ABOUT THE SIGNIFICANCE OF THE TRANSPORT BOUNDARY CONDITIONS IN MODELLING BOSPHORUS EXCHANGE FLOW

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INTRODUCTION

The Bosphorus, the Sea of Marmara and the Dardanelles form together the Turkish Straits System (TSS). The Bosphorus and the Dardanelles, which are long, shallow and narrow waterways, are the only connections between the Mediterranean and the Black Sea. Therefore, the TSS has ecological, financial, social and military significance, especially for the countries bordering the Black Sea.

The Bosphorus is the most significant component of the TSS that determines the hydrodynamic behaviour of the entire system (Sozer and Ozsoy, 2017). Therefore, a good understanding and evaluation of the hydrodynamic processes in the Bosphorus is crucial. The strait is mainly characterized by a two-layered flow structure: upper layer and lower layer flows. Water level differences between the neighbouring seas create the upper layer flow, while the lower layer flow is driven by the difference in their densities. The upper and lower layers are separated from each other by a thin interfacial layer. Characteristics of these flow layers display high spatio-temporal variability depending on meteorological and hydrological conditions (Oguz et al., 1990; Yuksel et al., 2008; Ozturk and Altas, 2021; Ozturk and Altas, 2022). Therefore, to understand the complex and dynamic Bosphorus exchange flow, detailed observations of the aforementioned driving forces are required along with well-calibrated and validated numerical models.

For this purpose, within the framework of the partnership between Kiel University and Yıldız Technical University, continuous measurements of water level, current speed, salinity and temperature were carried out in the Bosphorus with a high temporal resolution, to improve the current understanding of exchange flow dynamics in the strait and to better calibrate the Bosphorus circulation model. The main goal of the field survey was to improve the transport boundary conditions (salinity and temperature) of the model, which were previously defined through monthly observations. Preliminary results are discussed in this study.

METHOD

The measurements were carried out near the southern exit of the Bosphorus (see Figure 1) in September/October 2023 for a duration exceeding three weeks, at circa 35 m depth. A stationary 600 kHz-ADCP was used to profile current speeds in 3D with 1m vertical resolution (see Figure 2) as well as the water levels. The device recorded chosen parameters at 10-minute intervals. 10 CTD sensors distributed along the water column recorded conductivity, temperature and depth values at 5-minute intervals (Figure 3). The depths of the CTD sensors were adjusted so that the dynamics of the upper layer, lower layer and interfacial layer could be observed efficiently. While the measurements from 6 m below the free surface display upper flow layer salinity and temperature, measurements from between 12-22 m show the mixing at the interfacial layer and values recorded from the deeper points of the water column display the lower flow layer. In addition, atmospheric pressure and temperature data were obtained at 5-minute measurement intervals with a barometric sensor connected to the mooring buoy used to mark the deployment location of the instruments.

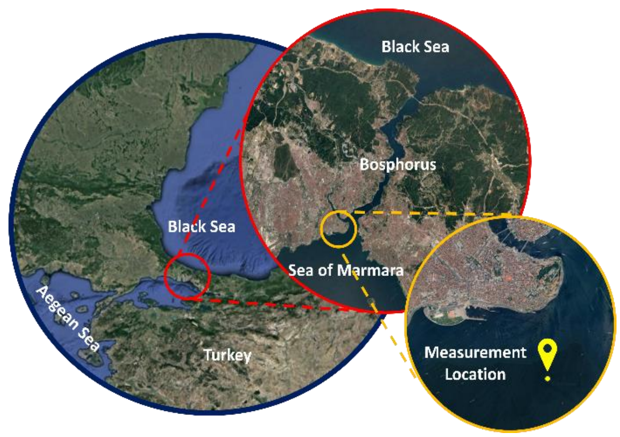

Figure 1 – Map of the Bosphorus and location of the measurements.

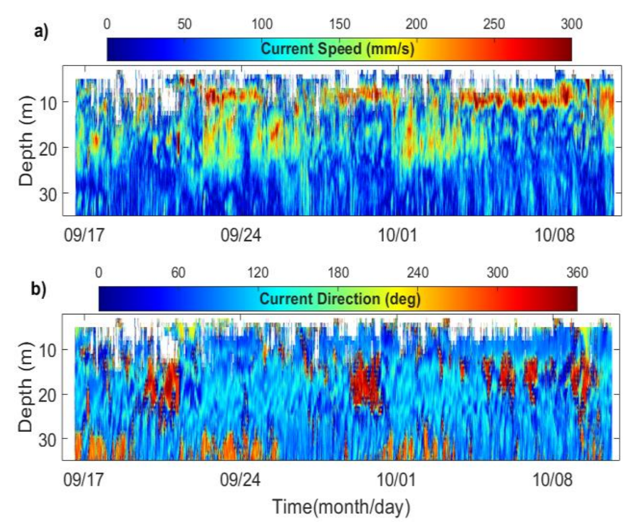

Figure 2 – a) Current velocities and b) directions measured during the field survey.

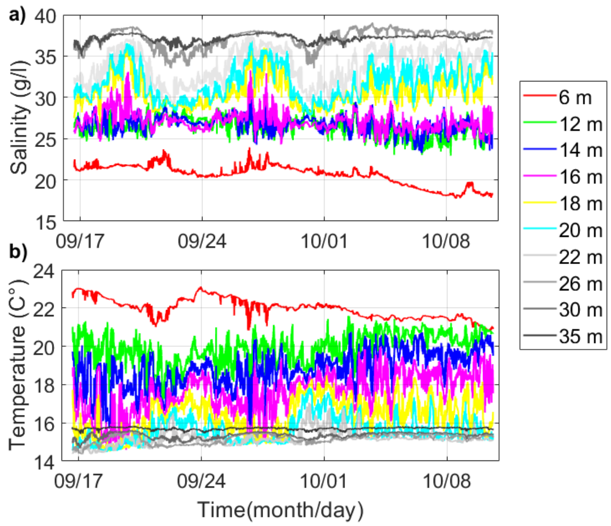

Figure 3 – a) Salinity and b) Temperature values measured during the field survey.

The horizontal resolution of the Bosphorus circulation model is approximately 50 m and the vertical resolution is ca. 2 m. Grid dimensions are sufficient to simulate the hydrodynamic processes of the flow field. Much attention was given to the meteorological forcing and boundary conditions. Data obtained from ECMWF (Hersbach et al., 2020; Ilicak et al., 2021; Ozturk and Altas, 2021) and the Turkish Meteorological Office were used to account for the meteorological conditions. The hydrodynamic boundary conditions were defined via water level measurements conducted during the field survey as well as the data obtained from the two online radars in Istanbul (UNESCO, IOC, 2022). Salinity and temperature observations were used to improve the transport boundary conditions of the model, which drive the lower layer flow and previously relied on monthly measurements. The k-ε turbulence closure model was incorporated into the model to account for turbulent kinetic energy dissipation. Additionally, horizontal large eddies (HLES) were also considered in the model.

RESULTS

The measurements demonstrate the characteristics of the two-layered flow structure. The salinity of the upper layer flow ranges from 17-23 ppt, while the salinity of the lower layer flow is approximately 37-38 ppt, as depicted in Figure 3. The temperature values begin at 23 °C near the free surface and gradually decrease to 14 °C at the bottom. The oscillations in salinity and temperature values suggest a significant amount of mixing occurring in the interfacial layer. Moreover, the upper layer flow appears to be more dynamic than that in the lower layer (see Figure 2 and Figure 3). Current velocities reach their peak values near the free surface. Current velocity distributions along depth vary over time depending on meteorological and hydrological effects.

The results showed that transport boundary conditions are of great significance in capturing the exchange flow accurately. Through the boundary conditions derived from the measurements, which provide a higher temporal resolution, the model simulated the behaviours of the interfacial layer and the lower layer with increased accuracy. This improvement allows a more detailed and precise examination of the processes that determine the flow structure and energy potential of the Bosphorus Strait. Studies examining the turbulence characteristics, momentum transfer between layers, and layer properties such as layer thicknesses and current speeds are currently underway.

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