Long-term trend of the sea level at the Romanian littoral

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Introduction

Sea level recording in Romania dates back to 1859, when European Commission of the Danube, in order to improve the navigation conditions at the Danube mouths, initiated the observation of the sea level by setting up a visual tide staff (VTS) where three readings were made daily. These values were afterwards used for the entire Danube leveling.

In 1933 a float-type gauge was placed at Constantza and it is still operational in the same place. Different institutions were in charge with the exploitation of this tide gauge such as Maritime Harbour Service or Military Hydrographic Service. Romanian Marine Research Institute as being subordinated to the Ministry of Waters, Forests and Environment Protection, was assigned to carry on this activity since 1970, the year of its foundation, and this work is ongoing. After 1974, three other tide gauges were put into function for a better coverage of the entire Romanian littoral.

Tide gauge network at the Romanian littoral

RMRI tide gauges that are operational are located in the following points: Constantza, Tomis, Sulina and Mangalia (Fig. 1).

Description of the tide gauges:

Constantza: (Fig. 1, Fig. 2, Picture 1, Fig 3a, Fig 3b);
Geographical position: 44°10'21.0" N, 28°39'34.0" E. Float operating tide gauge, OTT type, functional in Constantza Port since 1933, recordings on paper chart, changed once a week. Two VTS are used, one of them for control, and three readings are made daily.

Tomis: (Fig. 1, Picture 2), situated in a small marina, about 1.5 km north from Constantza Port. Float operating and VTS. Three VTS readings are made daily.

Sulina: (Fig. 1, Picture 3), situated at the northern limit of the Romanian littoral. Geographical position: 45°09'45.6" N, 29°43'37.2" E. Float operating tide gauge, type SUM, functional since 1977, daily charts. It is placed near the meteorological station 6 km downstream Sulina locality, on the southern side of the jetty. A horizontal pipe connects the stilling well with the open sea. Violent storms damaged the VTS and a new one is to be installed this year.

Mangalia: (Fig. 1, Picture 4) Situated in the southern area of the Romanian littoral in Mangalia harbour. Geographical coordinates are 43°48'30"N, 28°35'30"E. Float operating, SUM type, daily chart, VTS readings three times a day. Due to sand accumulation that obstructed the stilling well, it was relocated in Dec. 1998 to a new position on the opposite quay of the same port.

Characteristics of the hydrological and meteorological regime of the area

Situated at mid latitudes, the northwestern part of the Black Sea experiences the general conditions imposed by a temperate continental climate, with cold winters and warm summers. Siberian anticyclone influence alternates with the southern Mediterranean circulation. Consequently the rivers which debauch in this area will have an annual high in spring season when the precipitation in their hydrographic basins are in excess, and a minimum in warm seasons when evaporation processes become dominant.

The main components of the water balance in the area of our littoral (Altman, 1990; Bondar et al. 1991) is continental runoff via the Danube discharge, which is 60% of the total fresh water discharged into the sea, and precipitation and evaporation. The high sea levels in the first part of the year occur in the condition of a considerable increase of the river volume and important precipitation quantities (53% in May - August) and a reduced evaporation (37% in the first six months of the year. (Selariu, 1971)). Analysis of our data regarding Danube's annual regime indicates a maximum mean discharge in May of 23.74 km^3. Maximum discharge of 38.89 km^3 occurred in May 1970. The lowest mean discharge, 11.82 km^3, was recorded in October, with a minimum of 5.89 km^3 in October 1946.

The wind regime at the Romanian littoral is variable, but in certain seasons prevalent frequencies may occur (Climate of Romania). Long-term averages of the wind (1941 - 1997) indicate high frequencies from northern and western directions, 14.9% north and 15% west, where the highest mean speed was recorded as well (north 6.0 m/s). South and southeast winds present a notable frequency, 11.9% and 9.3%, respectively. Due to the coastline orientation, onshore winds produce a sea level rise (northerly and easterly), while offshore wind have an opposite effect (Fig. 4). A significant change of the sea level is induced by strong winds blowing from the same direction for more than 48 hours. Also, short term changes in the sea level are due to the sub-basin seiches (Blatov et al., 1984).

Sea level annual characteristics

As previously mentioned, sea level evolution presents high values in the first part of the year and low ones in the second (Fig. 5). Mean monthly values, which are positive all over the year, range between 6.84 cm in October and 21.24 cm in May. The maximum mean value, 46.40 cm occurred in March 1970, and the Danube discharge reached its maximum mean monthly value in May of the same year, 38.89 km^3. The low values in the autumn, -13.20 cm in October and -14.20 cm in November, are exceeded in February 1949, when the volume of the Danube is low (7.16 km^3), and severe winter conditions were recorded.

The highest amplitudes, 54.90 cm and 54.40 cm, occurred in February and March, respectively, while lowest amplitude, 35.20 cm, occurred in September and corresponded with the Danube volume's lowest amplitude of 16.27 km^3 in September as well.

Sea level long term evolution

A general, preliminary approach of the sea level long-term evolution indicates that a slight rise of the values is evident. Soviet scientist Altman (1990), considering the entire Black Sea basin, indicated a rising tendency between 1875 and 1985, especially in the last 50

years. His estimate is 1.5-2.0 mm/year. Romanian scientists (Banu, 1961; Bondar & Filip, 1963; Selariu, 1971) analyzed the sea level evolution in different periods and they all identified a rising tendency. Using data between 1933 and 1956, Banu (1961) indicated a mean value 12.7 cm and a tendency of 0.425 cm/year. Selariu (1971), for the period 1933 - 1969, found 13.02 cm as mean value and a tendency of 0.256 cm/year. Later on, studies of the Romanian Marine Research Institute (RMRI) found 13.5 cm for 1933 - 1978 and 14.3 cm for the period 1933 – 1983.

Analysis of the data set between 1933 and 1998 reveals the following aspects :

- annual means are positive, with only two exceptions: -2.44 cm in 1943, the lowest annual mean, and -1.22 cm in 1983;
- the highest annual mean (29.70cm) occurred in 1970, when exceptional runoff was recorded;
- negative values in the entire period represent only 9.7% of the data and these occurred between September and February;
- the mean sea level value, 14.2 cm, is positive relative to the initial reference zero;
- for the entire period, the linear rising trend (Fig. 6) has a value of 0.128 cm/year;
- the Danube's mean water flow at the outlet into the Black Sea during 1858-1988, with an average value of about 191 km^3/year, also has an increase trend in time (Bondar);
- the interannual and interdecadal variations have large amplitudes, and a long period oscillation could be detected;
- the averages computed for the 1946-1955 decade is 10.8 cm, while that of the 1966-1975 reaches 18.6 cm;
- spectral analysis reveals strong oscillations with periods of 2.5 years and 4 years, similar to those of the river discharge (Fig. 7);
- the correlation of the variables in the time domain (monthly averages) is significant (Fig. 8);
- the wind regime has only a temporary influence and does not affect the long-term evolution of the sea level.

Conclusions

The analysis of the data measured at the Constantza sea level gauge during 1933-1998 period revealed the existence of a rising trend, in good agreement with the estimates made by other authors for different locations (Gorjachkhin, 1995) or for the entire Black Sea basin (Altman et al., 1990). This is also consistent with the contemporary eustatic trend.

Also, significant interannual and interdecadal variations have been observed and estimated through spectral analysis. They are correlated with the changes in the Danube discharge, the main contributor to the river input into the sea. However, the time series are not long enough to allow for the secular oscillations to be accurately assessed.

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LEGEND
▼ Tide gauge and VTS

1933-1999

TOMIS MARINA

Location of the old tide g.

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BLACK
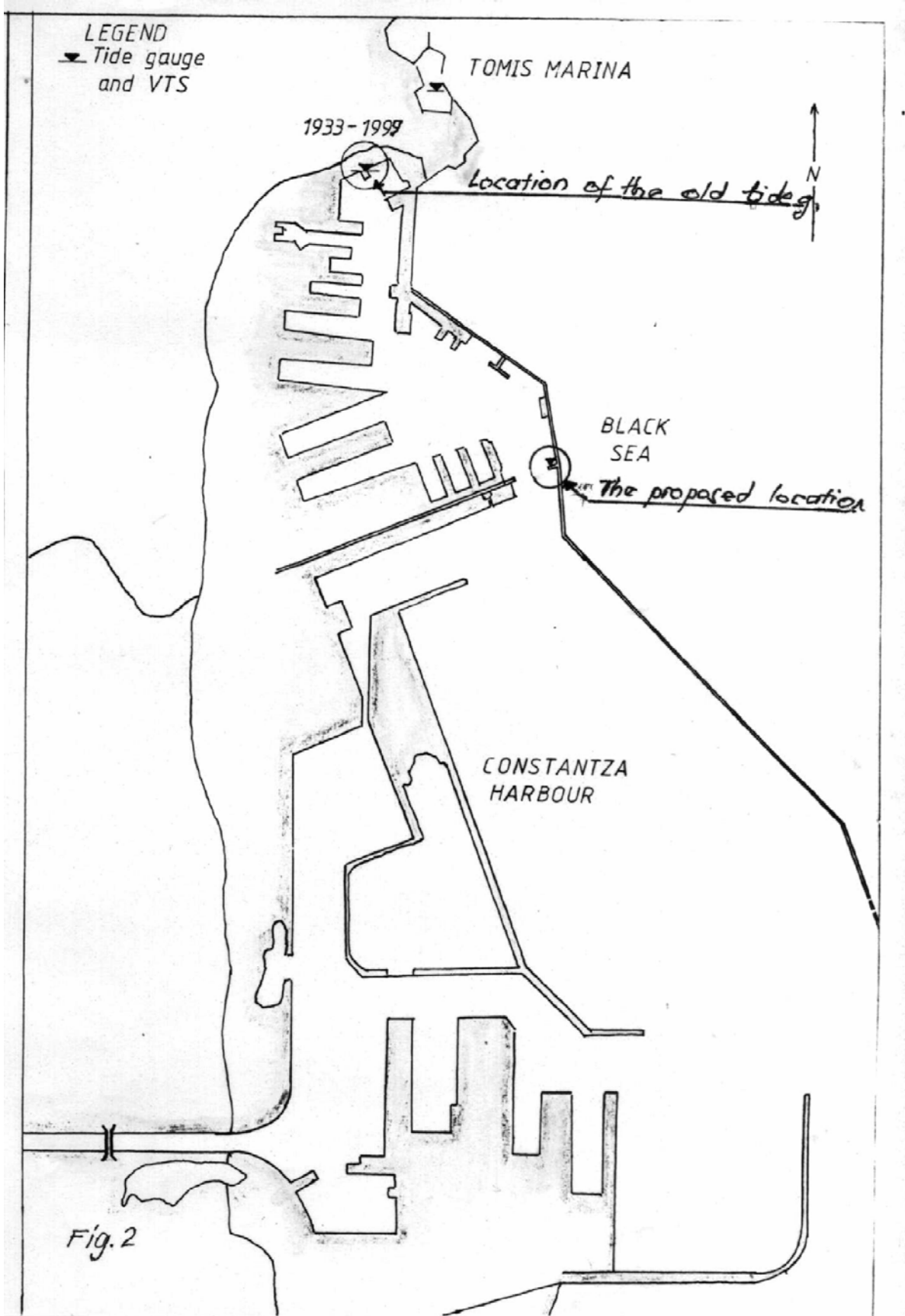SEA

The proposed location

CONSTANTZA
HARBOUR

Fig. 2

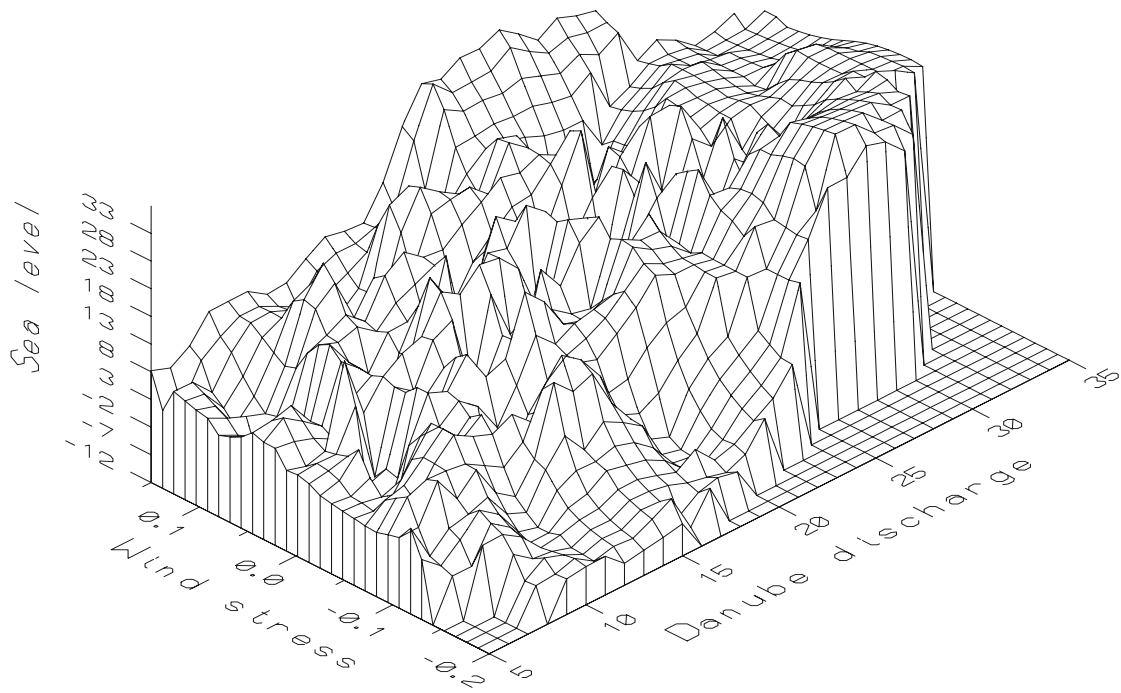Figure 1. Map of the Constantza area.

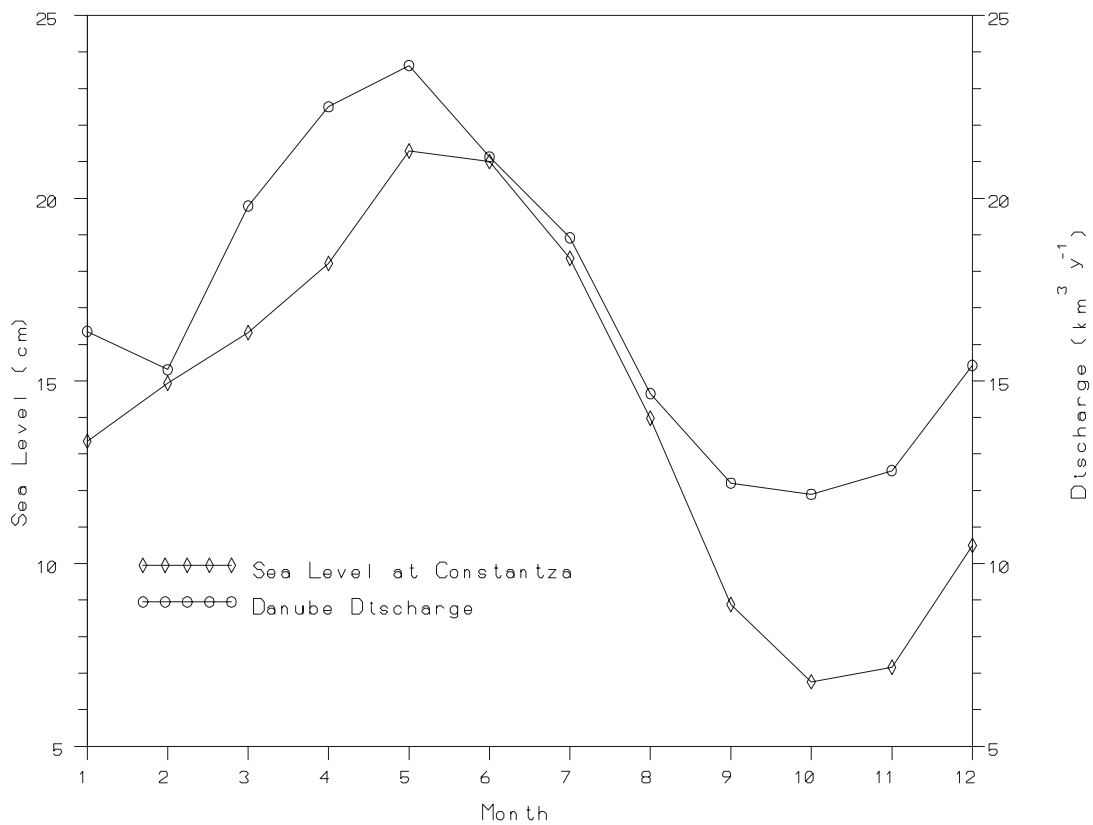Fig. 2 Correlation between sea level and hydro-meteorological parameters

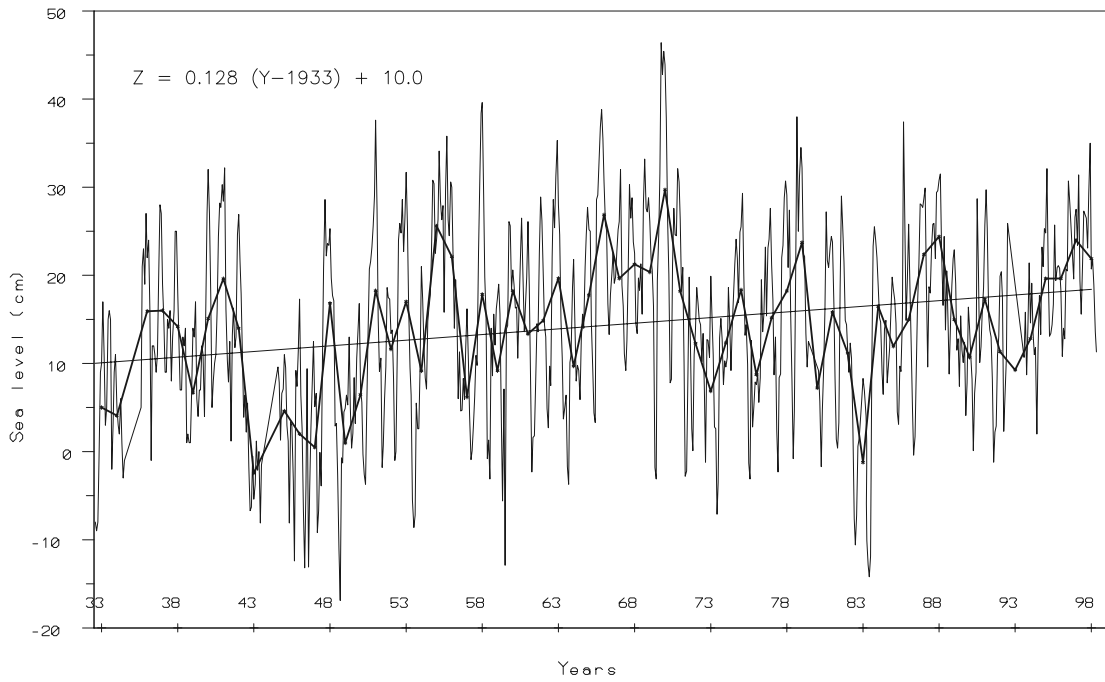Fig. 3 Annual evolution of the sea level at Constantza and Danube Discharge (1933 - 1998)

Fig.4 Evolution of the monthly and annual means of the sea level at Constantza and their trend
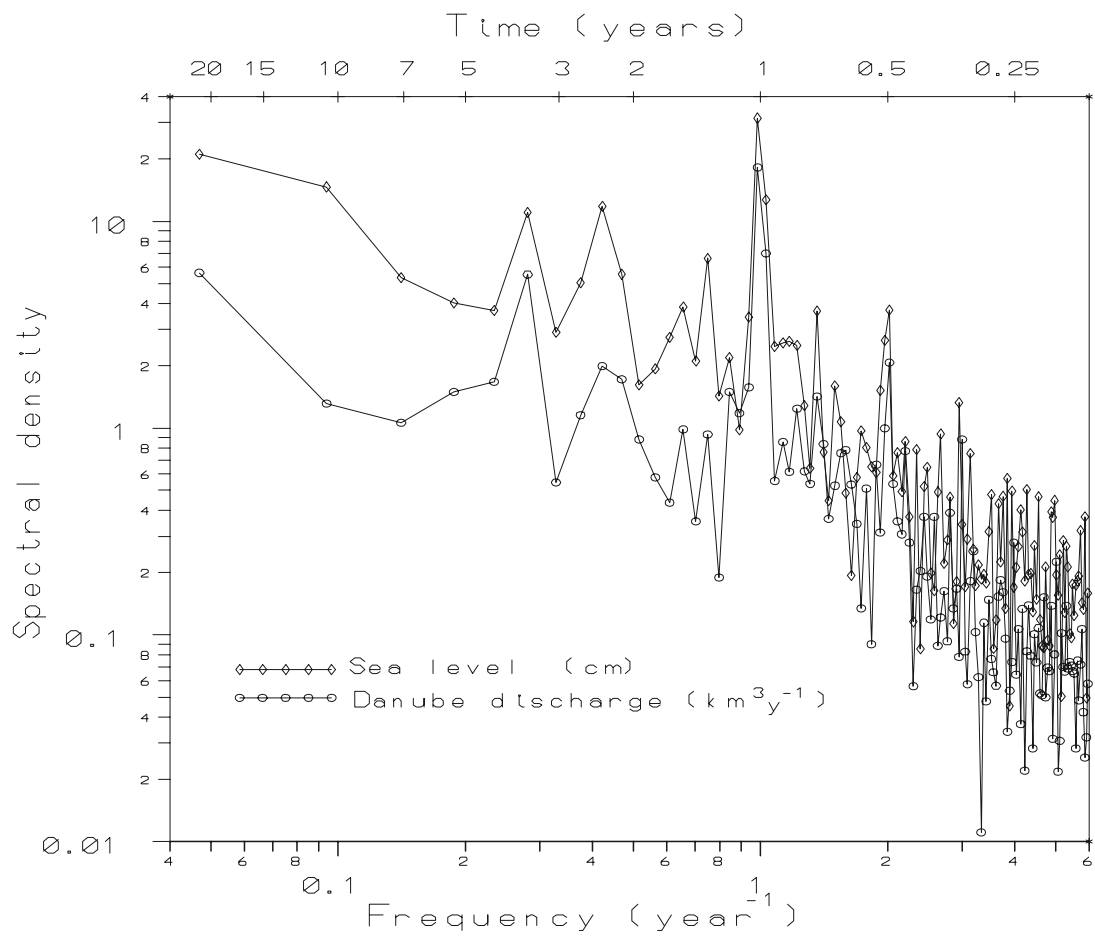

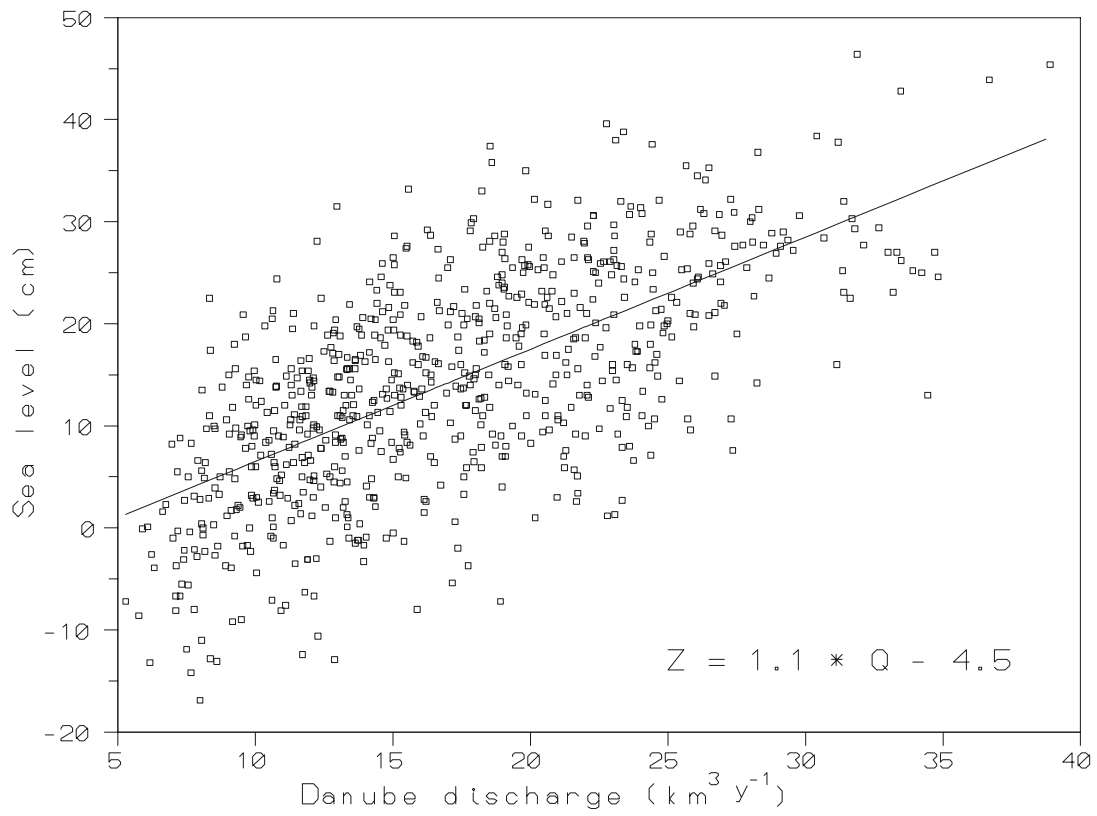Fig. 5 Spectral density of the sea level at Constantza and Danube discharge

Fig. 6 Correlation between sea level monthly means and Danube discharge