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Summer climate variability of the İzmir Bay based on long term temperature and salinity records (1996-2013)

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Abstract

The purpose of this study is to examine the temperature and salinity variability of the İzmir Bay based on available in-situ measurements between 1996 and 2013 in summer. The analyses were made for the whole Bay and also for the sub-basins of the İzmir Bay namely; inner and outer. The similarities and differences were tried to be revealed. The main finding of the study is that there is a strong increase of temperature during the last 10 years. After 2003, it is very interesting that the temperature increase almost 2°C in all two basins. This trend is greater than global warming which is almost 0.5°C. Although the salinity has decreasing trend in all the sub-basins, there is an anomaly in 2007. The salinity increases in this year. The impact of such warming and the anomaly in the salinity on the İzmir Bay needs more investigation.

Keywords: Global Warming, İzmir Bay, Seawater Properties, Summer, Time Series

Introduction

The İzmir Bay is one of the many bays at the highly indented eastern coast of the Aegean Sea. It is a boot-shaped Bay, and at the “toe” of the boot, the city of İzmir which gives its name to the Bay is located (Figure 1). İzmir, with nearly four million populations, is one of the densely populated city in Turkey. At the “heel” of the İzmir Bay, Gülbahçe Bay is situated. The İzmir Bay is a 40 km long and 20-50 km wide bay, the northern entrance has a width of 20 km. There is couple of islands inside the İzmir Bay. The biggest one is called Uzun Island which is located at the entrance of the Gülbahçe Bay. The İzmir Bay is connected to the Aegean Sea at the northern exit of the Bay. Historically, the Bay is divided to two regions (Inner, Outer) as seen in the Figure 1. The Yenikale Straits separates the Inner Bay from the Outer Bay.

The inner part, with averaged depth of 20 m, is the shallowest part of the Bay. The bathymetry increases toward to the Aegean Sea. The northern entrance of the Bay has a V-shape bathymetry. Knowledge about the circulation characteristics of the İzmir Bay is a key factor to predict the faith of the anthropogenic waters after it enters to the İzmir Bay from its discharge locations. The circulation in the İzmir Bay is mainly driven by the wind, bathymetry, and the shape of the coastline. Previous studies trying to understand the circulation structure of the Bay are very limited. There are a couple of modelling studies in the Bay which are mostly process oriented with idealized wind stress forcing. Sayın (2007) investigated the circulation characteristics of the Bay under the northerly wind.

Three distinct water masses were identified by Sayın et al. (2003). These are The Aegean Sea Water (ASW), İzmir Bay Water (IBW) and İzmir Bay Inner Water (IBIW). ASW enters to the Bay at the western part of the northern boundary; it is relatively saltier and warmer. IBIW is denser; it is produced at the Inner Bay which is very shallow and under the influence of strong winds suitable for the dense water generation. The relatively shallow coastal regions like İzmir Bay are very suitable for the generation of dense water. The contribution of the İzmir Bay to the amount of total dense water generated in the Aegean Sea is not known. The Aegean Sea region is believed as one of the dense water generation area in the Mediterranean Sea, and its importance increased after it was found that the amount of dense water generated in this region increase abruptly during early 1990. This event called Eastern Mediterranean Transient (EMT), and there are numerous studies on the mechanism of the EMT and its possible influence of the Mediterranean circulation and climate (Alpar, et al., 1997; Nittis et al., 2003; Altınok, et al., 2005; Roether et al., 2007; Özsoy et al., 2013)

There is no detailed study about the time variability of the surface temperature of the İzmir Bay. The analysis made by this study will show the temperature variability of the Bay. There are ample of studies related with the global warming, For example, long term air temperature observations from different data sources (NASA, NOAA, the Japan Meteorological Agency, and the Met Office Hadley Centre (United Kingdom) have shown that temperature anomalies between 1880-2014 years are increasing and the last decade was the warmest years. Global warming is shown to be almost 0.5°C (Hansen et al., 2010). Although this is a global trend, regional climates are also under the influence of global warming Although this is a global trend, regional climates are also under the influence of global warming. For this reason, it is expected that similar trend could be detected in İzmir Bay. In this study, this kind of trends will be investigated.

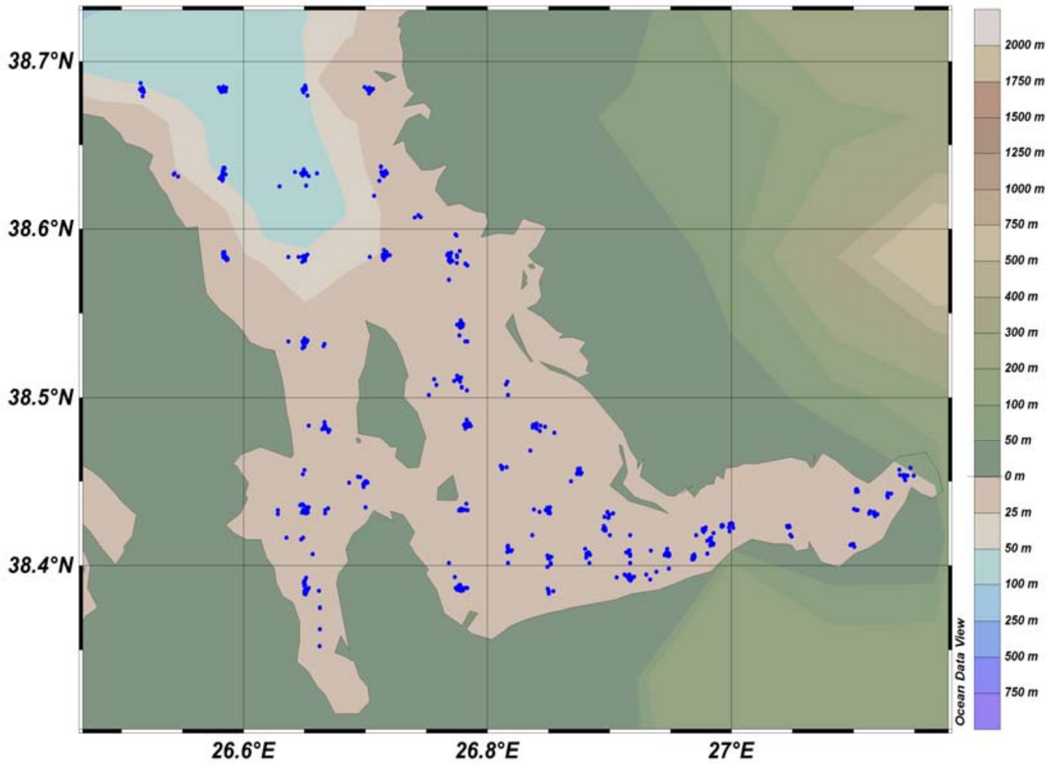

Fig. 1: Map of the İzmir Bay and locations of the CTD stations.

Data and Methodology

Monitoring studies in İzmir Bay have been carried out by the Institute of Marine Sciences and Technology of Dokuz Eylül University. CTD data was obtained from oceanographic cruises during the period of 1996-2013 (DBTE, 098, 1998; DBTE 124, 134, 141, 152, 2003; DBTE-163, -167, -180, -199, 2003).

In this study, only the summer months was investigated. The CTD can records temperature, salinity, conductivity, light transmission, and dissolved oxygen. In this study we are only interested in temperature and salinity. Figure 2 shows the number of CTD stations for each year. There are nearly 1100 CTD cast in the data set. The locations of the CTD profiles are shown on Figure 1 with the blue dots.

Time series graphs of temperature and salinity were made with the ODV (Ocean Data View) program. ODV is a computer program for the interactive exploration and graphical display of oceanographic and other ego-referenced profile, trajectory or time series data. The software is available for Windows, Mac OS X, Linux, and UNIX systems. ODV data collection and view files are platform independent and can be exchanged between all supported systems. In this study, the ODV software was used to averaging, selecting and plotting the data. The detailed information about the software may be found at *https://odv.awi.de/*.

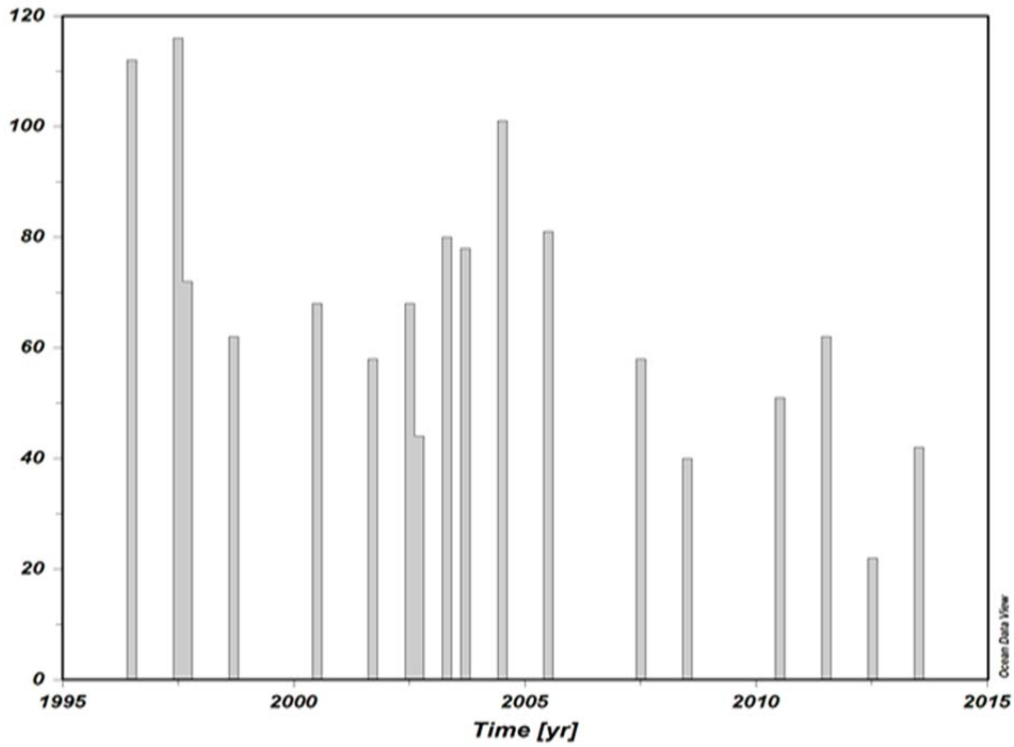

Fig. 2: Number of CTD stations for each year.

Results

The time series of the surface temperature and salinity (at 5 m) for averaged whole available data set were shown in Figure 3. The locations of the CTD stations were also shown in the map. The stations cover the whole Bay and they are sufficient to investigate the variability of the Bay. The most striking features of the temperature time series is the positive trend during the investigated period. The temperature increased about 2°C over the 18 years time period. This is much greater than global warming trend. Analysis of the global sea surface temperature data (obtained from http://www.ncdc.noaa.gov/cag/) for the August month has shown that there is 0.06°C increase of the temperature anomaly during the same period of the study. It shows that the regional response of the İzmir Bay to the global warming is much more intense. However, detailed analysis should be done to understand this behavior and it is not scope of this study. The other important feature of the temperature time series is the strong drop of temperature in 2002-2003 years. Georgiou et al. (2015) analyzed the temperature and salinity of the Aegean Sea. Although they analyzed the winter properties of the Aegean Sea, it is interesting that similar trend is also observed in their analysis. This finding shows that the relatively small İzmir Bay mimics the Aegean Sea climate and it could reflect the behavior of broader regional climate.

Surface salinity (at 5 m) time series for the whole available data was also shown in Figure 3. Although the salinity generally tends to decrease from 1996 to 2013, it increased between 2005 and 2008 and then the salinity decreases again after 2008. It is interesting that this higher salinity period is evident in all three basins of the İzmir Bay. Similar to temperature, the results of Georgiou et al. (2015) showed that the salinity also follow the general trend in the Aegean Sea upper layer salinity. This proves that the İzmir Bay could be used as a laboratory basin to study the climate of the Aegean Sea.

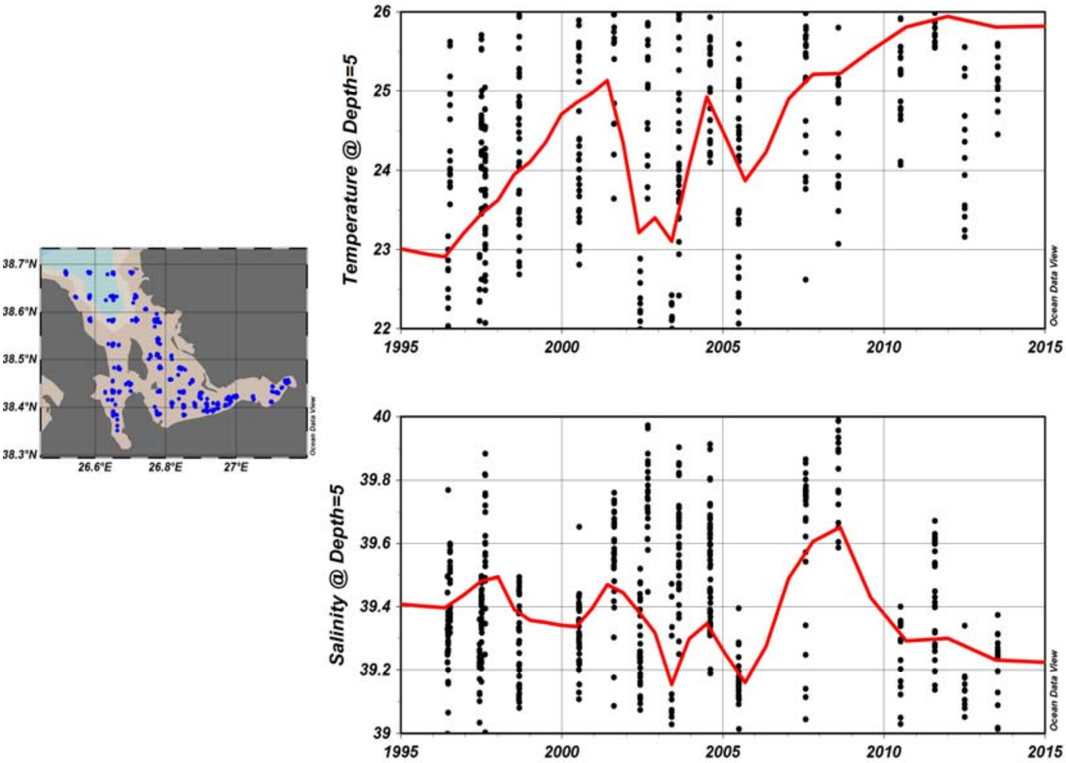

Fig. 3: Time series of the temperature and salinity averaged for the whole İzmir Bay

The same analyses were also made by separating the İzmir Bay to two sub-basins (inner and outer) to find the similarities and differences of the sub-basins. The temperature trend of the inner Bay was shown in Figure 4. The figure shows a positive temperature trend over the investigated period. The trend line shows that temperature increase almost 2°C over the 18 years (1996-2013) time period in the inner Bay. Although the temperature has positive trend, there are some significant declines. For example, in 2002-2003 the temperature dropped dramatically which is also evident in whole data as shown in Figure 3. The salinity time series in Figure 4 showed that inner basin salinity remained almost constant between 1996 and 2000. However, there is a salinity increase between the 2007-2009 years.

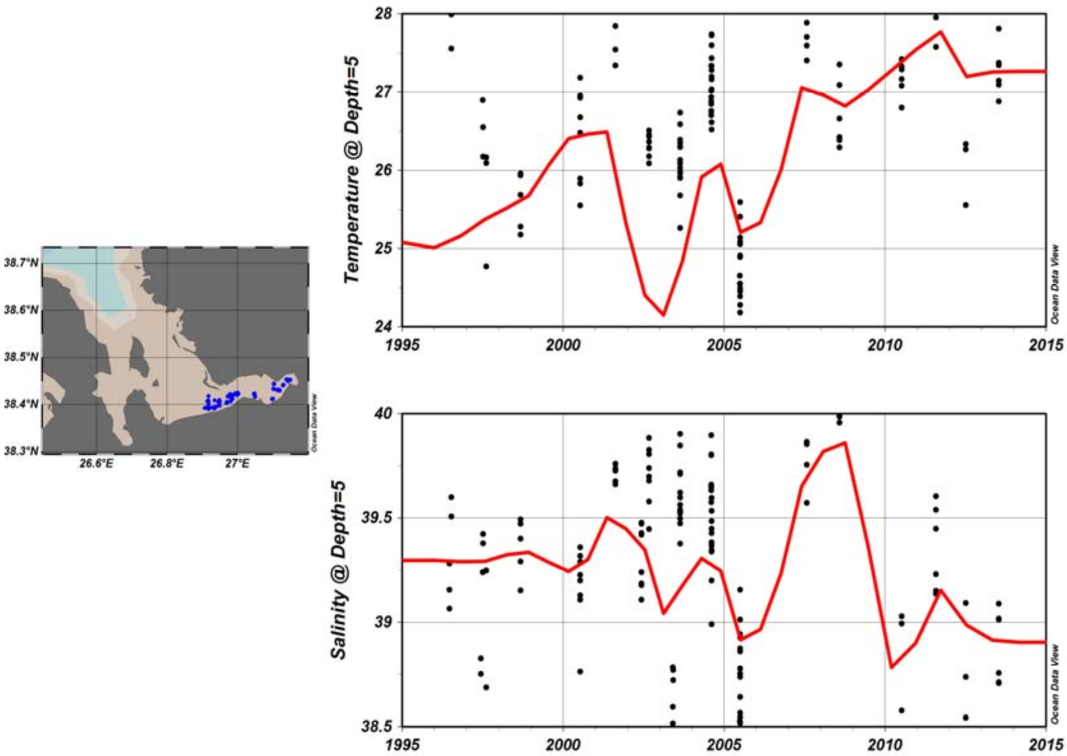

Fig. 4: Time series of the temperature and salinity averaged over the whole inner İzmir Bay.

Figure 5 shows the time series of temperature and salinity for the outer basin. The temperature shows positive trends similar to other basins of the İzmir Bay. The temperature has increased about 2°C from 1996 to 2013. Salinity time series was also shown in Figure 5. Salinity remained almost constant between 1996 and 2005. However salinity increased from 2005 to 2008 which is more evident in inner basin. The salinity decreased from 2008 to 2013. The increase in salinity in this period could be related with the precipitation characteristics of the region. According to Republic of Turkey Ministry of Environment and Urbanization's 2012 (T.C. Çevre ve Şehircilik Bakanlığı, 2014) Report about the İzmir, 2007 is the second driest year over the 40 years period and 2008 is also relatively dry year according to this study.

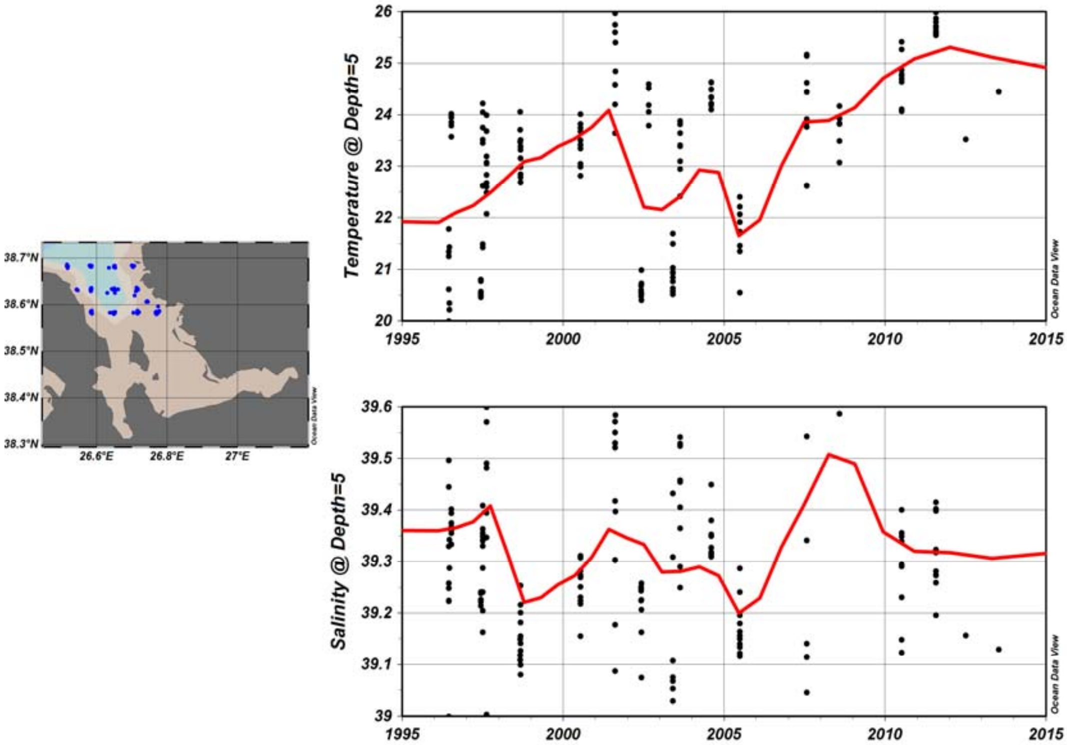

Figure 5: Time series of the temperature and salinity averaged over the whole outer İzmir Bay.

Conclusion

The study has used the temperature and salinity data for the İzmir Bay available for 18 years time period to investigate the trends of the time series. It is found that the temperature has a positive trend in all two sub-basins, and the salinity has a negative trend. The positive trend in temperature is greater than the global temperature trend. The reason for this behavior needs deeper analysis. There is a strong drop in temperature in 2003, this drop is also evident in Aegean Sea and it suggests that this is not a local event. In contrast, it could be related with the broader regional climate effect. The dramatic increase of salinity in 2007 which is observed in whole data set is also needs further investigation. It could be related with upper layer atmospheric teleconnection indices namely North Atlantic Oscillation (NAO) or North Sea Caspian Pattern (NCP) which is known affect the study region as shown by Gündüz and Özsoy (2005).

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