# Recent Changes in the Black Sea Pycnocline

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It is well known [1] that variability in the position of the Black Sea permanent pycnocline is mainly caused by dynamical processes: Ekman pumping, meandering of the Rim current, mesoscale eddies, *etc.* Consequently, the vertical distributions of oxygen, hydrogen sulfide, nutrients, *etc.* are better examined in relation to isopycnal surfaces [2]. This implies very little change in the average density structure of the pycnocline region within several years. Based on analyses of climatological data, Mamaev *et al.* [3] demonstrated the stationarity of the water volume above the lower part of Cold Intermediate Layer (CIL) (T=8° $\sigma_t$ = 15.6), claiming that the ventilation by winter cooling is confined to the upper part of the pycnocline (including the CIL).

Observed interannual variations of the temperature - salinity structure in the pycnocline region were attributed to possible changes in surface heat fluxes or freshwater input [4]. On the other hand, shifts in the position of the pycnocline are not evident in recent data [5].

Direct ventilation appears to be confined above the mean position of the pycnocline ($\sigma_t$ = 14.5 - 14.7), where convection and subsequent isopycnal injection is thought to be the major water mass formation mechanism [1,4,6]. Some ventilation of the upper pycnocline (down to $\sigma_t$=15.6) appears to occur in winter in the central parts of the sea [7]. Similarly, ventilation of the lower pycnocline can occur by entrainment of the Cold Intermediate Water (CIW) into the Mediterranean Water near the Bosphorus and its subsequent injection below the pycnocline region ($\sigma_t$ = 15.8 - 16.2) by intrusions of the resulting shelf modified waters [8].

Recent CTD measurements (basin-wide and partial surveys within the context of the CoMSBlack program and TU-Black Sea Project) in the Black Sea provide a unique opportunity to study pycnocline structure, and to understand the role of different mechanisms in its ventilation.

The position of selected $\sigma_t$ surfaces and the corresponding values of temperature are presented in the following. Both values are basin-averaged quantities, filtering effects of local dynamics:

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| $\sigma_t$ | average depth $m$ | | | | average temperature $°C$ | | | |
|---|---|---|---|---|---|---|---|---|
| | 1991 | 1992 | 1993 | 1994 | 1991 | 1992 | 1993 | 1994 |
| 14.8 | 65.6 | 70.4 | 72.1 | 74.7 | 7.30 | 6.94 | 6.33 | 6.58 |
| 15.0 | 71.0 | 76.5 | 80.5 | 81.4 | 7.50 | 7.26 | 6.86 | 6.88 |
| 15.2 | 77.0 | 82.1 | 86.5 | 87.7 | 7.66 | 7.53 | 7.31 | 7.18 |
| 15.4 | 84.0 | 88.8 | 92.8 | 94.2 | 7.81 | 7.76 | 7.62 | 7.47 |
| 15.6 | 92.5 | 96.9 | 100.2 | 101.8 | 7.96 | 7.95 | 7.88 | 7.74 |
| 15.8 | 102.5 | 107.0 | 109.0 | 111.4 | 8.13 | 8.10 | 8.08 | 7.98 |
| 16.0 | 115.9 | 119.8 | 121.6 | 124.8 | 8.30 | 8.27 | 8.25 | 8.19 |
| 16.2 | 135.1 | 138.2 | 139.3 | 143.3 | 8.46 | 8.43 | 8.42 | 8.38 |

The table shows considerable interannual variability in the thermohaline structure of the pycnocline. Gradual deepening of the isopycnal interfaces since 1991, together with cooling and freshening has been registrated. Meteorological data reveal a decrease in the average winter air temperature for the region in 1991 - 1993. Although the winter of 1994 was warmer, the cooling in the lower part of the pycnocline appears to have continued during this period as a delayed response to the earlier surface cooling.

The cooling between $\sigma_t$=15.2-16.2 surfaces is partly due to Bosporous influence, evident from the isopycnal temperature distribution in the vicinity of the Strait. In 1994, when the most dramatic changes were observed, the mean temperature in the central part of the sea was higher than for the whole area. It is estimated that lateral advection along isopycnals from the near Bosphorus region resulted in 0.03 C temperature decrease for the lower part of the pycnocline. This allows to estimate the volume of laterally injected water in 1993-94 to be about 2500 $km^3$. More than 50 percent of temperature decrease is estimated as due to vertical mixing.

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