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Research Article

The Effect of the Peak Discharges of River Danube on the Strait of Istanbul (Bosphorus)

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Abstract

The Strait of Istanbul (Bosphorus: SoI) is the meeting point of Black Sea and Marmara Sea. It is under influence of many hydrological, oceanographical and meteorological variables. Clearly, it is known that River Danube discharge reaches to the Sea of Marmara via SoI. The approximate distance between outlet of River Danube and northern end of the SoI is nearly 500km. In this study, the influence of the peak river Danube discharges (higher than 11000 m^3/s) on the SoI is investigated by using dataset of TAISEI Corporation, ISKI, Turkish State Meteorological Service and GRDC, Grains Research and Development Corporation. To this end, the power spectra of River Danube is calculated and compared with those of water level, surface layer water salinity and finally, surface water temperature data at the northern end of the SoI. In addition, the time series of water temperature, water salinity, and water level of the northern end of the SoI is examined together with time series of River Danube discharge between 1st Oct 2004 and 31st Sept 2005. The validation is performed by checking wind speed, air pressure and precipitation data on the SoI during that time.

Keywords: The Strait of Istanbul (Bosphorus), Water Level, Power Spectra, River Danube, Lag Time, Black Sea

Introduction

There are various studies in the literature that deal with hydrodynamics of the Strait of Istanbul (Bosphorus: SoI, Sur et al., 1994; Özsoy et al., 1996, 1998; Doğan et al., 1998; Oğuz T., 2005; Jarosz et al., 2011; Öztürk et al., 2012; Gündüz and Özsoy, 2016; Tutsak, et al., 2016; Stanev et al., 2017; Beji and Erdik, 2018; Erdik et al., 2018; Erdik et al., 2019a; Erdik et al., 2019b, Gündüzi et al., 2020; Saçu et al., 2020). However, there is only a few studies in the literature that deal with constructing the relationship of River Danube with the northern Strait of Istanbul. The conclusions drawn in those studies are mainly based on limited dataset and rough estimations. Sur et al., (1994) used monthly mean discharge of River Danube and monthly mean salinity of SoI to find out effects of River Danube on SoI. They roughly estimated the lag time approximately between 1-2 months. Similarly, Yüksel et al., (2008) observed the monthly mean water level of northern SoI and River Danube discharge and indicated 2-month lag time. Lastly, Şen et al., (2019) demonstrated a linear relationship between the 2-month-ahead monthly flow of the SoI, computed by a numerical model, and River Danube flow observations. In this study, a-year long 4 different higher resolution datasets (with a 1-day sampling rate) are used to investigate the relationship between River Danube and northern SoI. Those are discharge of River Danube and surface water temperature, surface water salinity, water level at northern end of SoI. In addition to this, wind speed, air pressure and precipitation data on SoI are also checked for validation.

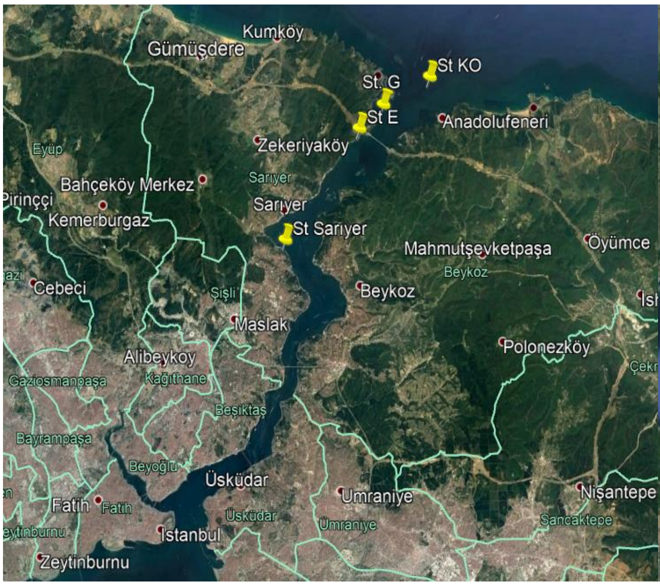
Table 1- Measurement locations and durations.

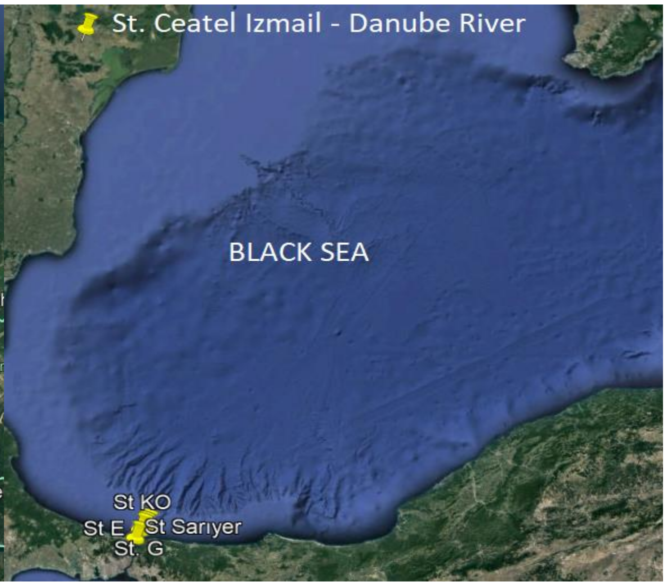
Stations	Measured Period	Measured Characteristics	Time Interval	Locations
St E	22.09.04-05.01.06	Water level, salinity and temperature	Hour	41^0 12' 13'' N, 29^0 05' 54'' E
St G	19.11.04-05.01.06	Wind speed, air pressure	10 min	41^0 24'' N, 29^0 6'' E
St Sarıyer	01.01.04-31.12.05	Precipitation	daily	41^0 08' 47'' N, 29^0 03' 0.7'' E
St K0	01.01.04-31.12.05	Salinity	monthly	41^0 13.50' N, 20^0 08' E
St Ceatal Izmail	01.01.04-31.12.05	Discharge	daily	45^0 21' 67'' N, 28^0 71' 67'' E

Data and Study Area

All data measurements and durations are clearly depicted on Table 1.

Wind speed, atmospheric pressure, water level, temperature and salinity were monitored in St. E and G by TAISEI Corporation, JAPAN, on behalf of General Directorate of Marmaray Project of Ministry of Transportation, General Directorate of Ports, Airports and Railways Construction of Turkey (Fig. 1a). On the other hand, water salinity measured in K0 by Istanbul Water and Sewerage Administration (ISKI) and precipitation measured by Turkish State Meteorological Service in Sarıyer Station are also employed. River Danube discharge data were measured for 2004-2005 by Grains Research and Development Corporation (GRDC, Fig. 1b). Locations of the aerial view of River Danube and SoI are clearly shown in Fig 1c.





a b

c

Fig. 1- General views of a) Station G, E, Sarıyer and KO on SoI and b) Station Ceatel Izmail on River Danube, c) Locations of River Danube and SoI.

Methodology and Results

The power spectra of River Danube (Fig. 2a) is plotted by using discharge data of one year and compared with those of water level (Fig. 2b), surface layer water salinity (Fig. 2c) and water temperature (Fig. 2d) at the northern end of SoI for the same period. As seen in Figs. 2 a-c, similar trends are observed between power spectra of River Danube and those of water level and surface water salinity, especially with periods of 4, 3, 2 and 1 months, depicted in red solid ellipses.

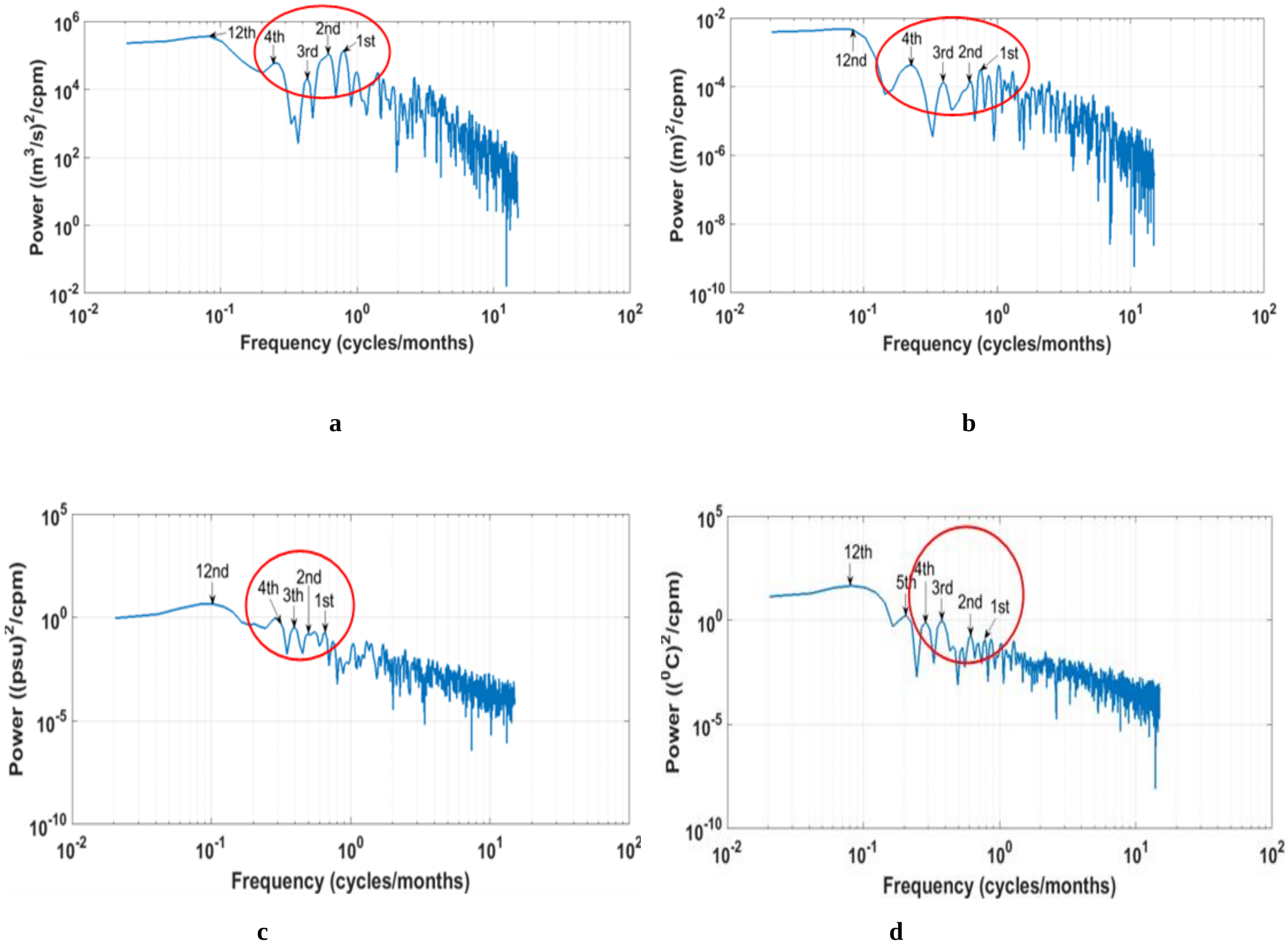


Fig. 2. Power spectras of (a) River Danube, (b) water level, (c) surface water salinity, (d) surface water temperature at the northern end of the SoI.

The influence of River Danube on SoI is clearly visible on those graphs. In addition, surface temperature power spectra (Fig. 2d) also demonstrates similarity with River Danube but with a little difference; the 5-month period is observed there, which is considered to be caused by local meteorological conditions around the SoI.

Maximum runoff discharge occurs at the 2nd of May, 2005 (214th day of the year), depicted in solid square (Fig. 3a). Water temperature loses its sharpness (Fig. 3b) while it has to rise dramatically because of the summer season and salinity stays stable (Fig. 3c) while those should be on rise because of the high evaporation effect in July. A dramatic increase in 15th July 2005 (288th day of the year) is obviously seen on the northern water level (Fig. 3d). Özsoy et al., (1996) states that there are three main effects to force the mechanism of water level increase in SoI. These are incoming fresh water to the Black Sea, atmospheric pressure differences and wind setup. In addition, precipitation might also increase surface water level in Black Sea (Ünlüata et al., 1990). To ensure that there is no extraordinary atmospheric phenomenon on the related dates that affect the water level instead of Danube River Discharge, the time series of the northern and eastern (Figs. 4a-b) wind speeds, air pressure differences (Fig. 4c) and finally daily precipitation from Sarıyer meteorological station (Fig. 4d) are also checked, depicted in solid squares. Clearly, wind speeds, air pressure, precipitations are observed minimal level during that day. Eastern and northern wind speeds are observed to be 5.402 m/s and -0.432 m/s, respectively (Fig 4a-b). And air pressure (Fig 4c) is about 1010 hPa and the precipitation is zero at that time (Fig. 4d). The period between the maximum discharge of River Danube (2nd of May, 2005) and the peak of the water level at northern end of SoI (15th of July, 2005) indicates that the lag time is 74 days, which is higher than the last study by Şen et al., (2019), estimated 2 months lag time, the highest one in the literature, Danube River to SoI.

The second maximum runoff discharge occurs at the 22nd of July, 2005 (295th day of the year), depicted in a solid ellipse (Fig.3a). A radical decrease is noticed both in surface water temperature (Fig. 3b) and surface salinity values (Fig. 3c) at the 27th of September, 2005, which clearly indicates the cold and fresh water impact of Maxima River Danube discharge on SoI. Additionally, water level of Northern SoI (Fig. 3d) shows a peak at the 27th (362nd day of the year) of

September, 2005, which coincides with the decrease of surface water temperature and surface salinity, which depicts incoming high volume freshwater from Danube River. Those aforementioned indications clearly demonstrate the influence of River Danube on SoI. The period between the second peak discharge of River Danube (22nd of July, 2005) and the peak of the water level at northern end of SoI (27th of September, 2005) indicates that the lag time is 67 days. Eastern and northern wind speeds (Fig 4a-b) are observed to be -2.963 m/s and 3.212 m/s, respectively. And air pressure (Fig. 4c) is 1017 hPa while annual mean air pressure is 1012 hPa. The precipitation is about 0 mm on that time (Fig 4d). In conclusion, the only effect to explain water level rising in northern SoI (27th of September, 2005) is found to be River Danube discharge.

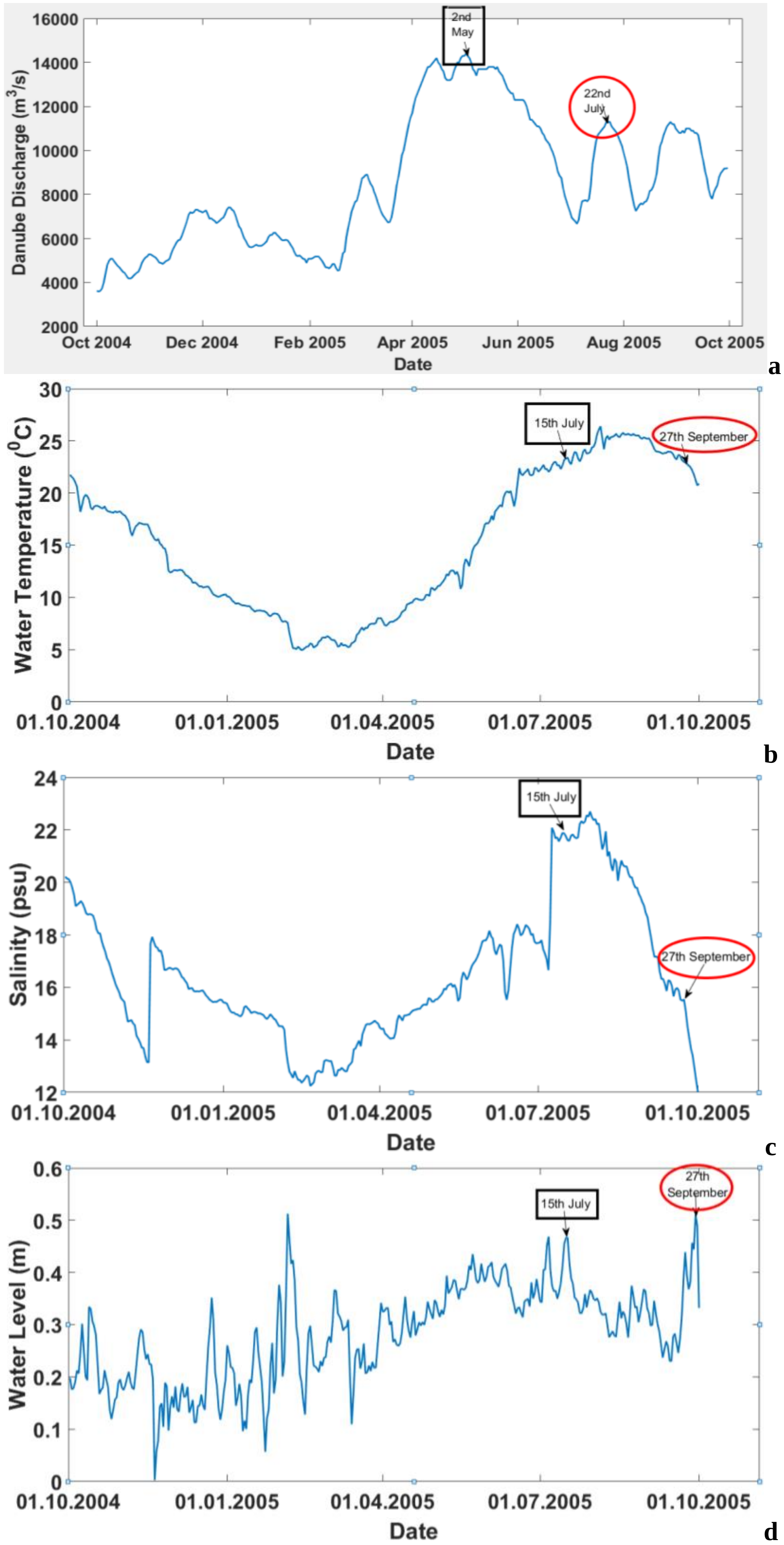


Fig. 3. Time series of (a) discharge values of Danube River, (b) Surface water temperature of SoI, (c) Salinity of SoI, (d) Northern water level of SoI.

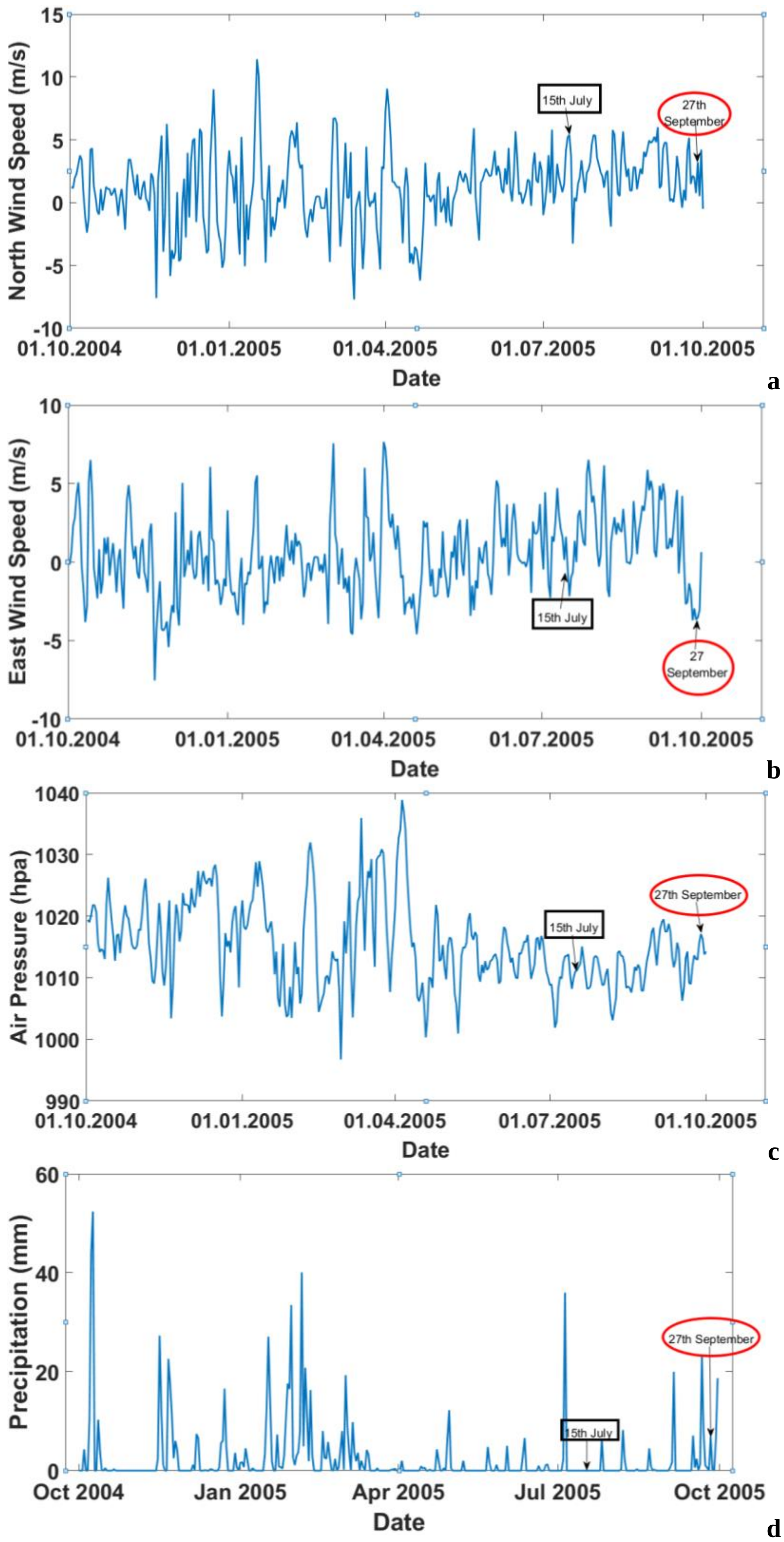


Fig. 4. Time series of (a) Northern wind speed, (b) Eastern wind speed, (c) Air Pressure of northern SoI, (d) Daily meteorological precipitation of Sarıyer station.

Discussions and Conclusions

Comparison of power spectra of River Danube discharge (Fig. 2a) and power spectra of water surface elevation, surface layer water salinity and water temperature of northern end of the SoI (Fig. 2b-d) obviously depicts that there is a correlation between Danube and SoI. Power density of River Danube on 4,3,2 and 1 months are clearly observed on power densities of water level, salinity and temperature of the northern end of the SoI.

Maximum runoff discharge of Danube on 2nd of May, 2005 (Fig 3a) cause maximum water level at the Northern end of SoI (Fig. 3d) in 15th July 2005. This means that the lag time is 74 days. The second peak discharge at 22nd of July reaches to the SoI in 27th of September, 2005 when the water level at the Northern end increases. That means the lag time is 67 days for that season.

The River Danube discharges which are under value of ~11000 m^3/s cannot be detectable on water level, salinity and temperature time series of SoI due to the local oceanographical and meteorological effects around SoI.

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