Black Sea biogeochemical regime recent decades variability: the role of climatic and anthropogenic forcing

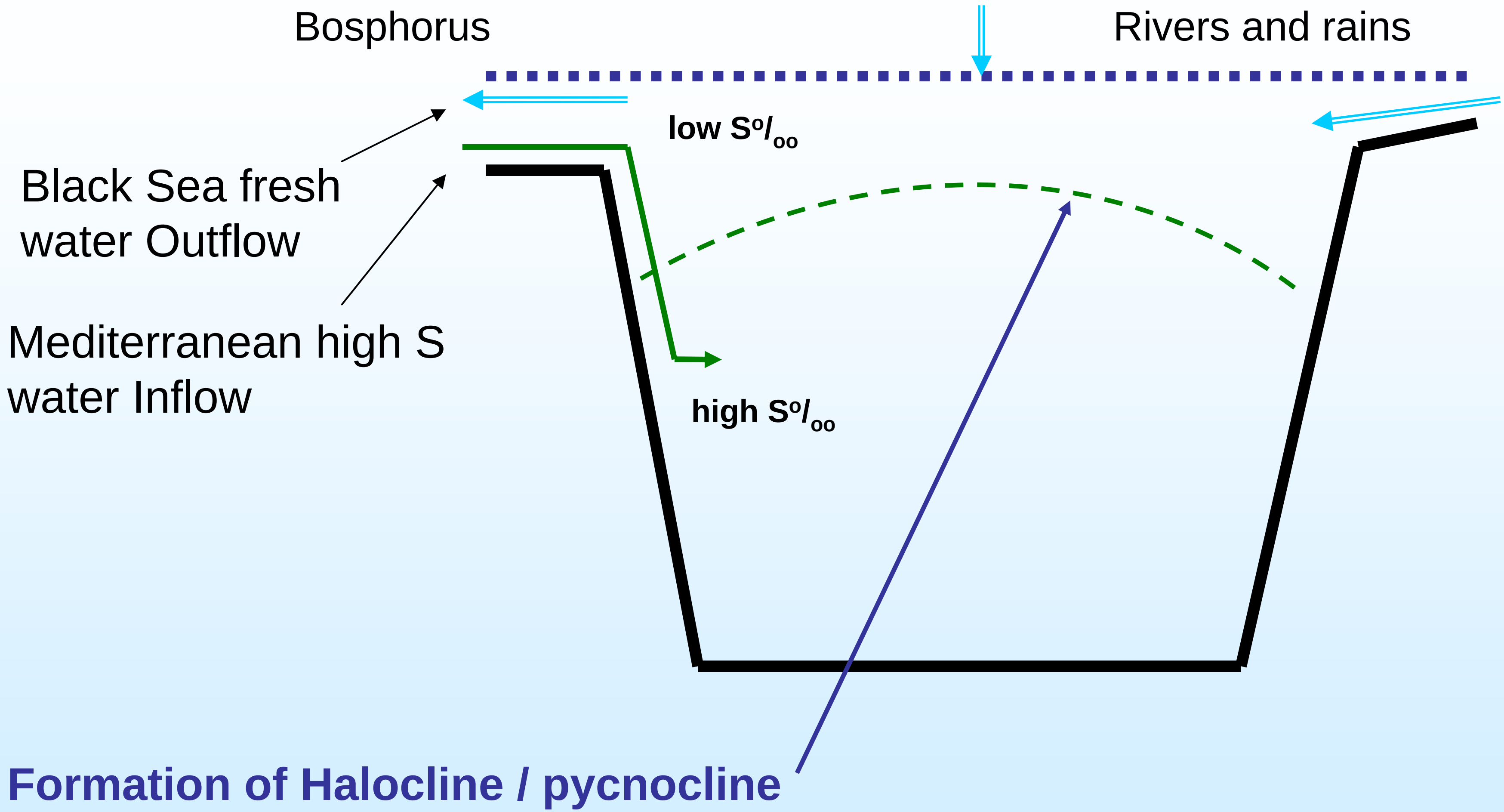
S. Pakhomova[1], E. Vinogradova[1], **E. Yakushev[2]**, A. Zatsepin[1], G. Shtereva[3], V. Chasovnikov [1], O. Podymov[1]

[1] P.P. Shirshov Institute of Oceanology, RAS, Moscow, Russia

[2] Norwegian Institute for Water Research, Oslo, Norway

[3] F. Nansen Institute of Oceanology, BAN, Varna, Bulgaria

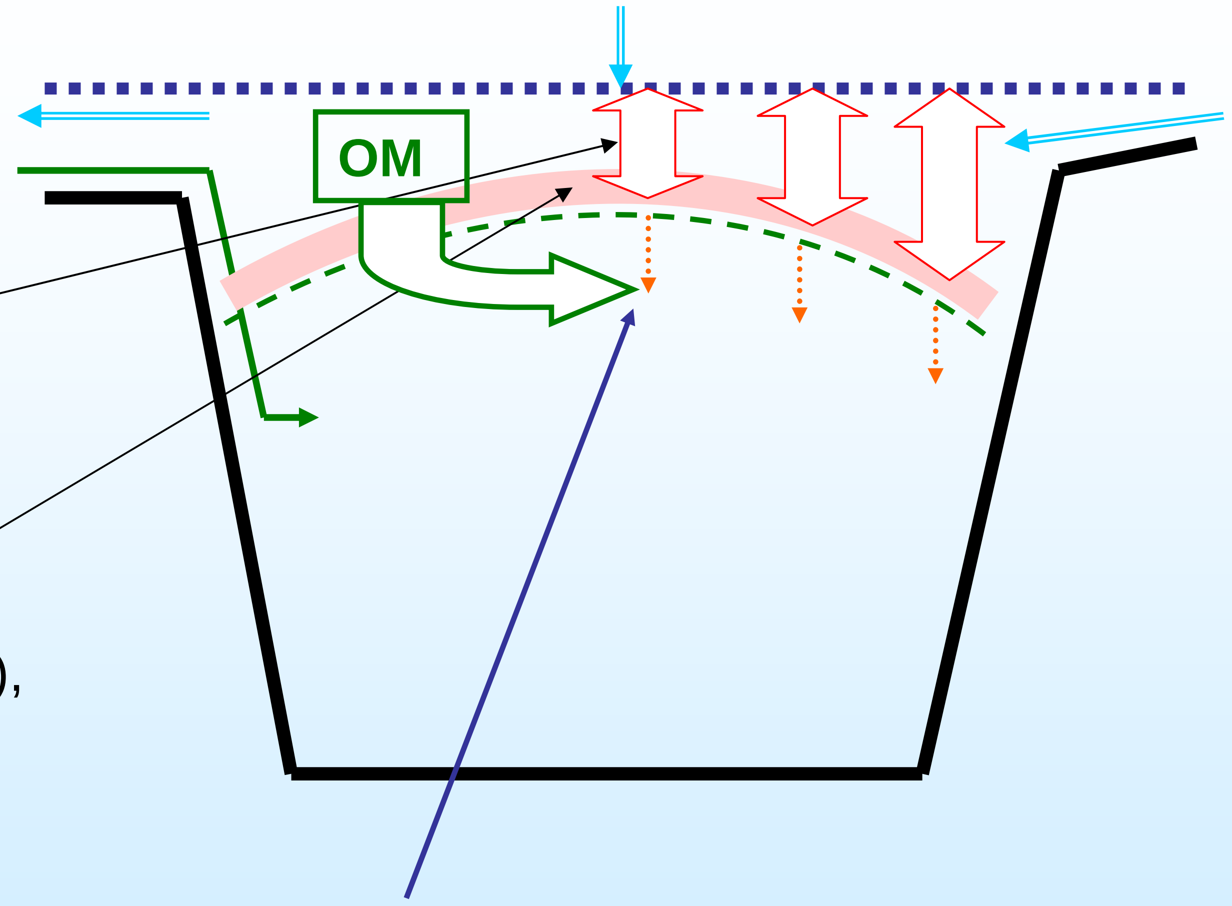
Black Sea structure



Black Sea structure

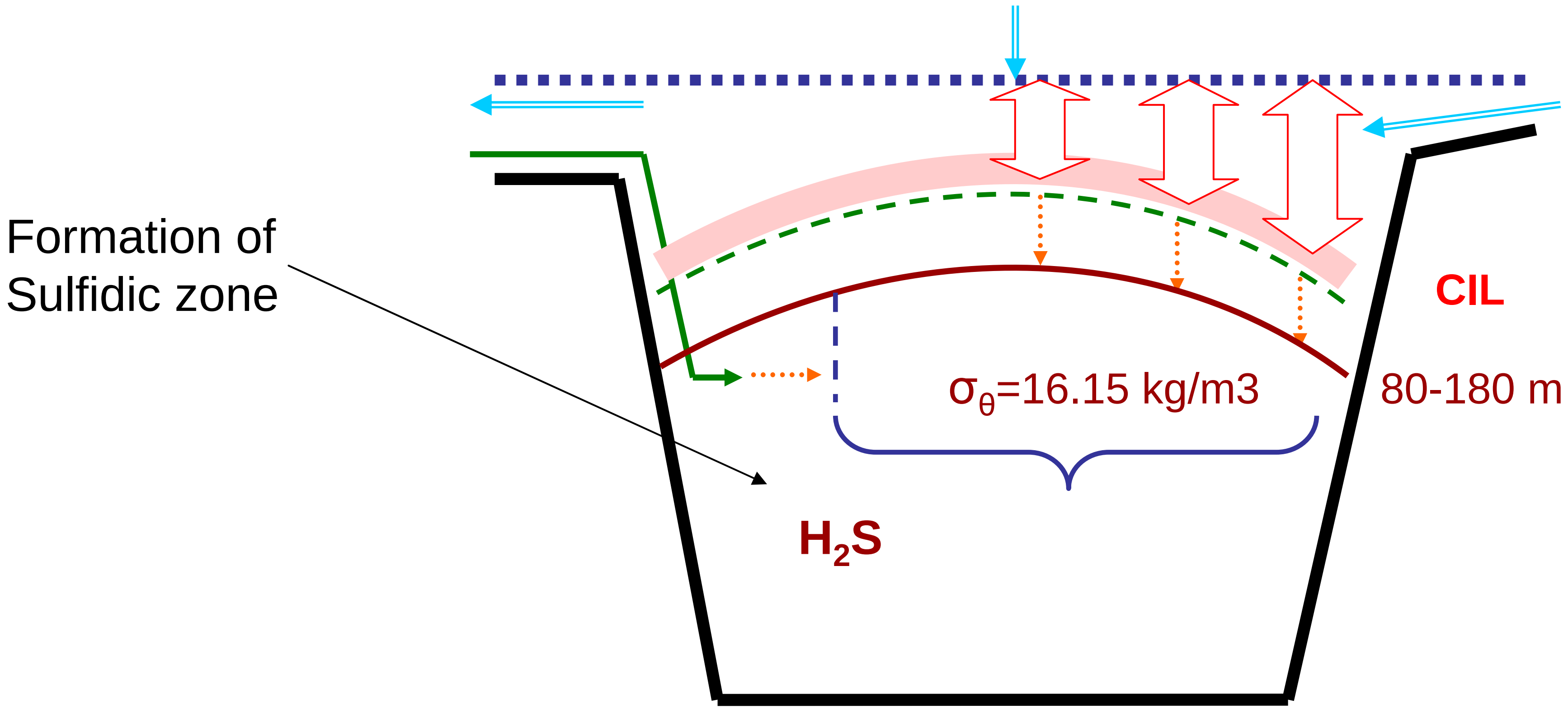
Winter mixing occurs
down to halocline

Formation of CIL
(Cold Intermediate Layer),
σ_θ=14.5 kg/m^3



Weak turbulent transport of O_2 exists to the deeper layer

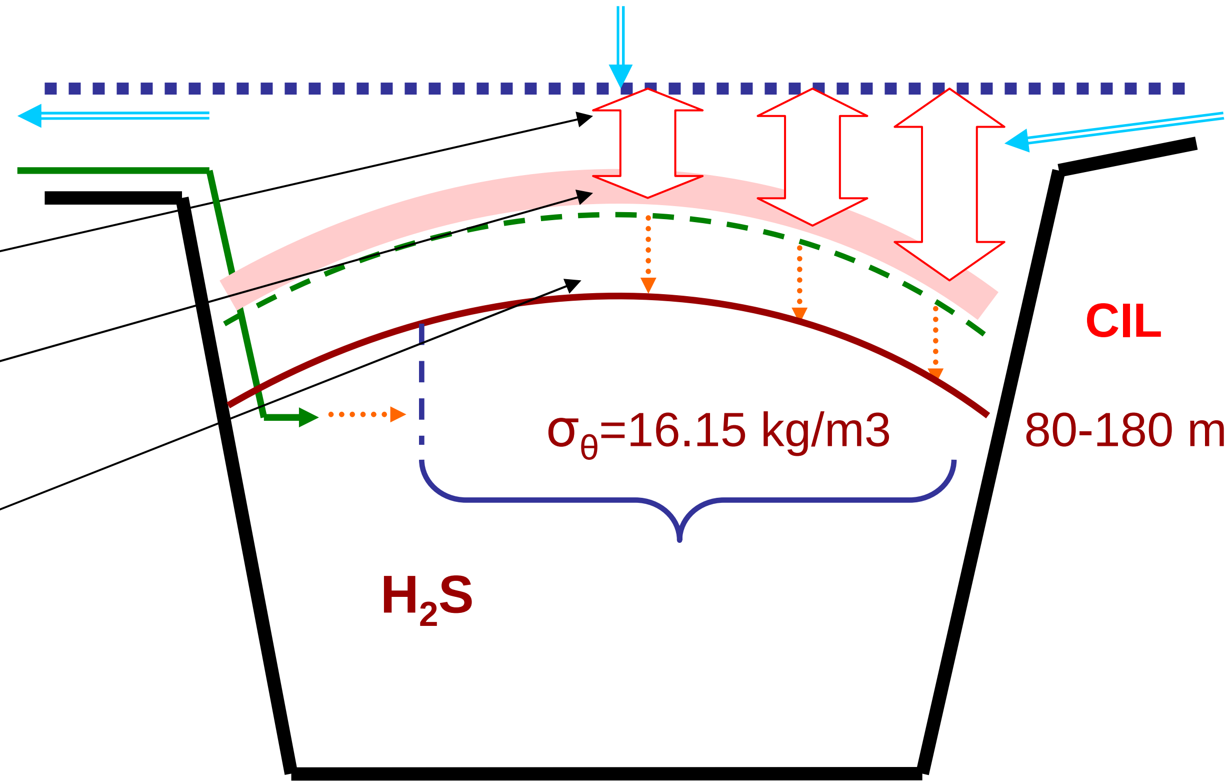
Black Sea structure



Black Sea structure

Biogeochemical regime:

- Surface layer
- CIL
- redox layer



Objectives

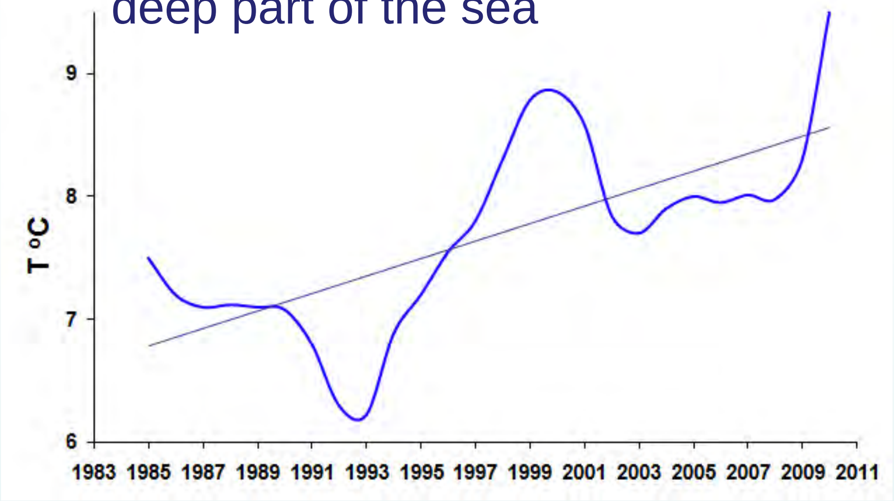
The upper layer chemical dynamics in the NE Black Sea reflects rather “integrated” than local changes of the Black Sea chemical parameters due to less influence of Danube River inflow compared to the western and southern.

Goals:

- ✓ to estimate the recent decadal changes of the nutrient regime and oxic/anoxic boundary position in the northeastern (NE) and western (W) Black Sea areas and
- ✓ to reveal the role of climatic and anthropogenic forcing in the Black Sea biogeochemical variability

Dissolved oxygen concentrations in the surface layer (0-5m)

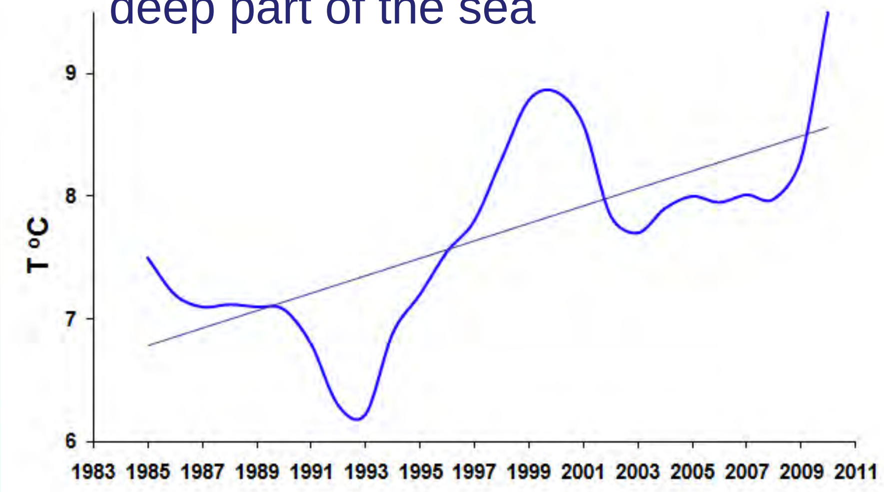
Mean winter satellite SST over the deep part of the sea

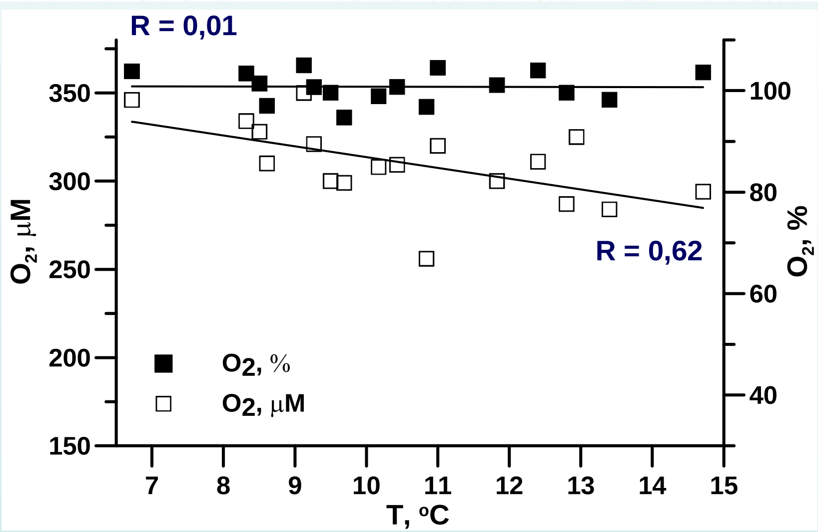


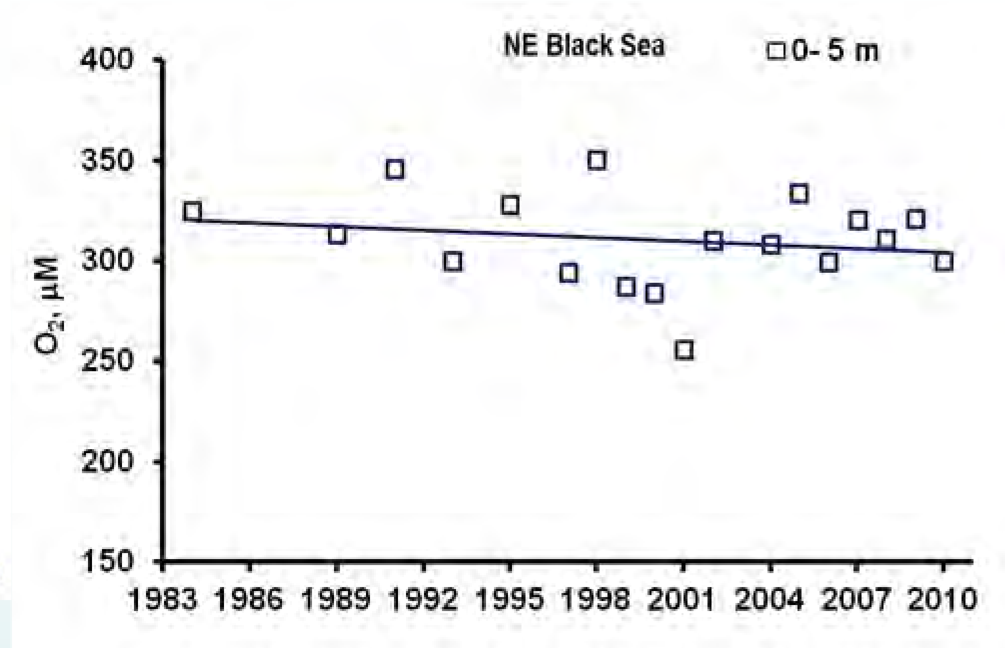
During the last decades the winter means satellite SST has trend to increase with a min in 1993 and max in 1999-2001 and 2010.

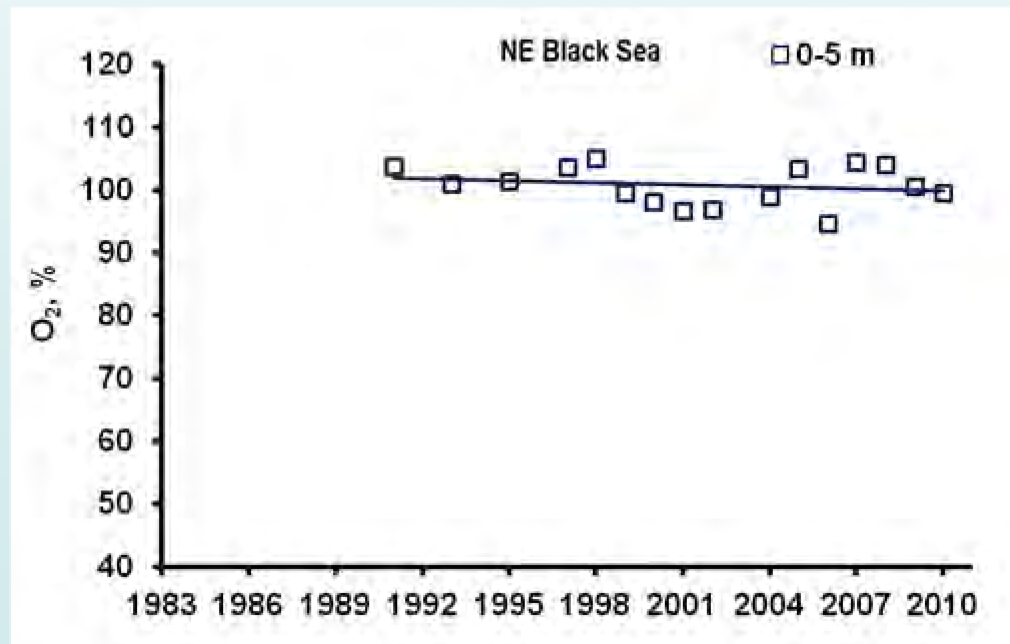
Dissolved oxygen concentrations in the surface layer (0-5m)

Mean winter satellite SST over the deep part of the sea





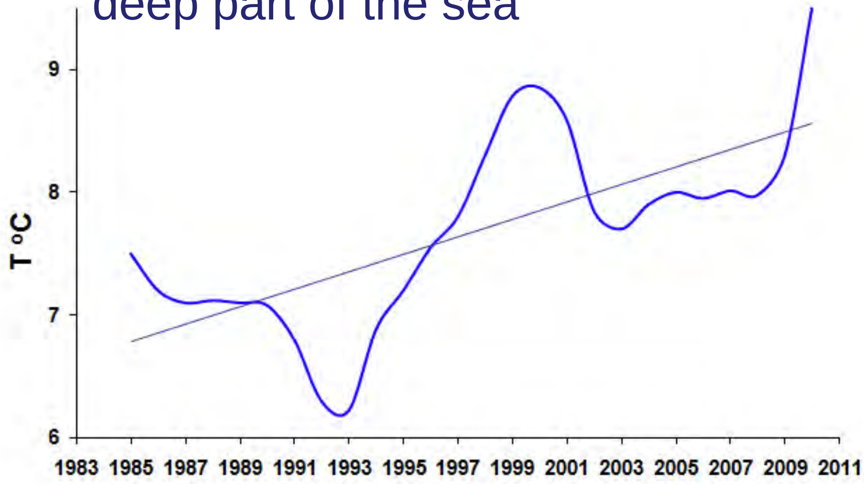


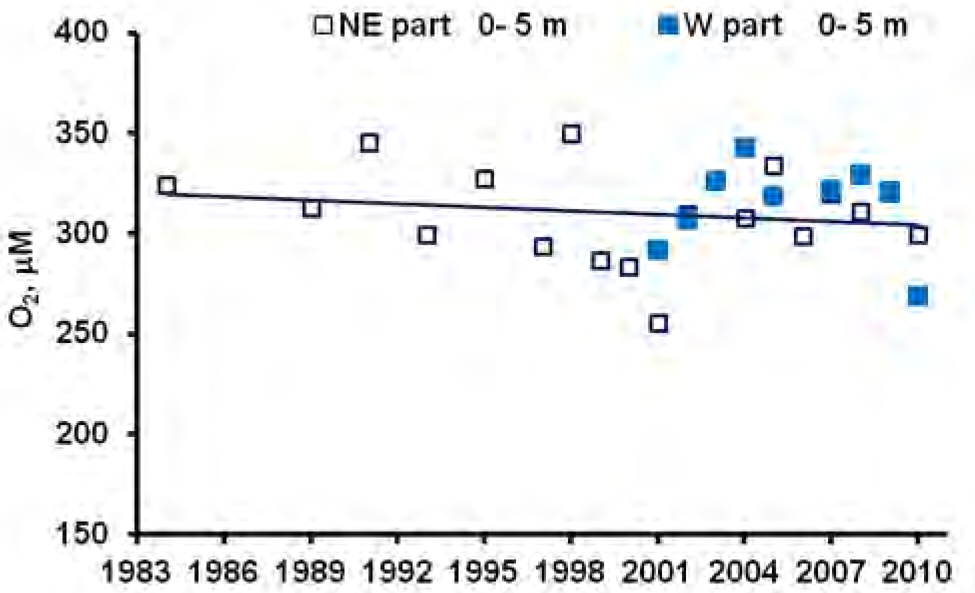


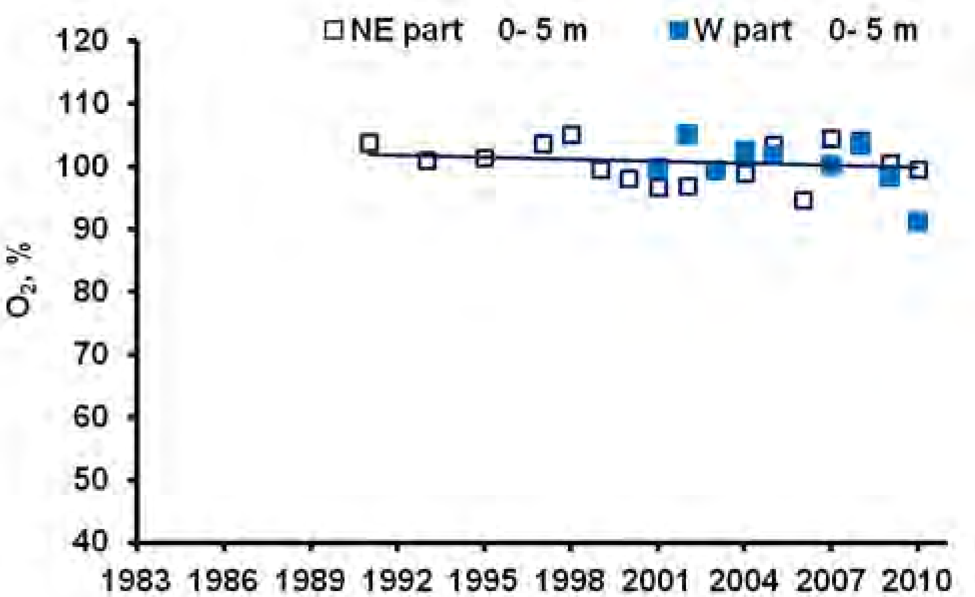
The slight decadal trend to decrease of winter DO concentration revealed a negatively correlated pattern with SST.

Dissolved oxygen concentrations in the surface layer (0-5m)

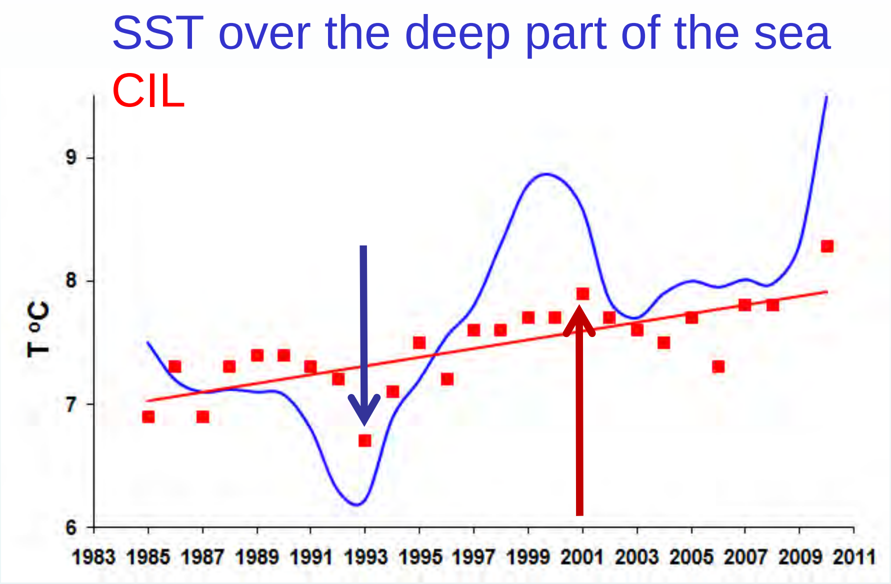
Mean winter satellite SST over the deep part of the sea





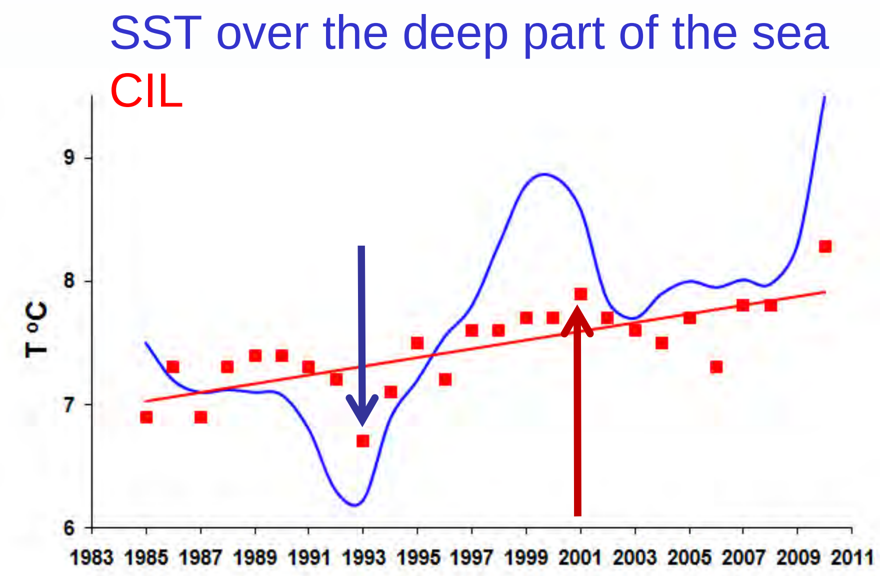


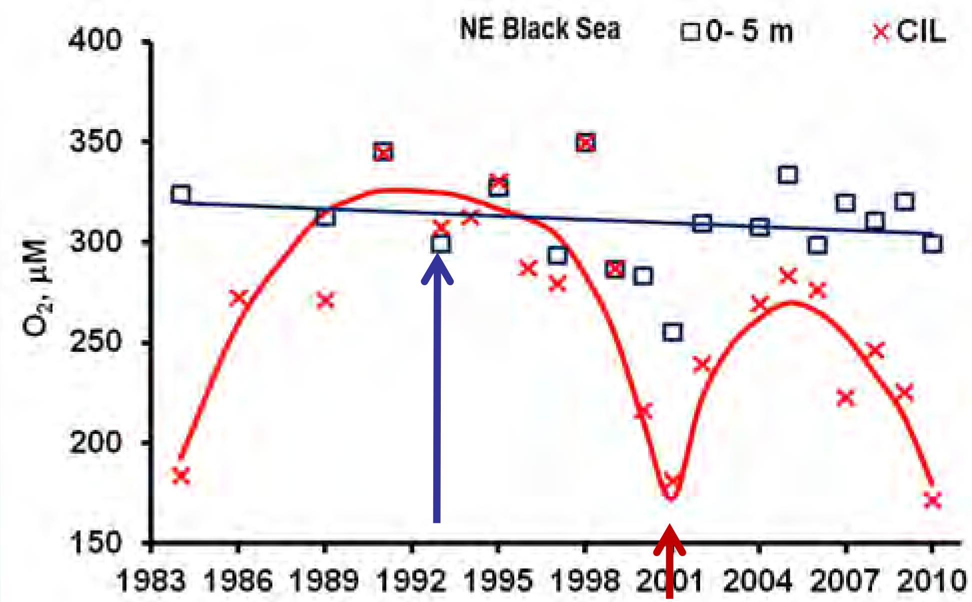
Dissolved oxygen concentrations in the CIL σ =14.3-14.5



The interannual T variability in the CIL is twofold lower than for surface layer and has a clear trend to increase during recent decades reflecting the regional climatic warming.

Dissolved oxygen concentrations in the CIL σ =14.3-14.5

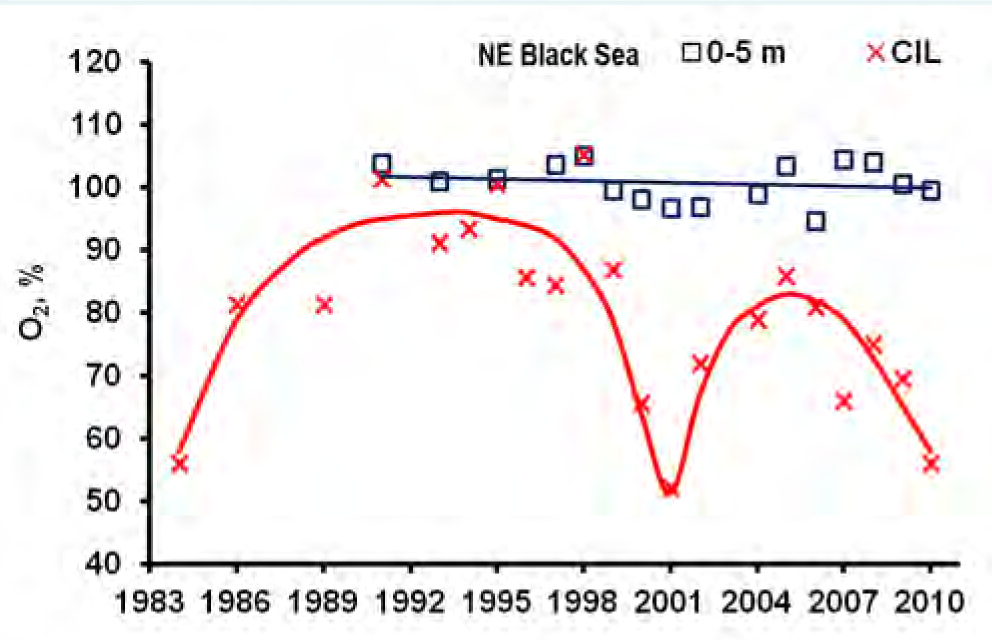




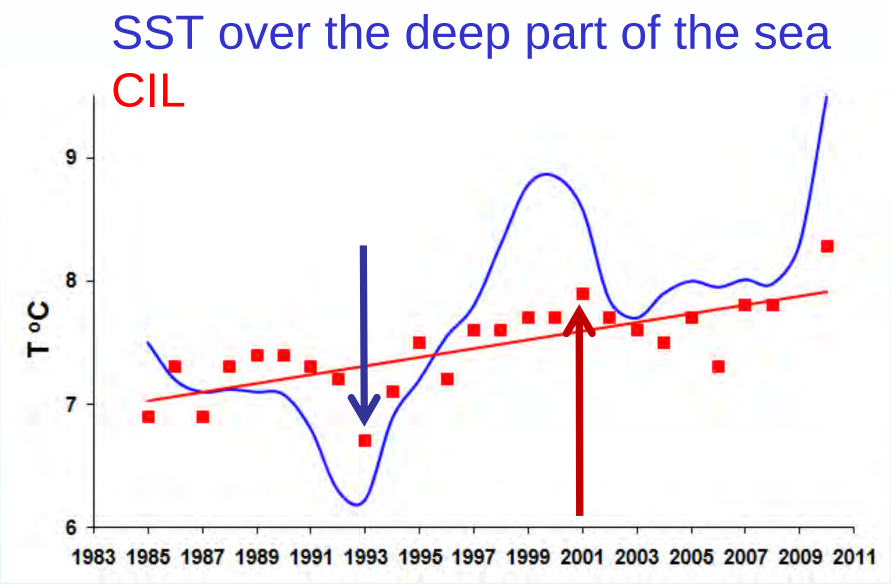
arm winters result in decreasing of DO concentrations in the CIL more than in the surface layer.

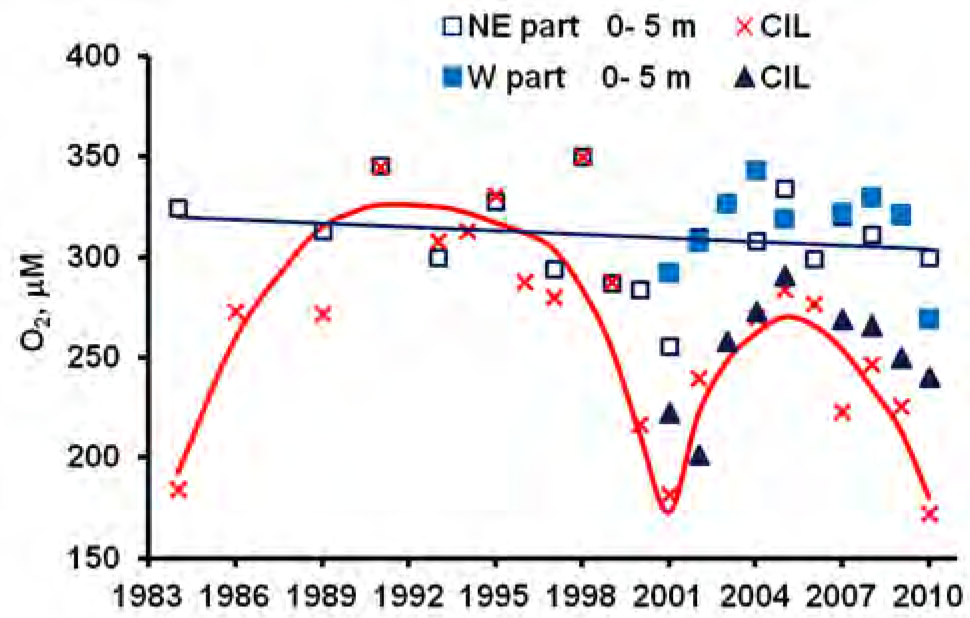
DO concentrations in the CIL correspond with those in surface layer until 1999 reflecting annual renovation of the upper part of the CIL (σ = 14.3-14.5).

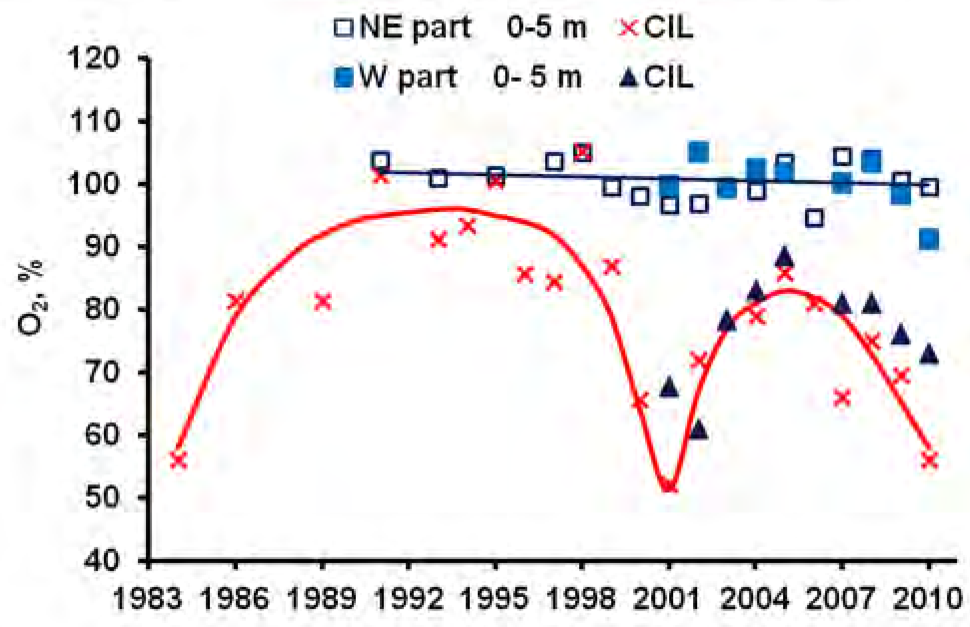
After 2000 marked and stable differences between DO content in the surface layer and the CIL has been observed, that points to absence of fully renovation of the CIL.



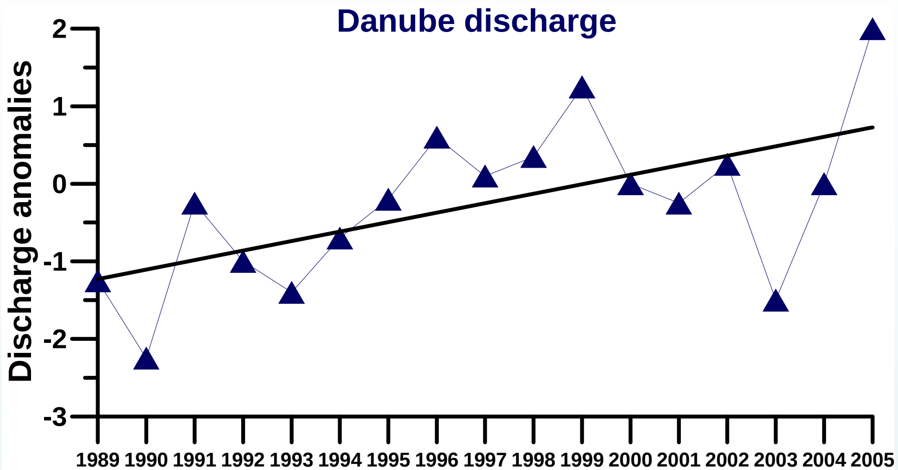
Dissolved oxygen concentrations in the CIL σ =14.3-14.5



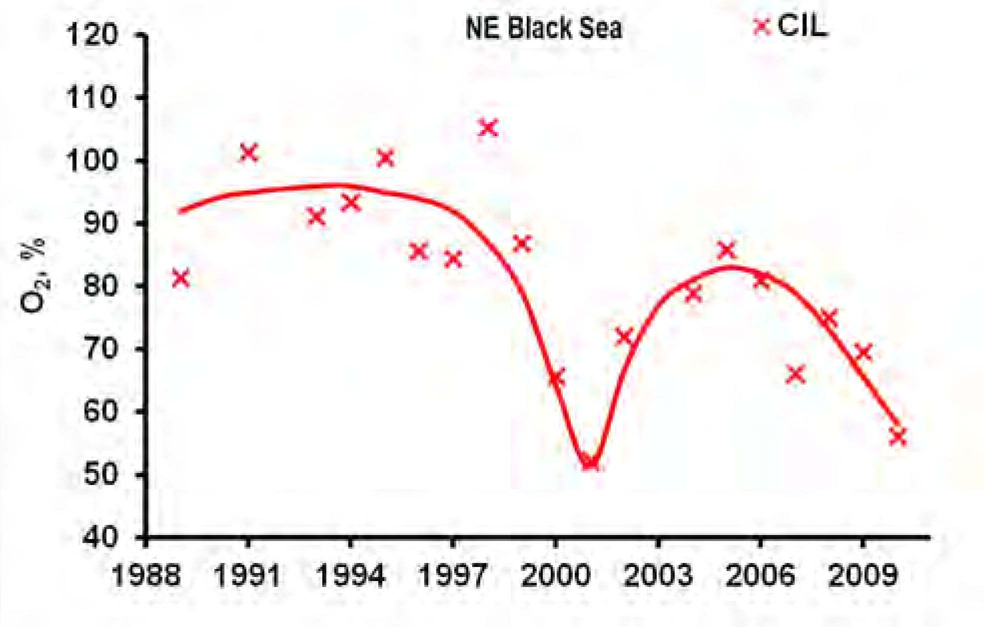


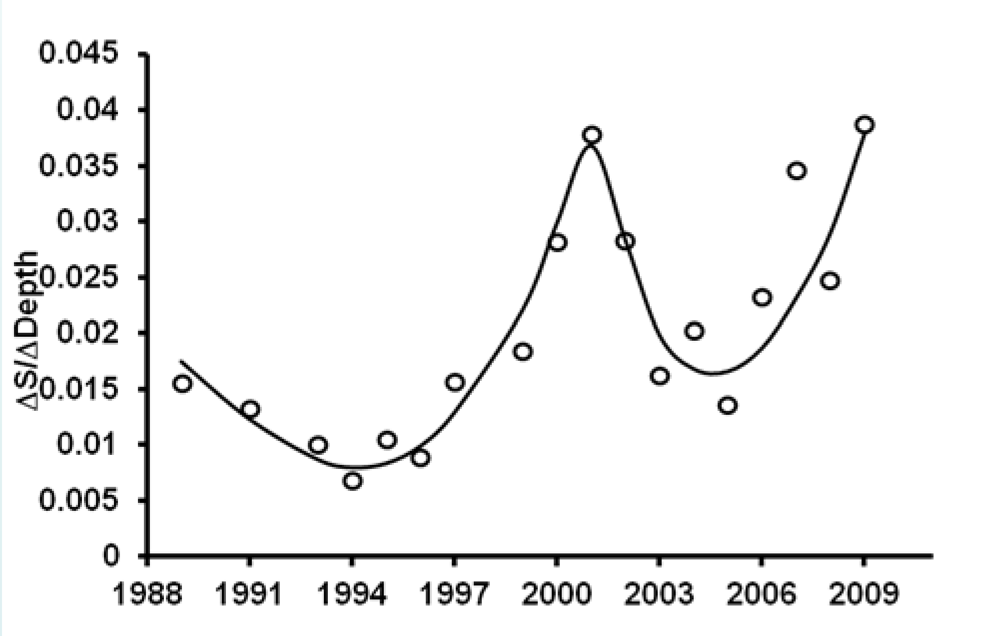


Influence of coastal discharge



Oguz & Velikova, 2011



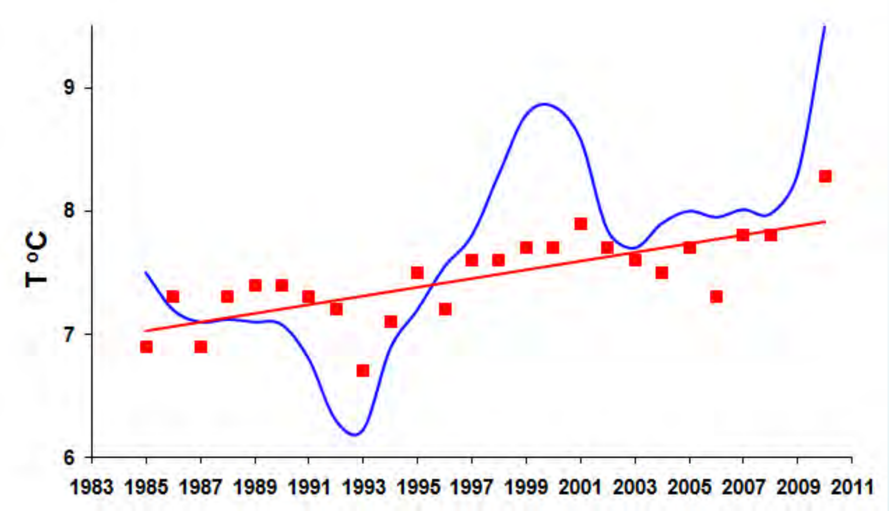


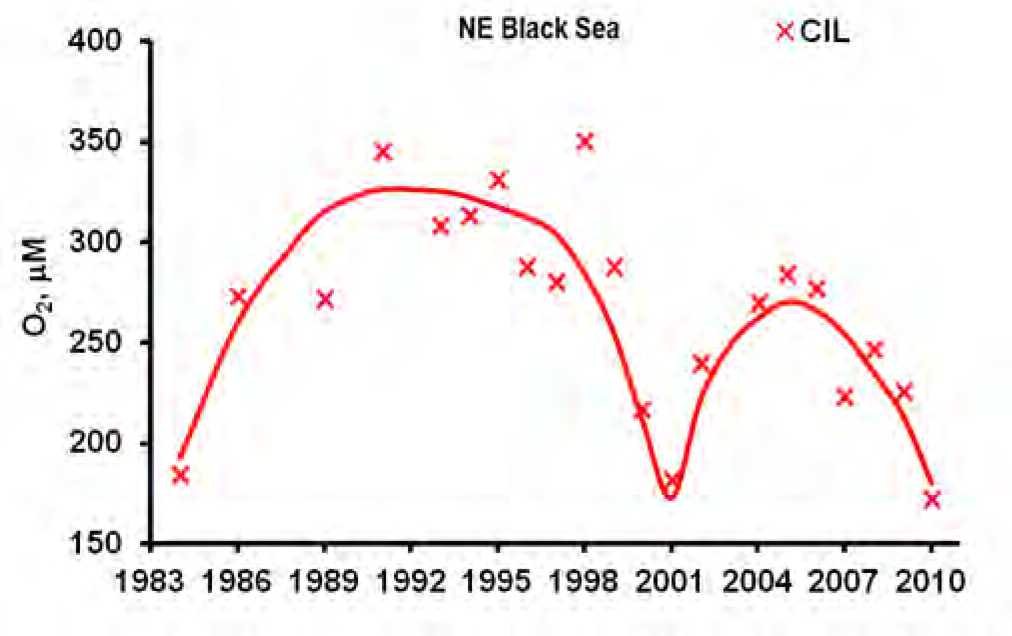
One of the reason leaded to prevention of the CIL renovation is growth of density gradient due to restriction of vertical mixing.

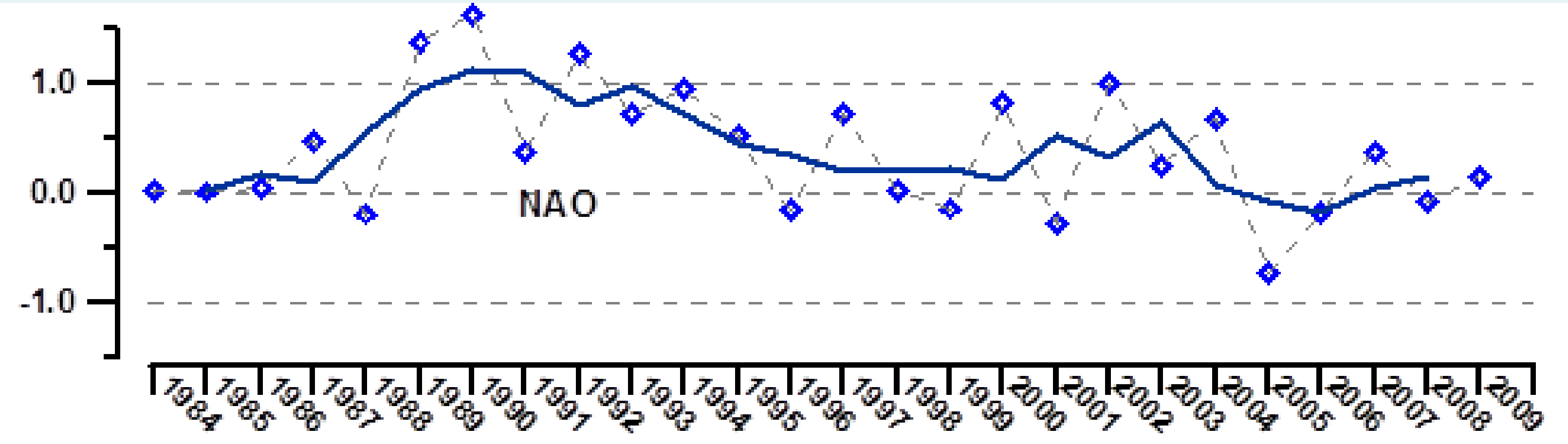
Surface freshening may be caused by increasing of coastal discharge that could lead to increasing of density gradient.

Correlation with NAO Index

SST over the deep part of the sea
CIL

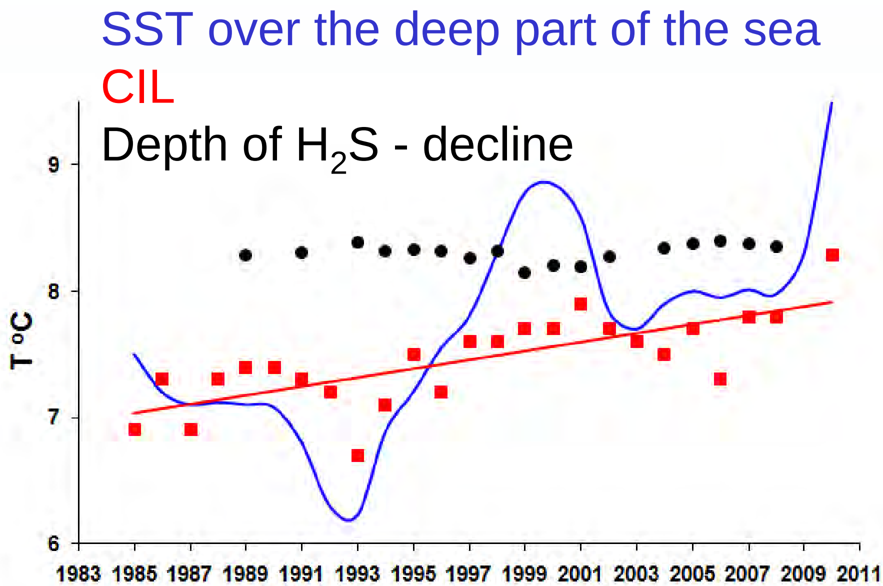


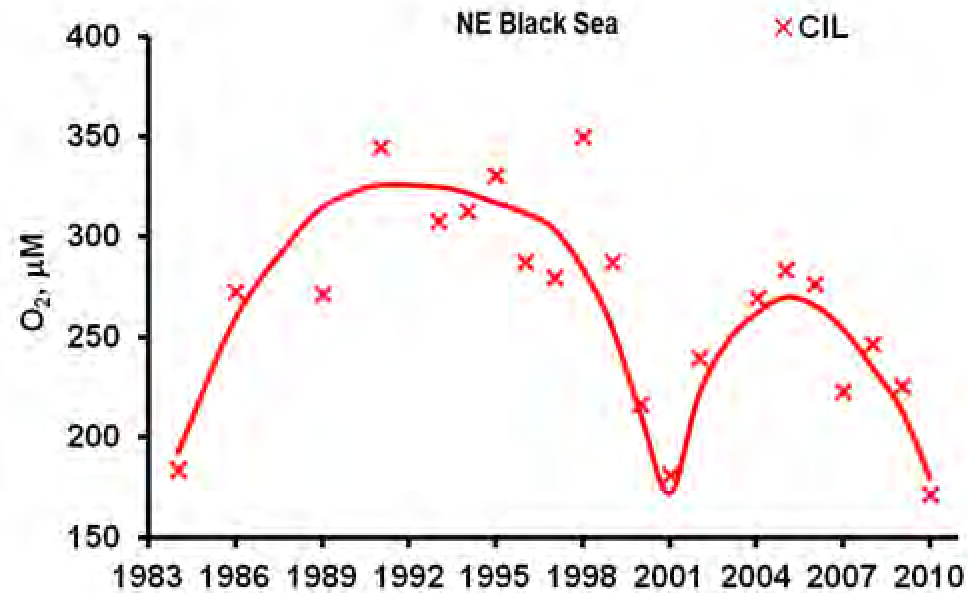


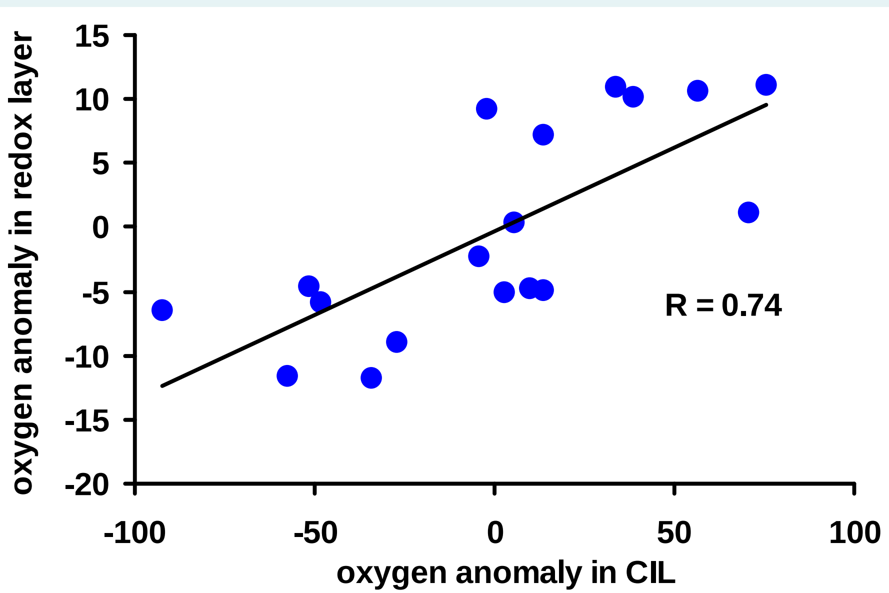


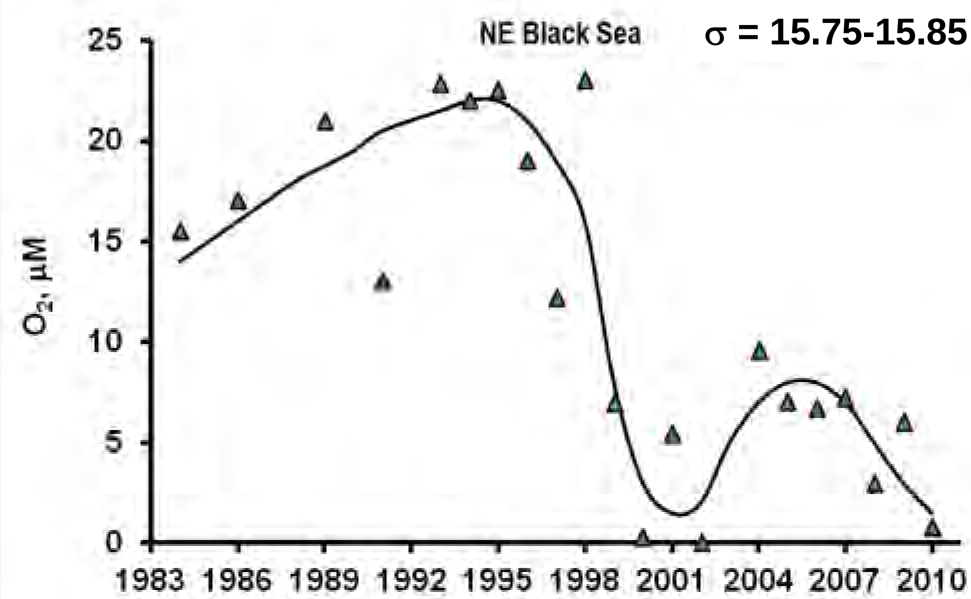
North Atlantic Oscillation standardized 3-month running mean Index
(http://www.cpc.ncep.noaa.gov)

Dissolved oxygen concentrations in the redox layer

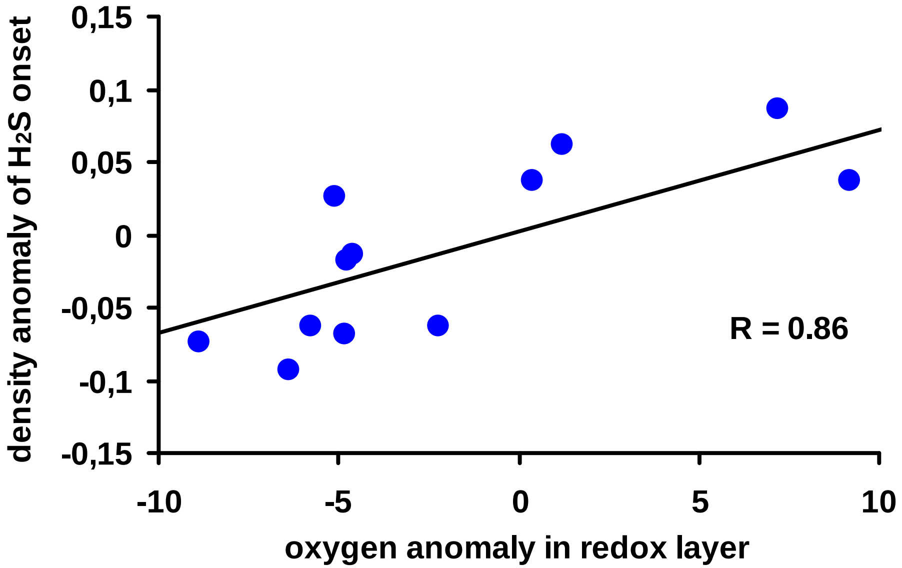


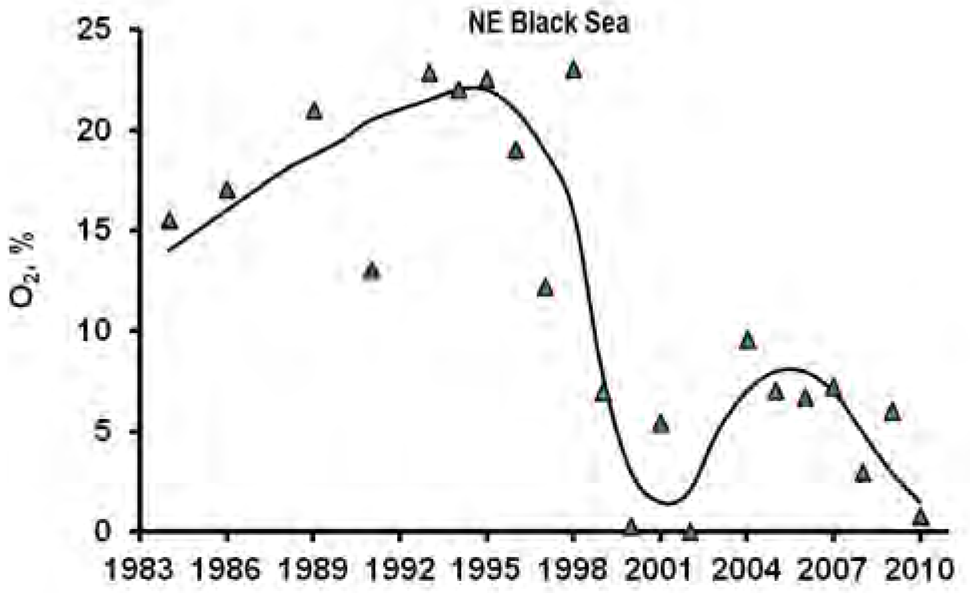






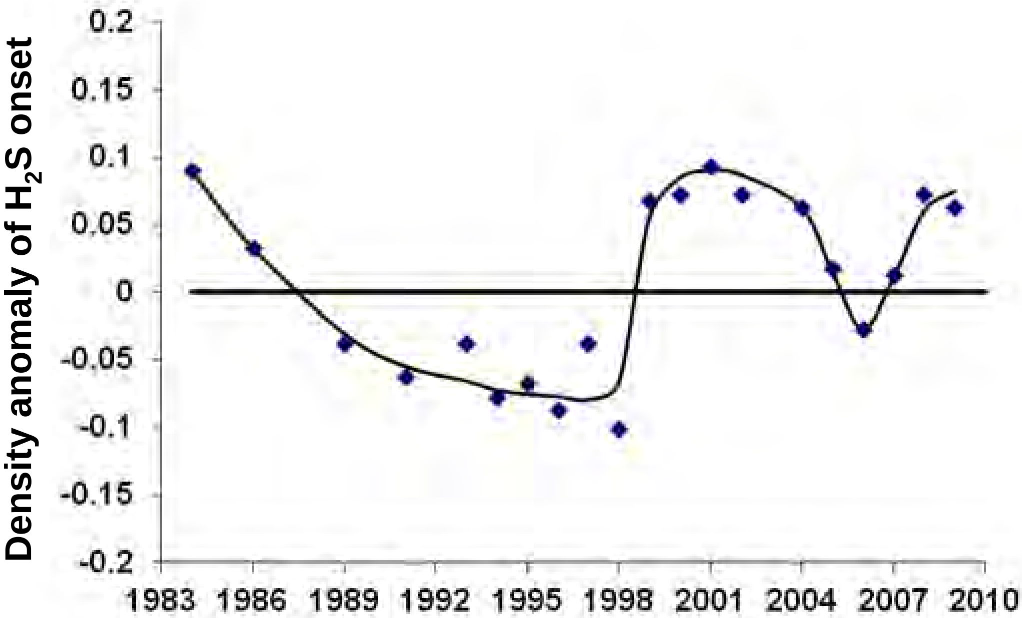
Hydrogen sulfide boundary position





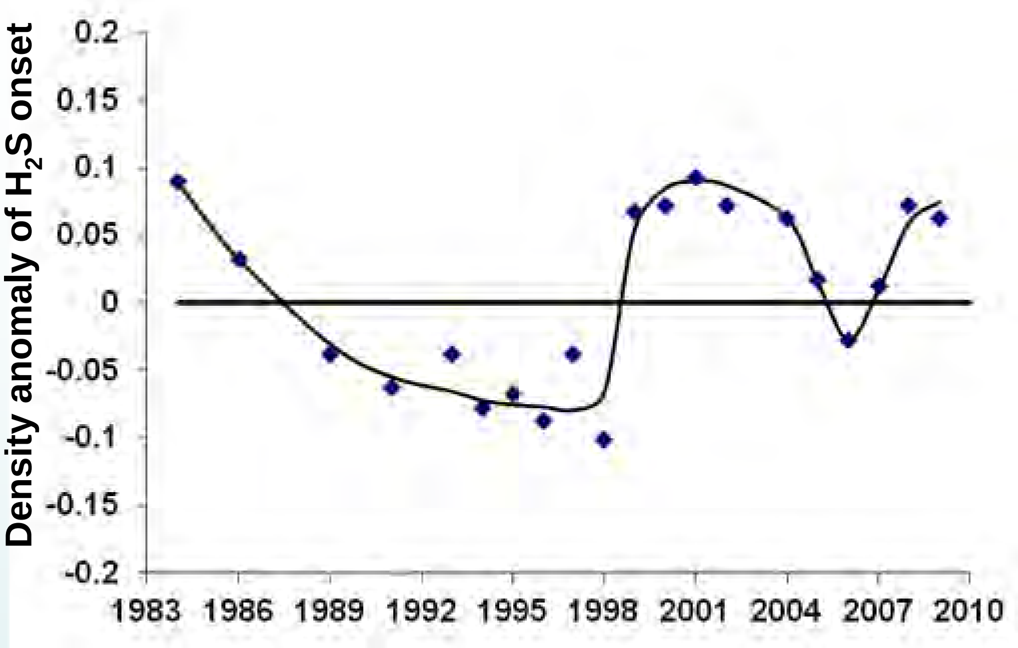
Hydrogen sulphide boundary position contrarily corresponds to DO content.

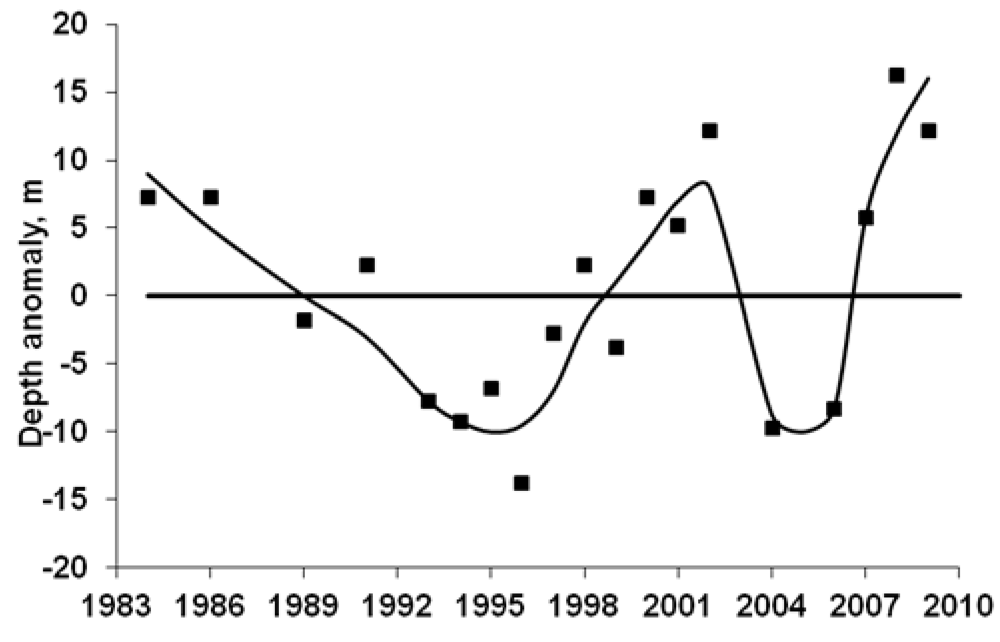
Decline of DO concentration is attended by elevation of hydrogen sulphide boundary. The density level of hydrogen sulfide disappearance was characterized by 16.15-16.25 in 1991-1998. After 2000, the position of hydrogen sulfide was stabilized at a new level 16.10.



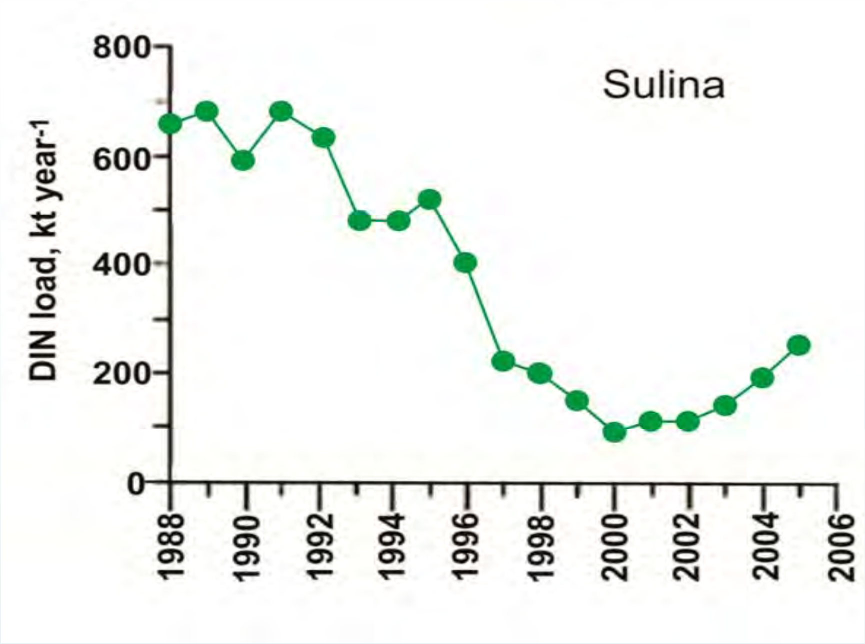
Hydrogen sulfide boundary position

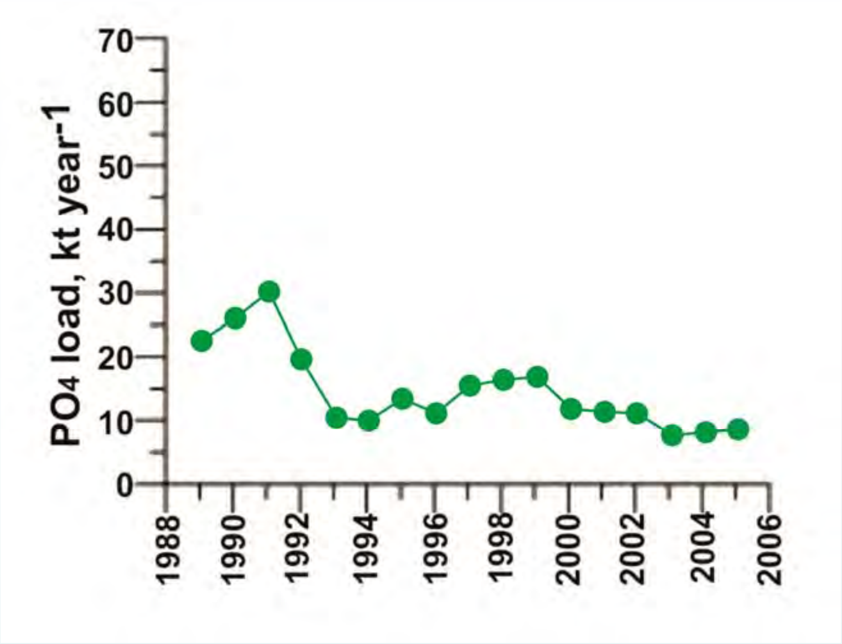
The depth range of hydrogen sulfide boundary position is about 20-30 m and nearly coincides with density variability.





Nutrients variability in the Danube River discharge

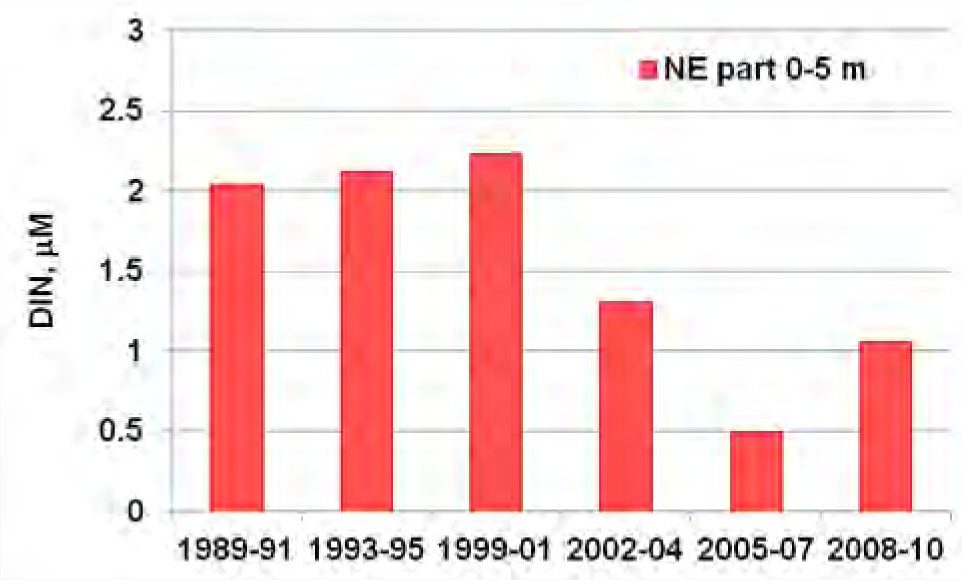


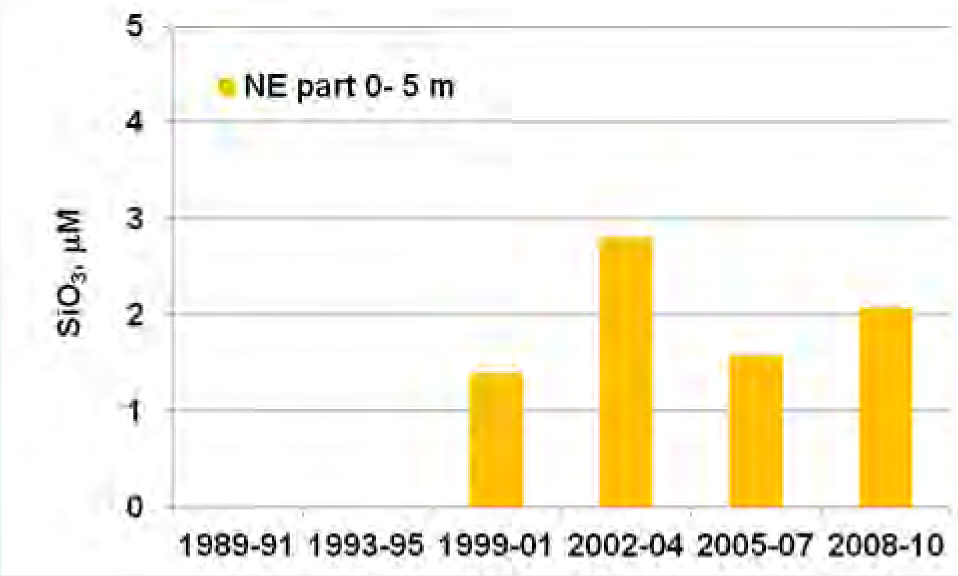


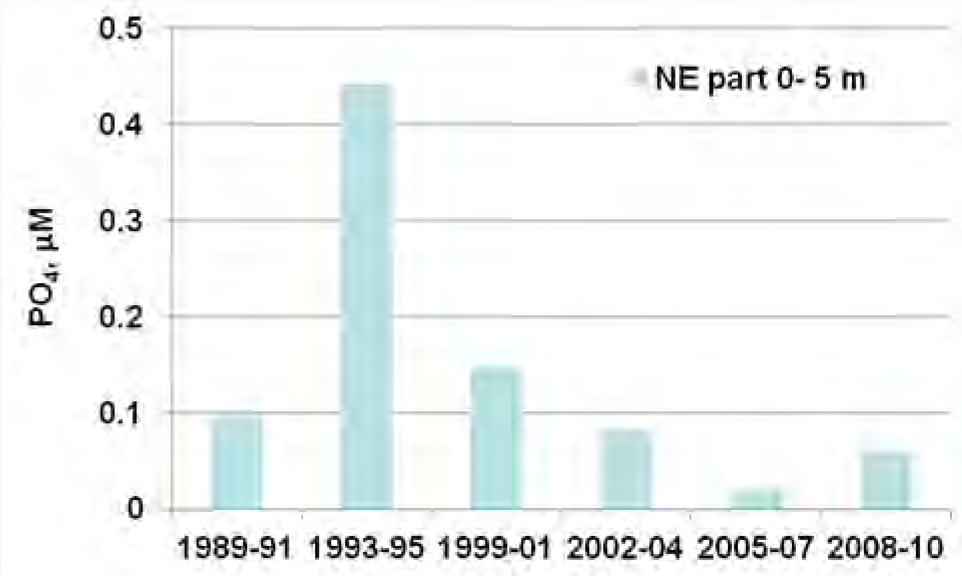
BSC, 2010. Black Sea Biodiversity Outlook. Ed.: V. Velikova.

The coastal discharge in the BS during last two decades has changed significantly with a relatively stable decrease in inorganic P since beginning of 1990s and N species after 1995. No clear trend in changes for silica.

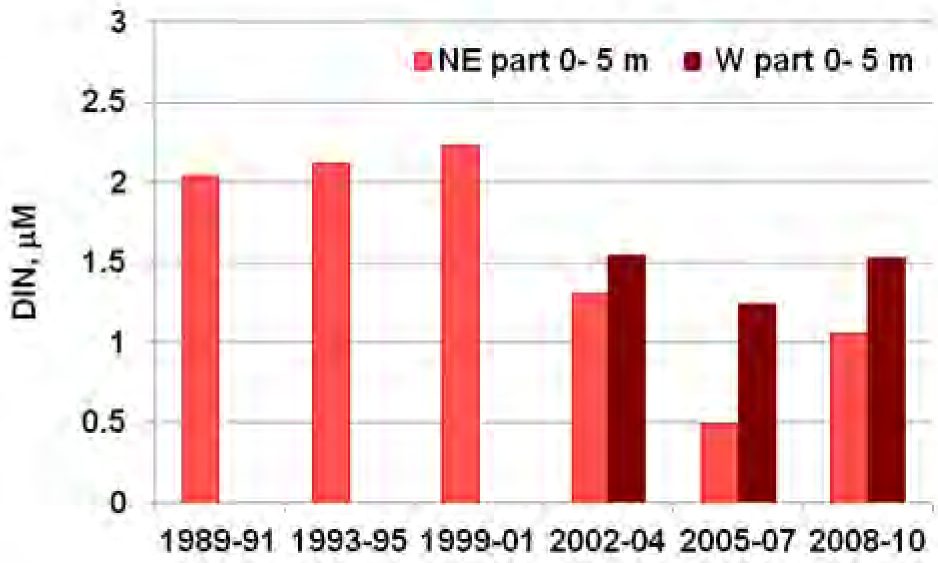
Variability of winter nutrients concentration

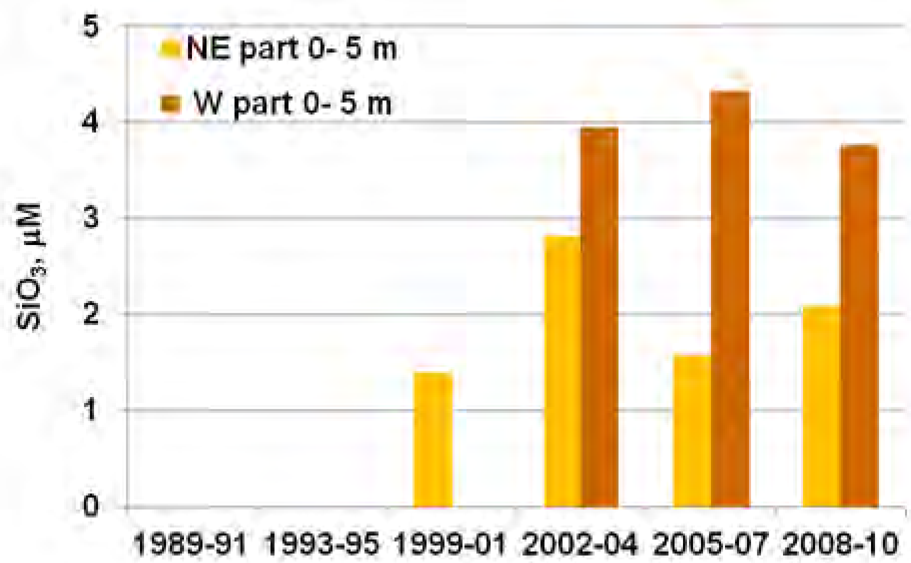


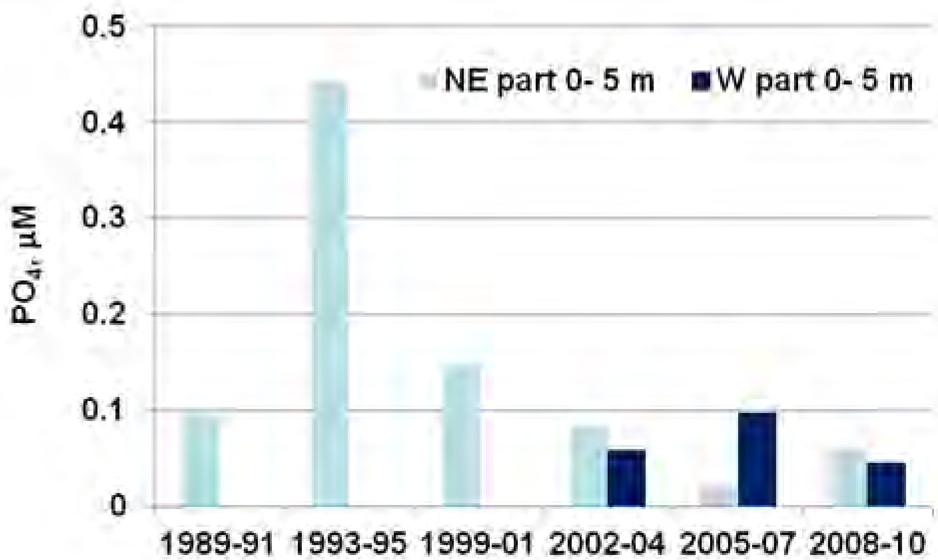




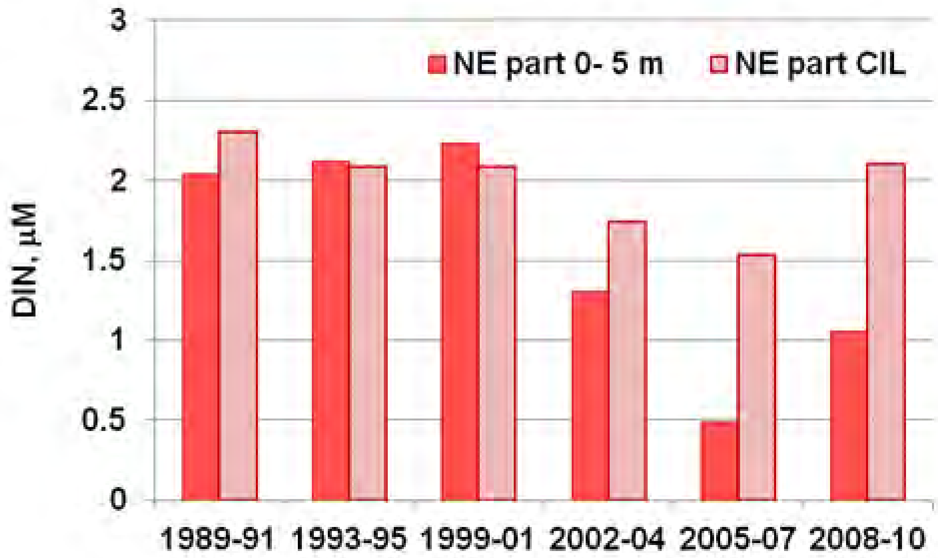
Variability of winter nutrients concentration

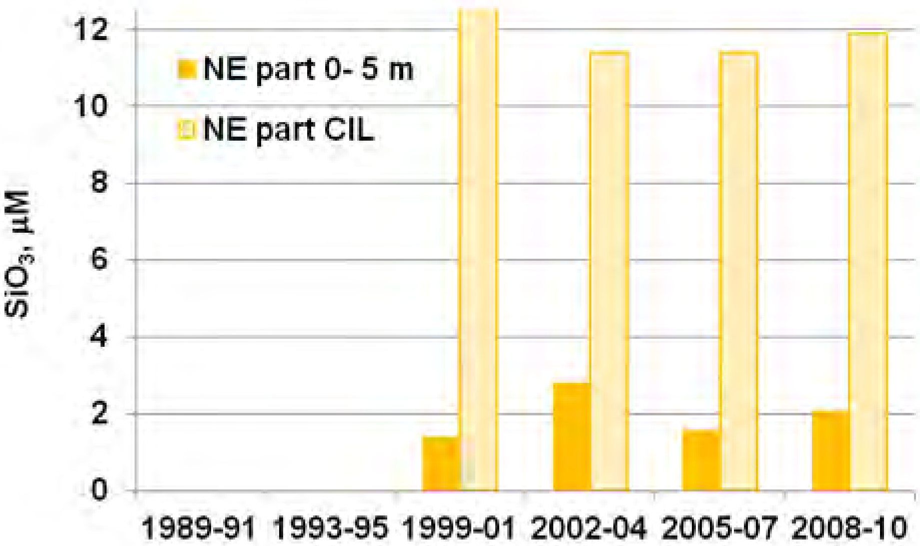


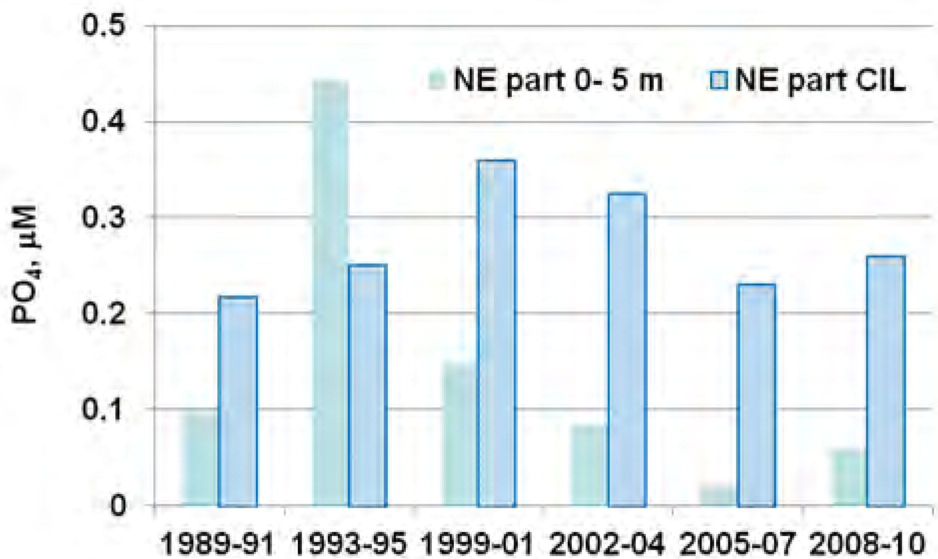




Variability of winter nutrients concentration







Interannual nutrient variability in the CIL follows to once in surface layer but smoothed in DIN and P max in 1991-2001 and min in 2005-2007. Silica interannual variability hadn't any trends.

Conclusions

1. The biogeochemical regime of the BS oxygenated upper layer was drastically changed after 1999. DO concentration in the CIL has decreased by 20% relatively to the surface layer. This indicates that the CIL waters was not fully renovated in winter seasons during last decade. The restriction of the winter mixing can be explained by (.) increase of T and (..) increase of S gradient at the CIL.
2. The decreased oxygen concentration in the CIL has lead to changes in the oxic-anoxic interface position. In warm periods (years with warm winters) elevation of the hydrogen sulphide boundary by about 10-20 m has been observed. This could have possibly resulted in decrease of the oxic zone volume up to 10%.
3. Nutrient content in the surface layer in the W and NE BS has a trend to decrease during last decade, that is more pronounced in the W part. This confirms the Black Sea ecosystem re-establishes after 1970-80 eutrophication period.
4. No clear connection was revealed between nutrient and oxygen dynamics that testify to an absence of an intensive eutrophication during the two last decades.
5. Variations of the oxygen content in the upper layers and the H_2S boundary position are determined by climatic forcing (an increase of SST and an increase in the river discharge). Nutrient supply (i.e. anthropogenic eutrophication) does not affect on it.


Thank you for attention!
The work was partly supported by Russian Federal Program
“The World Ocean” and EC FP6 Integrated Project “SESAME”