Sea-Level fluctuations in the Black and Caspian Seas and Global Climate Change

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The Earth's climate is an extremely difficult nonlinear system with numerous feedbacks, the dynamics of which are not obvious. Many publications contain inconsistent opinions concerning the causes of global warming. A central place in these discussions is occupied by the question of the anthropogenic factor as a principal cause of the greenhouse effect, which lies at the root of global warming. Some authors argue that anthropogenic influences are already acting as the dominant warming factor (Meleshko, 2007). Contrary to this opinion, the influence of greenhouse gases on climate change has not yet been proven (Yegorov, 2007; Datsenko and Monin, 2006; Boichenko and Voloschuk, 2006).

The scale of global climate change for the past decades is one of the most hotly debated questions. The data cited in the literature differ slightly; however, all have ascertained appreciable warming during the 1930–40s and over the last two decades (Fig.1).

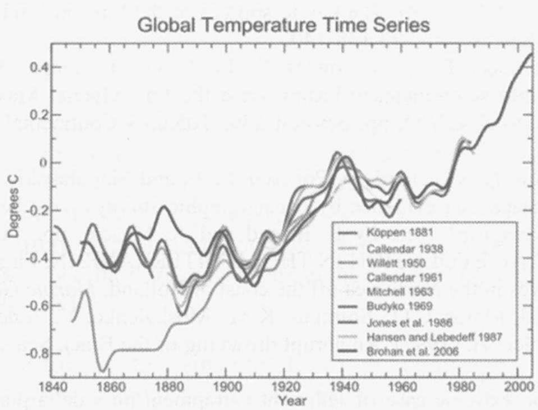

Figure 1. Published records of surface temperature changes over large regions (стоять (http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_Ch01.pdf). Köppen (1881) = tropics and temperate latitudes using land air temperature; Callendar (1938) = global using land stations; Willett (1950) = global using land stations; Callendar (1961) = 60°N to 60°S using land stations; Mitchell (1963) = global using land stations. Budyko (1969) = Northern Hemisphere using land stations and ship reports; Jones et al. (1986a,b) = global using land stations; Hansen and Lebedeff (1987) = global using land stations; and Brohan et al. (2006) = global using land air temperature and sea surface temperature data (which is the longest of the currently updated global temperature time series [Section 3.2]). All time series were smoothed using a 13-point filter. The Brohan et al. (2006) time series shows anomalies from the 1961 to 1990 mean (°C). Each of the other time series was originally presented as anomalies from the mean temperature of a specific and differing base period. To make them comparable, the other time series have been adjusted to have the mean of their last 30 years identical to that same period in the Brohan et al. (2006) anomaly time serie (IPCC Fourth Assessment Report).

Boichenko and Voloshchuk (2006) have convincingly proven that the alternation of long periods of warming and cold snaps in the extra-tropical parts of the Northern Hemisphere observed during the last hundred years can be considered as a component of natural variations. Climate change in the northwestern region of the Black Sea has shown an increased trend in mean annual surface temperature. The values of the trends (angular factors) are summarized in the Table 1.

Table 1. Values of the trends (angular factors) in the mean annual surface temperature.

Parameters	Observed period	Size of angular factor with the amendment
Global temperature	1854–1989 (n = 136)	0.76 ±0.06
Northern Hemisphere temperature	1854–1989 (n = 136)	0.68 ±0.06
Temperature (Odessa)	1876–2004 (n = 122)	0.28 ±0.09
Precipitation (Odessa)	1867–2001 (n = 135)	not significant

Regional temperature changes, in comparison with global changes, are less pronounced. This results from the fact that warming has a width differentiation (amplifies at high latitudes). At mid latitudes, it is shown not to be as pronounced. It is notable that that from the middle of the 1920s, the situation varies slightly; there is an insignificant increase in mean annual temperature and a substantial increase in precipitation.

This increase has been caused primarily by a positive trend in the discharge of freshwater into the sea and an increase in atmospheric precipitation over the seawater. These changes have been caused by changes in atmospheric circulation, particularly the strengthening of meridional circulation of the air masses. With the rise in global temperature, we observe that strengthening meridional circulation forms a positive trend in components of the water balance of the Black Sea. Here, sea-level change as a whole will be correlated with sea-level change in the World Ocean (positive dependence; Figure 2). The considered parameters produce a complex system of interconnected factors, which considerably complicates the analysis of relationships. Even to a greater degree than the temperature, the numerical values of atmospheric circulation over the Black Sea are connected with considered parameters (sea level, river discharge, atmospheric precipitation).

A stronger link with these indicators is found in the Caspian Sea. The analysis of components of water balance in the Caspian Sea has revealed that the basic contribution (up to 72% of dispersion) in variability of sea level is attributed to inflow of river water (discharge zone of the Volga River basin; Mikhaylov, 2004). The reasons for the change in the Volga discharge include variability in atmospheric precipitation (largely during the winter) in the river basin. The precipitation regime, in turn, is defined by atmospheric circulation. It has been proven that an increase in sediment discharge into the Volga basin is caused by sub-latitudinal atmospheric circulation, and a reduction – to a sub-meridional type.

This circumstance explains some of the discrepancy in the graphs presented above (Fig. 2). Results of our research have shown the possibility for change in the processes occurring in the marine environment, essentially simultaneously with changes in atmospheric circulation. This link is better expressed in the fluctuations of the Black and Caspian Seas than in global temperature changes, though it is undoubtedly caused by the latter.

The original source of the moisture in the Volga basin is the North Atlantic climate. It is there, where an increase of evaporation from the sea surface leads to an increase in the amount of moisture transferred to the continent and, consequently, to an increase in atmospheric precipitation in the Volga basin. Recent fluctuations in the Caspian Sea level have been influenced mainly by anthropogenic factors (Fig. 2). For example, there was a reduction in discharge because of irrevocable losses to filling of water basins, evaporation from the surface of artificial reservoirs, and water extraction for irrigation. It is believed that since the 1940s, irreversible water consumption steadily increased, which has led to reduction of inflow of river water to the Caspian Sea and an additional decrease in its level compared with the natural trend. At the end of the 1980s, the difference between actual sea-level and the restored (natural) one has reached almost 1.5 m (Malinin, 1994). Thus, total water consumption in the Caspian Sea for those years has been estimated at 36–45 km^3/year (the Volga accounting for nearly 26 km^3/year). If not for the withdrawal of river water, the rise in sea level would have begun not in the late 1970s but in the late 1950s.

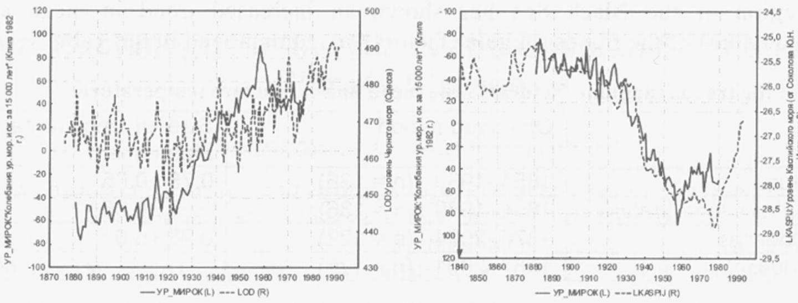

Figure 2. Comparison of the World Ocean level to the level of Black Sea (left) and with the level of the Caspian Sea (right). In the graph on the right, the Y-axis is directed downwards.

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