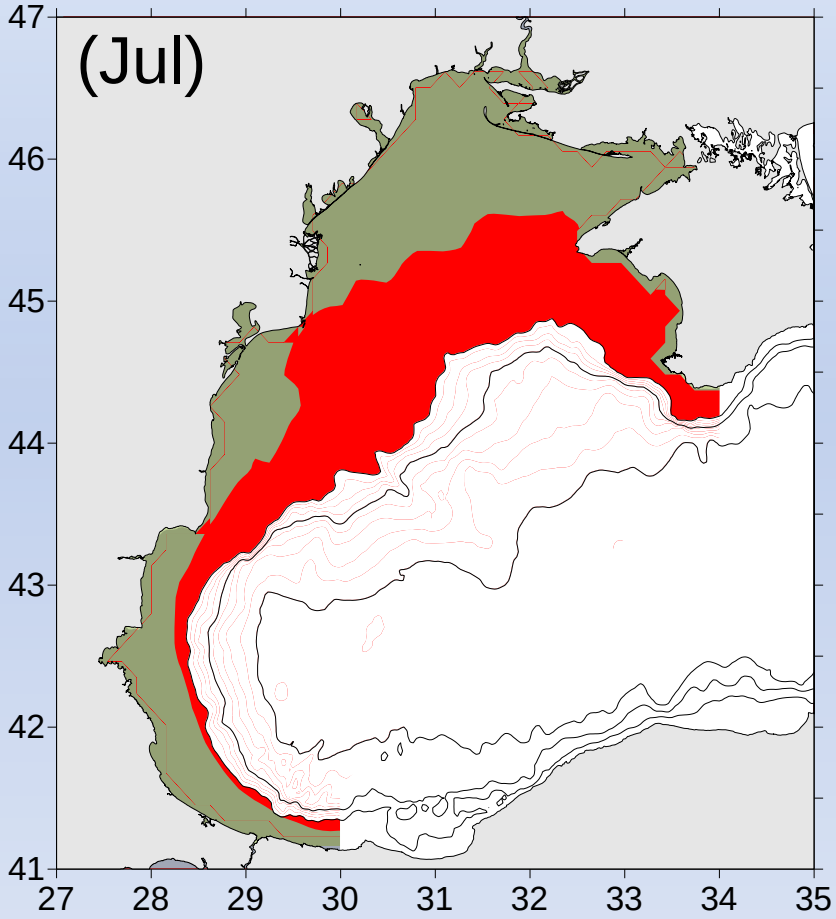
Climatic cross-section in October



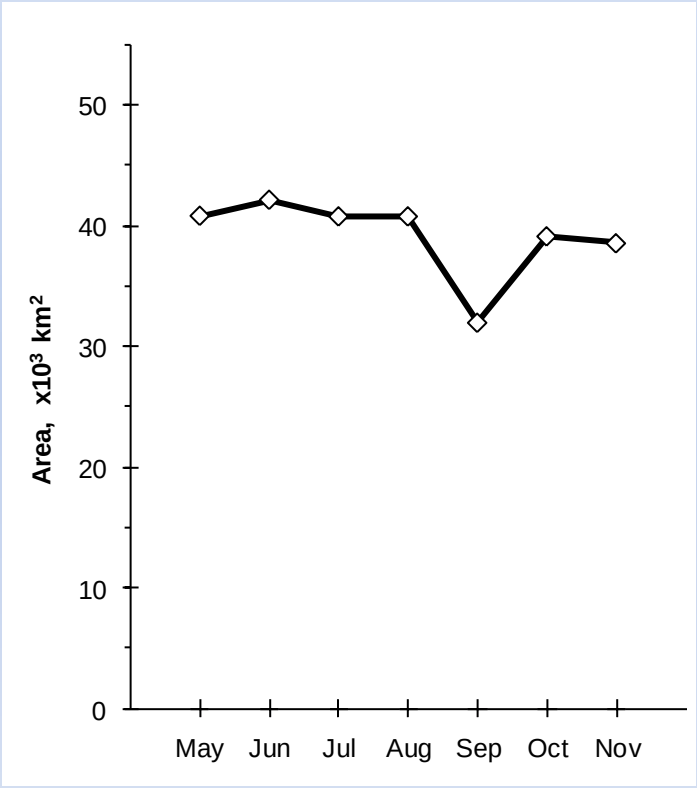
shaded: **temperature**, *thin lines:* **density**

bold line: **mixing energy penetration depth** (10 KJ/m^2)

Spatial extent of ‘locked’ waters

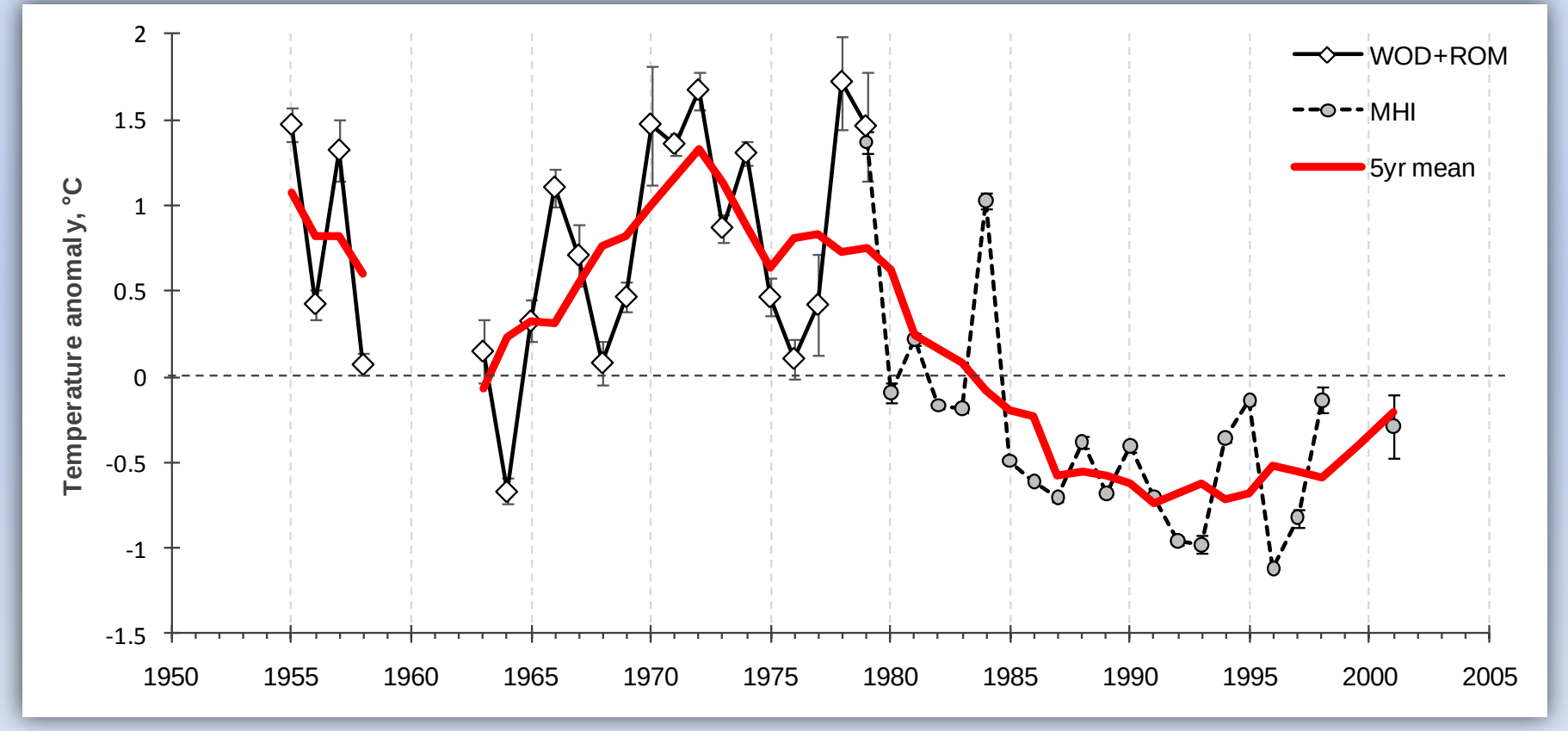


Shelf bottom covered by waters denser than σ_θ=14.2 kg m^{-3}



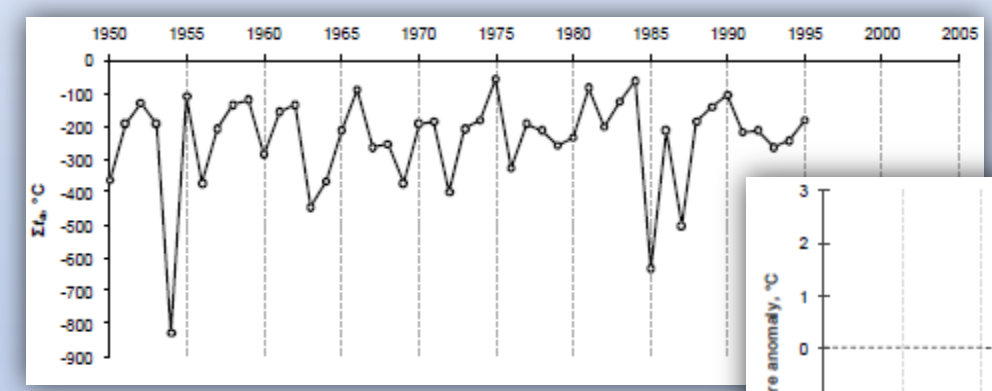
Area of the shelf bottom covered by locked waters

Interannual variability

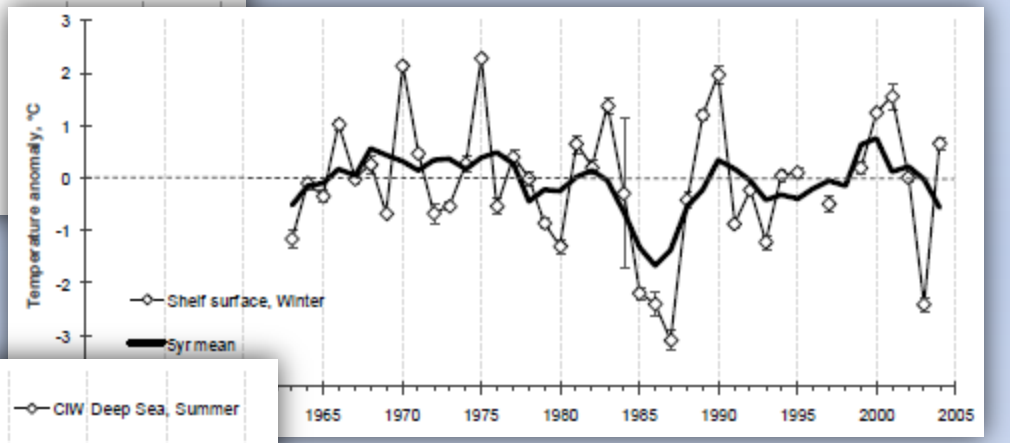


Temperature anomaly (°C) of 'locked' waters
in the benthic boundary layer on the shelf (May-Nov)

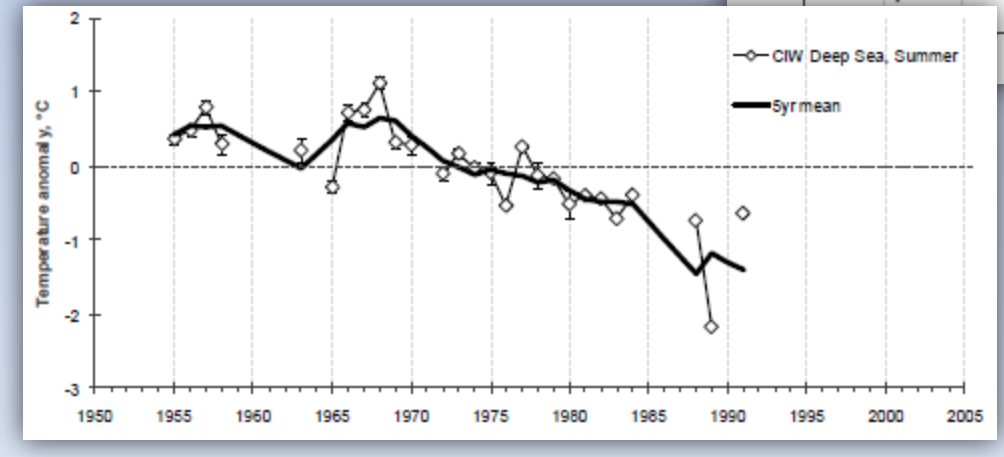
Other time series



Winter severity index



Shelf Surface (Winter)

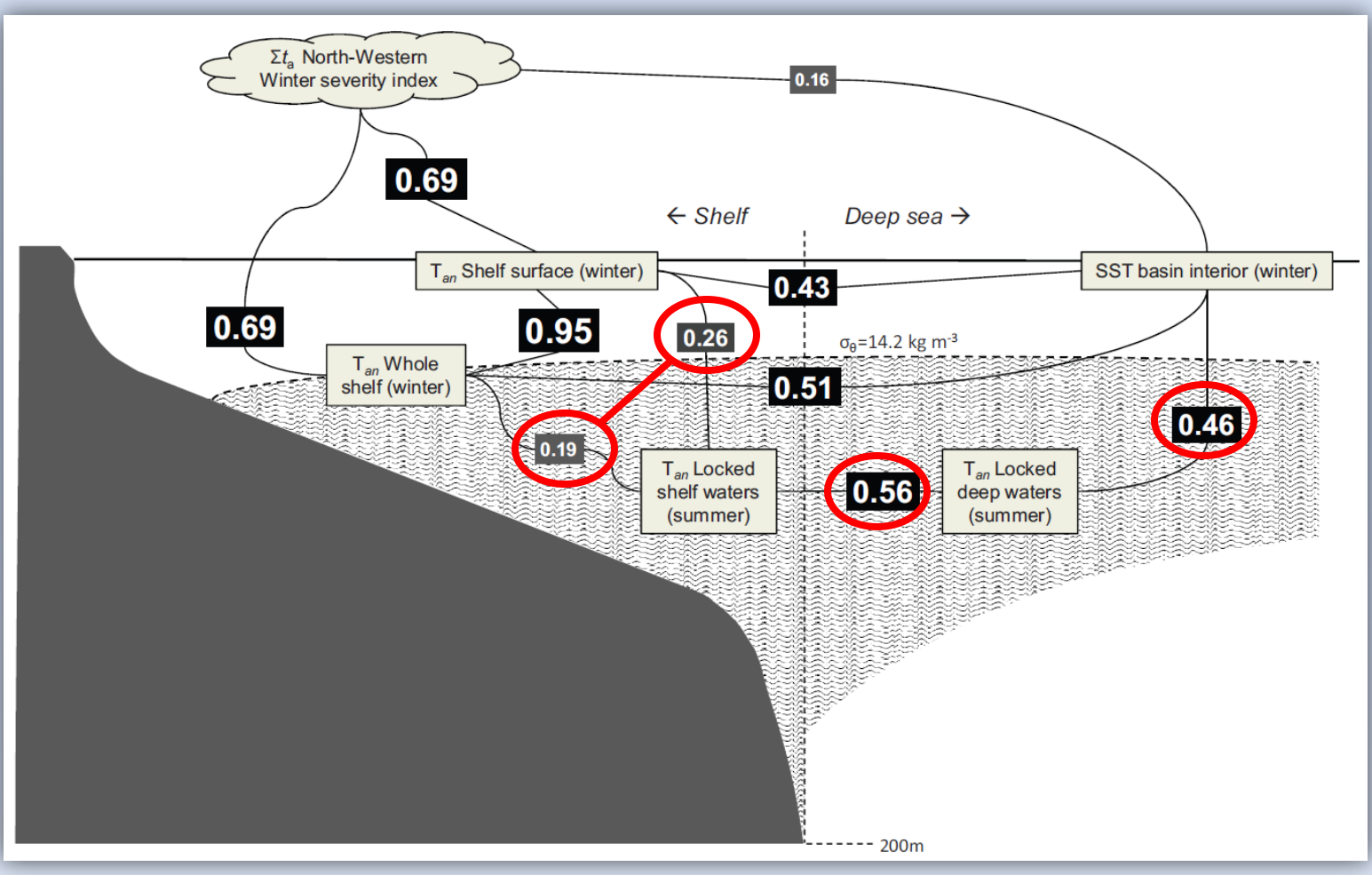


Deep Sea, Cold Intermediate Layer (Summer)

Plus:

- Whole Shelf (Winter)
- Deep Basin, Surface (Winter)

Correlations



Pearson correlation (R-values) between various temperature time series.

Conclusions

- ‘Locked’ waters are isolated from surface processes (~50% of shelf area)
- Temperature varies in near-bottom layer
  - warm phase (1960s - 1970s)
  - cold phase (1980s - 2000s)
- Cooling coincides with ecosystem recovery
- Shelf-Deep sea exchanges are more important for ventilation of the shelf bottom waters than winter convection on the shelf itself

Publication

Interannual Temperature Variability in the Benthic Boundary Layer over the Black Sea Shelf

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References

- Ivanov, L.I., Belokopytov, V.N., Özsoy, E. and Samodurov, A., 2000. Ventilation of the Black Sea pycnocline on seasonal and interannual time scales. *Mediterr. Mar. Sci.*, 1/2: 61-74.
- Özsoy, E. and Ünlüata, Ü., 1997. Oceanography of the Black Sea: a review of some recent results. *Earth-Sci. Rev.*, 42(4): 231-272.
- Shapiro, G. I., Aleynik, D. L. and Mee, L. D. 2010. Long term trends in the Sea Surface Temperature of the Black Sea. *Ocean Science Discussion,* 7, 91-119.

Abstract

Long-term changes in the state of the benthic boundary layer (BBL) on the North-Western shelf of the Black Sea are assessed using analysis of intra- and interannual variations of temperature in the near-bottom water mass as well as their relations to physical parameters of both shelf and deep-sea waters.

Large data sets of hydrographic observations over the 20th century are first compiled into high-resolution monthly climatology at different density levels. The temporal evolution of the BBL is then revealed via anomalies from the climatic mean, which are aggregated into spatial compartments and seasonal bins. For the purpose of this study the BBL water mass is defined as such shelf water below the seasonal pycnocline which is unable to mix vertically with oxygen-rich surface waters. This water mass is thus considered "locked" as it is isolated from the effects of atmospheric processes at the surface and the action of the "biological pump" is suppressed.

During the summer half of the area of the shelf bottom is occupied by such locked waters, but the BBL can be ventilated horizontally with deep-sea waters through isopycnal exchanges. A long-term time series of summer temperature anomalies in the locked water mass reveals a warm period in the 1960s/70s, followed by cooling of the BBL during 1980-2001. The transition between the warm and cold periods coincides with a regime shift in the Black Sea ecosystem.

Correlations between the temperature in the BBL on the shelf with the temperature of Cold Intermediate Waters in the deep sea indicate that isopycnal shelf-deep sea exchanges are more important for ventilation of the benthic boundary layer on the shelf than winter convection on the shelf itself.