# CLIMATE, RIVER DISCHARGE AND SEA-LEVEL CHANGES DURING THE PERIOD OF INSTRUMENTAL OBSERVATIONS

*Likhodedova O.[1], Konikov E.G.[2]*

[1]Department of Engineering Geology and Hydrogeology, I.I. Mechnikov Odessa National University, 2, Shampanskii Per., Odessa 65058, Ukraine, log44@mail.ru; Scientific and Educational Center of Geoarchaeology, Marine and Environmental Geology (SECGMEG), Odessa 1.1.Mechnikov National University, 2, Shampansky Per., Odessa 65058, Ukraine,
konikov@mail.ru

**Keywords: spectral analysis, atmospheric circulation, drainage basin**

## Introduction

In actuality, the study of the dynamics of Black Sea level has implications for the development of the coastal zone, as well as economic and ecologic issues. The longest period of instrumental observations of sea-level (Odessa) spans 140 years (beginning in 1876). The majority of investigators hols a view of eustatic character of Black Sea level changes during the period of interest (Fomicheva 1986; Altman 1990). A significant role is attributed to the discharge of freshwater (fluvial, atmospheric precipitation) into the Black Sea. The leading role in this influx is the fluvial water discharge in the northwestern part of the basin - Danube, Dnieper, and Dniester (approximately 85% of the total discharge).

## Results and Discussion

Based on the results of data processing, the fluctuations in river discharge reveal themselves in both annual and multi-year sea-level changes (Fig. 1).

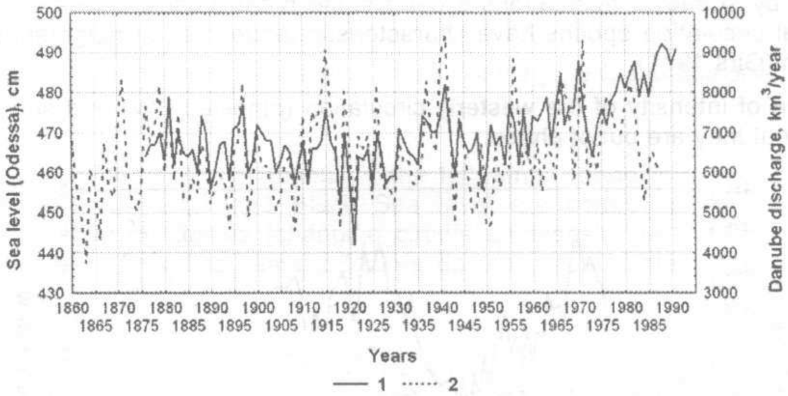


Figure 1. Plot comparing mean annual sea-level changes in the Black Sea (1) and Danube River discharge (2).

A mutual spectral analysis of Danube discharge and sea level shows high coherence coefficients for the periods 2-5, 11-14, 22, and 28 years. Maximum coefficient values (0.94 and 0.84) correspond to periods of 2.2 and 5.0 years. River discharge is largely defined by the character of atmospheric processes and their intra-centennial and multi-annual changes. The correspondence of these processes creates a cumulative climatic effect of warming and cooling phases, as well as increase and decrease in precipitation. The discharge of Danube, Dnieper, and Dniester Rivers is expressed differently during these periods (Fig. 2A). The differences are related to latitudinal extent of their drainage basins, as well as their longitudinal positions. It should be noted that during periods dominated by westerly atmospheric circulation, the river discharge changes nearly synchronously, whereas during epochs of meridional circulation there is a phase shift in the fluctuations of Danube discharge relative to Dnieper and Dniester. As a whole, the multi-year fluctuations of the annual discharge (Fig. 2B) are defined by the changes in climatic conditions (temperature, precipitation), which are in turn controlled by the atmospheric circulation.

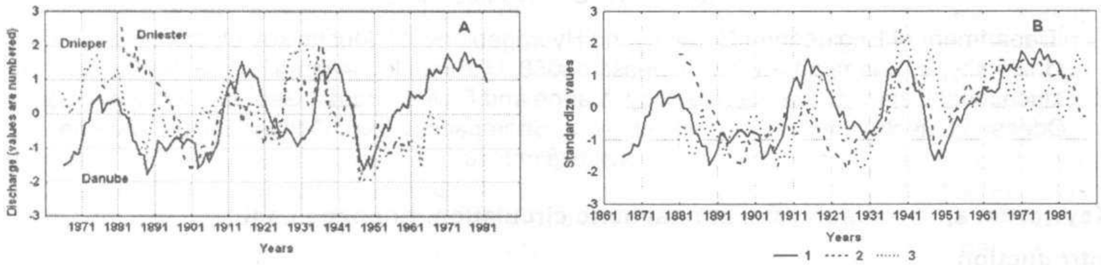


Figure 2. A. Mean annual discharge of Danube, Dnieper, and Dniester; B. Mean annual discharge of Danube (1), annual precipitation (2) and air temperature in Odessa (3). Note the 11-year smoothing and standardization of spectra.

Sea-level changes are controlled to a large degree by circulation shifts (epochs) and associated climatic (near-surface air temperature, precipitation, atmospheric pressure), hydrogeologic (river water discharge), hydrologic (storm activity) and other factors. As demonstrated earlier (Likhodedova, Konikov 2006), during epochs dominated by westerly circulation (W and NW) sea level fluctuates around a mean value with a slight negative trend. During epochs with easterly circulation (E and NE) sea level rises. The angular trend coefficient in both cases is 0.64 at the confidence level of $p<0.05$. Essentially the same relationships are observed in the Mediterranean Sea level. The westerly circulation epoch is characterized by sea-level fluctuations around some mean position, whereas the easterly and meridional circulation epochs have characteristic tendencies of heightened level in the Mediterranean (Girs 1971).

The correlation of intensity of the westerly circulation (amplitude W) and sea level (Fig. 3) demonstrate that they are out of phase.

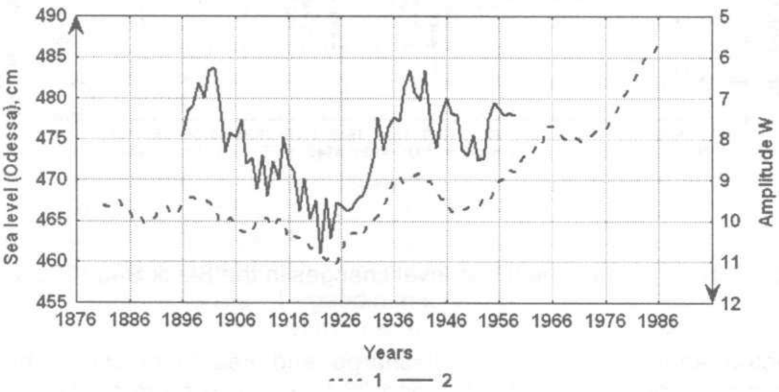


Figure 3. Comparison of sea level (1) and amplitude W (westerly circulation; 2) with 11-year smoothing.

Spectral analysis of the amplitude W and sea level shows a presence of high coherence coefficients in the long-period components. The repetition of circulation processes of the westerly type characterizes the intensity of general atmospheric circulation. During increase in westerly circulation intensity, the Black Sea level drops; during weaker periods, it rises. As mentioned by Likhodedova and Konikov (2006), a characteristic feature of mean annual changes in sea level during the 1876-1991 period is a shift from its fall to a rise during the 1920s. On average (based on a linear trend), sea level during 1876-1921 dropped by 6.5 cm, whereas during 1921-1991 it rose by 26 cm. Sea-level fluctuations during the first period reached 37 cm, for the second - 50 cm. The rate of sea-level change during 1876-1921 was 0.14 cm/yr; for 1921-1991 it was 0.37 cm/yr.

Short-period sea-level fluctuations are conditioned by changes in freshwater influx, while the trend is controlled by the long-period changes in the level of Atlantic Ocean, which are manifested by the volume of water exchange through the Bosporus Strait. Sea-level changes in the World Ocean and river discharge into the Black Sea are the resonance of the activity of global factors (global atmospheric processes). This is confirmed by the similarities in the trends of sea-level changes in Brest (Atlantic coast of France) and the Danube discharge (Fig. 4).

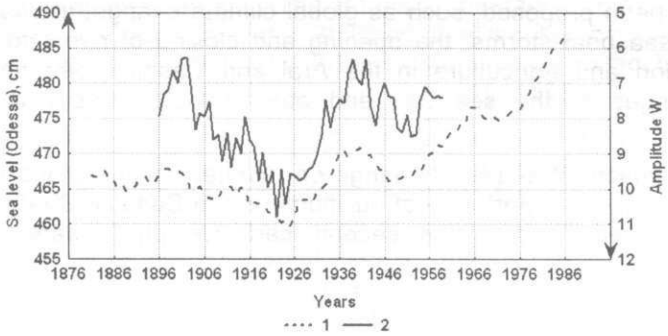


Figure 4. Changes in mean annual sea level in Brest, France (1) and Danube discharge (2).

**Conclusions**

The main conclusion of our investigations is the following: during the instrumental period, fluctuations in river discharge and Black Sea level are controlled by the changes in atmospheric circulation processes (changing circulation types). The positive trend in sea level and discharge is linked to climatic factors on the global scale: global warming and relative increase in humidity.

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