

MODELING OF CLIMATE CHANGE EFFECT ON THE CURRENT POWER POTENTIAL OF A SEA STRAIT

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INTRODUCTION

Ocean currents represent a potentially notable untapped, energy reservoir (USDOI, 2006). The regions with strong current velocities such as narrow straits connecting two water bodies exhibit high current energy (power) potential especially where the water depths are relatively shallow (EECA, 2009).

The Bosphorus, given in Figure 1, connecting the Black Sea to the Sea of Marmara is a typical narrow sea strait generally with a two-layered flow pattern (Figure 2): the upper layer current flows south towards the Sea of Marmara while the underlying one does in the opposite direction towards the Black Sea (Yüksel et al., 2008). The predominant mechanisms are the higher water level of the Black Sea for the upper layer and the denser water of the Sea of Marmara for the lower layer flow (Oğuz et al., 1990). The flow structure of the strait shows notable variability both temporally and spatially depending on the forcing conditions, namely hydrological and meteorological conditions, on both entrances. The hydrological conditions are determined by the river runoff, predominantly the Danube River, into the Black Sea while the meteorological conditions are determined by wind structure and air pressure difference. The hydrodynamic structure of the strait is dominated by the Danube River's freshwater intrusion from mid-spring to early summer and is dominated by severe storms during the fall and winter. The rest of the year is very calm both hydrologically and meteorologically and possesses relatively low current velocities. Even though the tide is very low ($O(6\text{ cm})$) in the region, previous studies show that the high current energy potential of the Bosphorus is comparable to the straits whose flow is driven by strong tides (Ozturk et al., 2017).

In the present study, both the theoretical and extractable current energy potential of the Bosphorus were studied in the light of two considered climate change scenarios: RCP2.6 and RCP8.5.

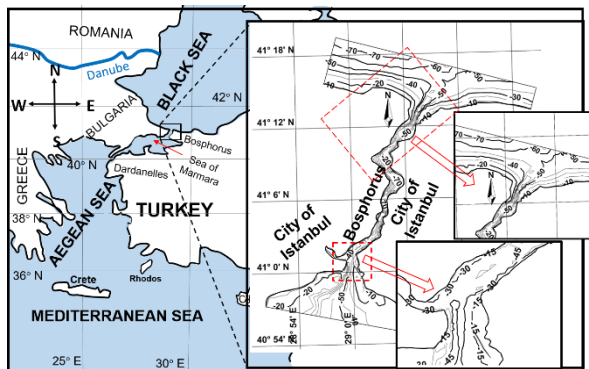


Figure 1 - The location of the Bosphorus

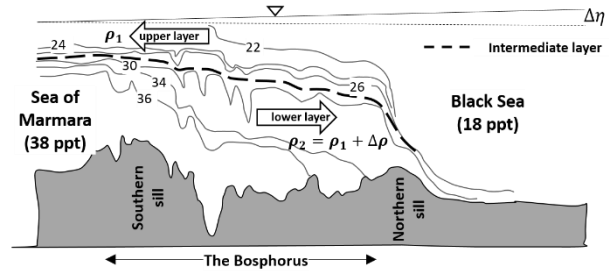


Figure 2 - Schematic presentation of two-layered flow structure in the Bosphorus. The labels on the isoclines in Figure denote the salinities in ppt.

MATERIAL AND METHOD

The climate change scenarios (e.g., RCP 2.6, 4.5, or 8.5) projected more frequent and severe meteorological conditions in the future (2030-2100) in the region of Bosphorus (Demircan et al, 2017). The annual average wind speeds, however, are expected to decrease. The same scenarios also forecast an increase in the projected mean winter Danube discharge runoff into the Black Sea by $\sim 5\%$ for RCP2.6 and $\sim 12\%$ for RCP8.5 in the near future and $\sim 18\%$ for RCP2.6 and $\sim 19\%$ for RCP8.5 in the far future. On the other hand, the projected summer discharges are calculated to change by $\sim 5\%$ for RCP2.6 and $\sim -1.5\%$ for RCP8.5 in the near future and $\sim 9.5\%$ for RCP2.6 and $\sim -3\%$ for RCP8.5 in the far (Probst and Mauser, 2015). Here, the plus sign indicates an increase, while the minus sign indicates a decrease in the river discharges compared to the current conditions.

In this study, high-resolution EUR-11 meteorological data (wind fields and atmospheric pressure fields) provided by the Rossby Centre regional atmospheric model are considered. The model data forced with boundary conditions provided by EC-EARTH (Strandberg et al., 2014) was used in the analysis, which is available via the EURO-CORDEX database. The following procedures were followed to study the climate change effect on the extractable current power of the Bosphorus:

- (1) we set the relation between the water level components (wind speeds, atmospheric pressure difference, and the Danube River discharges into the Black Sea) by using a machine learning approach (Gaussian Regression process) using the available one-year-long water level measurements, meteorological data and the Danube River runoff into the Black Sea.
- (2) we produced artificial river discharges and meteorological data series by using Monte Carlo Simulation, which is widely used for these kinds of

processes (Yue et al., 2002), in accordance with two climate change scenarios (RCP2.6 and RCP8.5). The water levels, then, were produced between these artificial hydrological and meteorological conditions assuming the validity of the relation obtained in the previous step (1).

(3) The flow structure of the Bosphorus was simulated in the light of both these artificial and the available water level and meteorological conditions. Delft 3D modeling approach was used, which was developed by Deltares. Delft3D is widely used in many areas including modeling of stratified and density-driven flows (Koşucu et al., 2019). The numerical model of the Bosphorus was both calibrated and validated using available simultaneous water level, salinity-temperature and current measurements between October 2004 and October 2005.

RESULTS

The simulation results indicate the notable spatial and temporal variation in the current power potential during the measurement period between October 2004 and October 2005. The Bosphorus has the largest current power potential for the period between mid-spring and early summer, and the southern half of the strait presents a higher current power potential than the northern half (Figure 3). The upper layer flow, especially the surface layers, reaches its peaks (~2.5 m/s) locally during the northern storm events, which occur mostly in autumn and winter. The current speeds, however, show more variability having a power potential ranging from 5 to 7 GW monthly average, which is comparable to the tidal flow potential. The current power, therefore the current speeds, are more stable during spring when the largest Danube River discharges reach and drive the strait's flow for around 40-45 days.

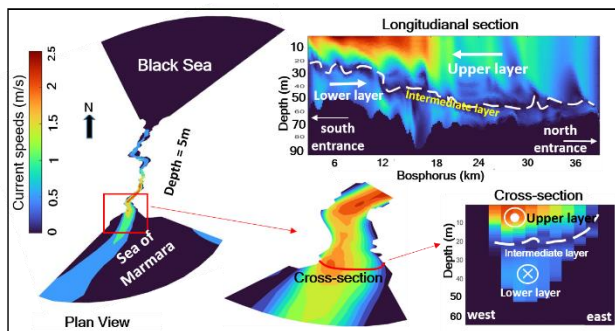


Figure 3 - The numerical modeling results of the variation of the current power potential of the Bosphorus.

The numerical modeling results showed that the converter allocation changed the current structure in neighboring areas decreasing flow speeds to the half order. The values, however, were still over the threshold of required operation speeds for the considered devices. The power potential of the Bosphorus presents significant variability in the future depending on the selected climate change scenario. In general, modeling results reveal notable increases both in potential and extractable current power of the strait for the period between mid-fall to mid-spring in the future, which is compatible with the

Danube River runoff behavior in addition to the variation of the storm characteristics. In the rest of the year, however, especially in summer, the rate of the cold spots, indicates lower current speeds than the threshold value (<1m/s). The relatively more stable period of current power potential shifted to late winter to early spring due to the projected shift in the Danube River flow regime in the future in the light of climate scenarios. Overall, modeling results indicate higher spatial and temporal current power potential in the Bosphorus except for summer months.

ACKNOWLEDGMENT

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