VARIATIONS IN THE SEA SURFACE TEMPERATURE OF THE BLACK SEA DURING THE 20TH CENTURY

Georgy Shapiro [1]*, Dmitry Aleynik [2] and Laurence Mee [2]
[1] University of Plymouth, Plymouth, UK - gshapiro@plymouth.ac.uk
[2] Scottish Association for Marine Science, Oban, UK

Abstract
There is growing understanding that recent deterioration of the Black Sea ecosystem was partly due to changes in the marine physical environment. This study focuses on sea surface temperature variability over the 20th century. Results show that the deep Black Sea was cooling during the first three quarters of the century and was warming in the last 15-20 years; on aggregate there was a cooling trend. The Western shelf was more volatile and did not exhibit a statistically significant trend. The cooling of the deep Black Sea is at variance with the general trend in the North Atlantic and may be related to the decrease of westerly winds over the Black Sea, and a greater influence of the Siberian anticyclone. The timing of the changeover from cooling to warming coincides with the regime shift in the Black Sea ecosystem.
Keywords: Black Sea, Continental Margin, Deep Sea Basins, Temperature

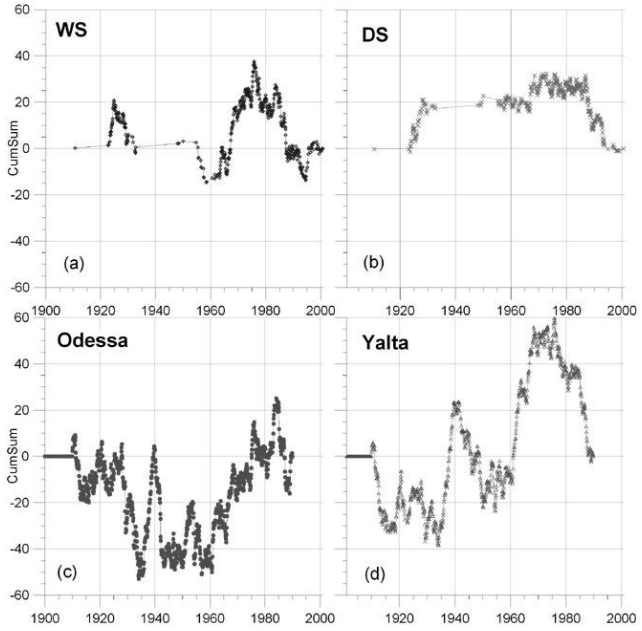

Fig. 1. The CUMSUM charts for aggregated temperature anomalies on the western shelf (a) and deep sea (b), and the CUMSUM charts for air temperature anomalies at coastal stations Odessa (c) and Yalta (d).

Introduction
Europe's four regional seas (the Baltic, Black, Mediterranean and North Sea) have all suffered major ecological change in the past three decades. The causes of degradation of the Black Sea ecosystem have been frequently cited as eutrophication due to increased fluvial nutrient load as a result of the Green Revolution [1] and the arrival of invasive species [2]. However, there is an increasing appreciation that current climate change can trigger a major response in the structure and function of marine ecosystems on a decadal timescales [3, 4, 5]. The warming of the World Ocean over recent decades has been firmly established [6]. In the Black Sea, studies of long term changes of the physical properties are sparse.

Data and methods
The source of data for this study was obtained from a number of reputable sources including the World Ocean Database 2001, the Romanian Marine Research Institute, the Goddard Institute for Space Studies and some others. In contrast to previous Black Sea studies, the monthly temperature anomalies rather than the absolute values are used as indicators of temporal changes in Sea Surface Temperature. The benefit of using anomalies is that unlike the absolute temperatures, the SST anomalies are highly correlated at stations separated as far as 1200 km [7]; this fact allows aggregating observational data over large areas of the Black Sea**.**

Results and Analysis
The SST and air temperature trends over the 20th century were estimated with both parametric and non-parametric statistical methods by calculating coefficients of linear regression, as well as Pearson, Spearman and Kendall-tau correlations. All four statistical methods clearly show that there was a definite cooling trend in the deep Black Sea over the 20th century at negative rate of (-0.86 ± 0.3) °C per 100 years. On the western shelf there is no statistically significant trend. The linear trend in the air temperature in the central Black Sea represented by the data set from Yalta weather station is negative showing a modest cooling at (-0.3 ± 0.1) °C per 100 years. In contrast to this, air temperature in the western Black Sea measured at Odessa weather station shows a positive trend at (0.3 ± 0.2) °C per 100 years. A further analysis using a CUSUM method has been carried out on an interannual and decadal scale showing a number of regime shifts in the deep Black Sea in years 1927, 1966, 1968, 1986 and 1997. On the western shelf, the regime shifts and the most significant cooling periods of the SST are associated with the most severe winters observed in 1947, 1954, 1985 and 1987. Unusual temperature trends in the Black Sea could be attributed to the variations in the overlying weather pattern, however the link is non-linear.

A relatively small (R=0.65) correlation coefficient between variations in air and sea temperatures exemplifies a non-linear response of the sea to changing weather conditions. The analysis of CUSUM charts suggests that it is the shifts in the established weather regimes on a decadal scale rather than interannual variations of meteorological forcing which lead to changes between warming and cooling phases of SST evolution, particularly in the shelf regions. The shelf and the deep sea response show different patterns of their responses to the weather conditions, which results in de-coupling of the SST variations of on the western shelves and the deep sea.

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