



- **RESEARCH ARTICLE** -

Analysing Sea Surface Temperature Change in Gulf of Iskenderun from 1982 to 2015

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Abstract

Climate change is one of the major challenge for Earth Systems in this century. Since the Industrial revolution, energy demands of countries has been rapidly increased which also causes an accelerated burning fossil fuels and increased greenhouse gases emission (GHG) into the atmosphere. Sea surface temperature (SST) is a pointer of the water temperature, which mainly related to sea surface layer and also plays an important role for keeping the energy balance between atmosphere and marine ecosystems. Various studies show that surface temperature of the inner seas surface temperature is affected by anthropogenic climate change. Gulf of Iskenderun is located in the southeast Mediterranean region of Turkey. The Gulf is important mainly for its industrial facilities and thermal power stations of Turkey. Due to the Suez Canal and strait of Gibraltar the gulf has also very important meaning for migration of the alien species into the Mediterranean Sea. To investigate the sea surface temperature (SST) change in the Gulf of Iskenderun over the period of 1982-2015 we used remote sensed data, which have 4x4 km high spatial and daily temporal resolution. This data collected from Copernicus Marine Services which based on satellites Advanced Very High Resolution Radiometer (AVHRR) Pathfinder Version 5.2 (PFV52). In the study period, the highest SST is determined in a JJA (June-July-August) season. The warmest region was the north is part of the bay. The SST change about 1.5° C in the study period.

Keywords:

SST, climate change, remote sensing

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Introduction

Climate change is one of the major challenges for Earth Systems in this century. Since the Industrial revolution, burning of fossil fuels for energy demand of the countries has been rapidly increased, and that causes a rapid increase in greenhouse gases emission (GHG) into the atmosphere. Increasing GHG emissions leads to change of on terrestrial and marine ecosystem process at global and regional scale. Furthermore, oceans have captured nearly half of all anthropogenic CO₂ emissions in the atmosphere (Pörtner, 2008). Various studies show that the CO₂ increase cause an increase in ocean surface temperature (Nagelkerken et al., 2015). Sea surface temperature (SST) is the pointer of the sea water temperature, which is also tightly connected with the ocean's surface layer (Doney et al., 2012; Roemmich et al., 2015). The sea and ocean surface layers play an important role in keeping the balance between atmosphere and marine ecosystems. Likewise, SST indicate biogeochemical interaction among between marine habitats and atmosphere (Sakalli, 2017). The Mediterranean Sea is a semi-enclosed sea and it was highly considered the first change of temperature because of global warming (Béthoux et al., 1990). The sea owing to transition zones between tropical and mid-latitude climates variations, making it susceptible to effects of global climate change (Gogou et al., 2016).

Lelieveld et al. (2002) have noticed in one of their study that warming of the Mediterranean Sea has been started the early 1980s. Nykjaer (2009) used Pathfinder AVHRR 5.0 version, observed SST data for a period 1986-2005 and reported approx. 1.2 °C increase in SST over the Mediterranean Sea. Furthermore, the study showed that SST increase were not stable throughout the year, and the primarily SST increases begin May, June, July period. Shaltout & Omsted (2014) analysed SST change in Mediterranean Sea using by remote sensed dataset for a longer period (1982-2012) and indicated SST increased about 0.24 °C per decade. Skliris et al. (2012) investigated satellite-derived (1985-2008) and in situ (1973-2008) SST dataset. Both dataset indicate the SST increased significantly in region for the same periods. A change in SST affects several biophysical, biochemical processes in the marine ecosystems and also between the atmosphere and marine ecosystems (Guldberg & Bruno, 2010; Halpern et al., 2015). Marbà et al. (2015) investigated impacts of SST changes on marine biota in Mediterranean Sea by using AVHRR Pathfinder version 5.2 remote sensed SST data, which have 10x10 km high spatial and daily temporal resolution during the period 1980-2011. In this study, it was reported that the SST has been raised 0.25°C per decade and 0.65 °C from eastern to western in the Mediterranean Sea. The main outcomes of the study were that the Mediterranean Sea is one of the most vulnerable regions regarding its marine biota, and an increase in SST has been enhancing the vulnerability in the Sea. The study also indicated that impacts of rising SST leads to changes phenological and metabolical stresses in the marine organisms. Turan et al. (2016) analysed changes of SST and probable impacts on the biodiversity in the Turkish coasts of the Mediterranean, Marmara and Black Sea. The study showed that SST have significantly increase in all seas since the last two decades. They pointed out that biodiversity will be clearly change in the Mediterranean Sea, and invasion rates of the alien species will be significantly increase especially due to increase of SST in the Mediterranean Sea. During the last decades the number of lessepsian species has significantly increased in Turkish marine waters (Turan et al., 2015; Gürlek et al., 2016). Öztürk & İşinibilir (2010) reported an increase in number of alien jellyfish species in the Turkish coast of the Mediterranean Sea. Authors indicated that these species caused several negative impacts on

human health and tourism. They reported that one of the major reasons of the alien jellyfish invasion is SST rises in the Mediterranean Sea. The Gulf of Iskenderun is located in the northeast of the eastern Mediterranean Sea. The gulf influenced by cyclonic current system in the Mediterranean due to wide bay entrance. The greatest stream poured into the gulf is the Ceyhan river. The Gulf of Iskenderun is also one of the main industrial hubs of Turkey (Avşar, 1999). The gulf is crucial to marine species within the Mediterranean Sea.

Within frameworks of our study, we aimed to analyse the spatial and temporal change of the SST in the Gulf of Iskenderun that is located in the Northeast of the Mediterranean Sea and on the Southern coast of Turkey.

Materials and Methods

Study Area and Data

Gulf of Iskenderun extends 65 km in length and 35 km in width on the southern coast of Turkey. Region is surrounded by the Misis and the Nur mountains where located 2275 km² field in the eastern mediterranean sea. The gulf average depth is about 70 meters (Avşar, 1999). The region climate type generally refers to type of the Mediterranean climate condition which defined by hot and humid summers, and mild and wet winters. To investigate the SST change in the bay we used remotely sensed data, which 4x4 km high spatial and daily temporal resolution. This data collected from Copernicus Marine Services which based on satellites Advanced Very High-Resolution Radiometer (AVHRR) Pathfinder Version 5.2 (PFV52). The data set was developed which entirely new land mask, modified grid, sea ice and wind speed ancillary data to support SST data.

Methods

For visualization of the data, we used climate data operator software version 1.6.0 (CDO, 2015). For seasonal average distribution of SST was illustrated over the period 1982-2015. Seasonal SST differences illustrated DJF, MAM, JJA, SON (each capital character shows month's name). Furthermore, we investigated seasonal and annual SST variability using linear regression analysis for 1982-2015. Anomalies in SST were also calculated by using the following equation (1): where i is the number of each grid cell, n and k are start and end of the data collected years, respectively. SST_{mon} is the monthly SST for each grid cell, and SST_{Anom} is the SST anomaly for each grid cell.

Equation (1).

$$SST_{Anom(i)} = \frac{SST_{mon(i)} - \sum_{k=1982}^{n=2015} SST_{mon(i,k)}}{n - k + 1}$$

Results

Annual average SST change illustrated with linear regression in the Gulf of Iskenderun over the period 1982 to 2015. Results of the analysis signed that annual average of the SST significantly increasing approximately 0.5°C per decade (Figure 1).

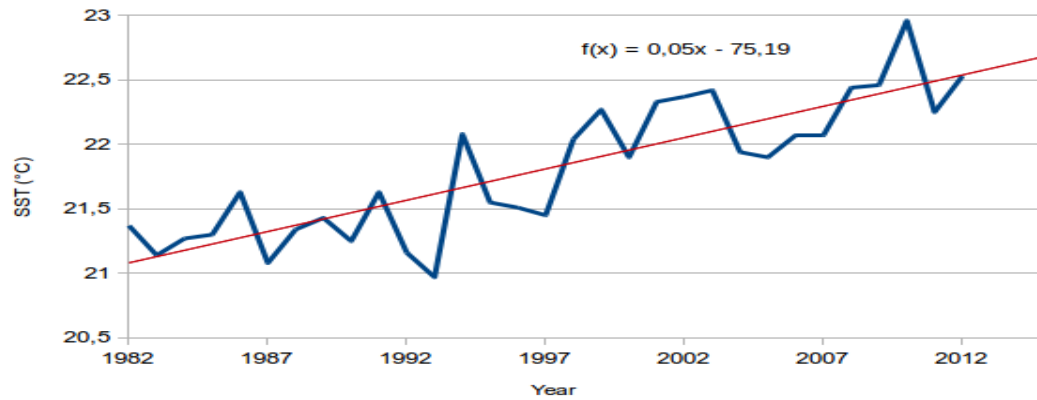


Figure 1. Annual average sea surface temperature change in the Gulf of Iskenderun over the period 1982 to 2015.

In study period, the warmest and coolest years detected in 2015, 1993 respectively. SST anomalies of the Gulf of Iskenderun were calculated by using equation (1). SST value indicated mainly negative anomaly between 1982-1997, whereas it indicated positive anomaly between 1997-2015 (Figure 2).

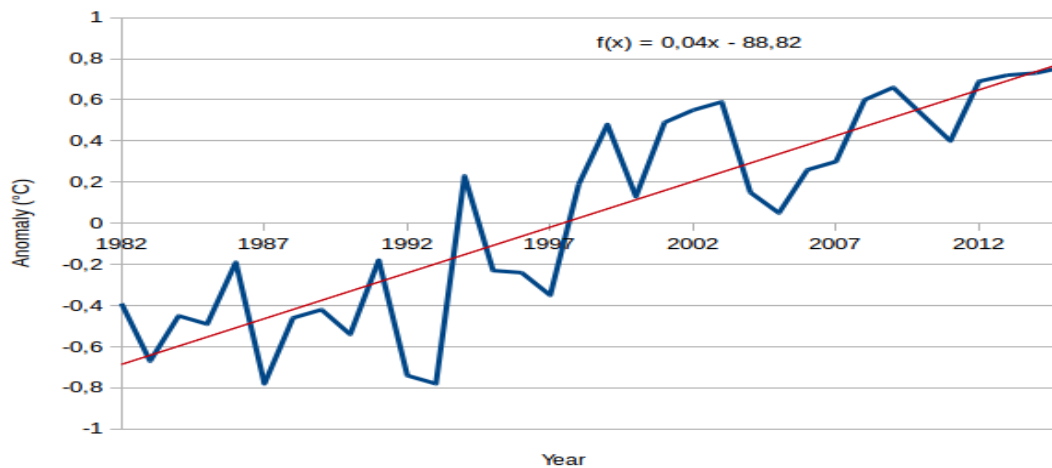


Figure 2. Anomalies for 34 year in Gulf of Iskenderun.

Seasonal SST changes are illustrated as blue trend for DJF (December-January-February), yellow trend for MAM (March-April-May), red trend for JJA (June-July-August), green trend for SON (September- October-November) seasons. Maximum SST increased during the summer period which showed red trend. Furthermore, winter and spring seasons of SST fluctuation are close to each other. For all seasons, SST differences change between 17-27 °C approximately. The maximum and minimum SST observed during the summer and winter seasons respectively (Figure 3).

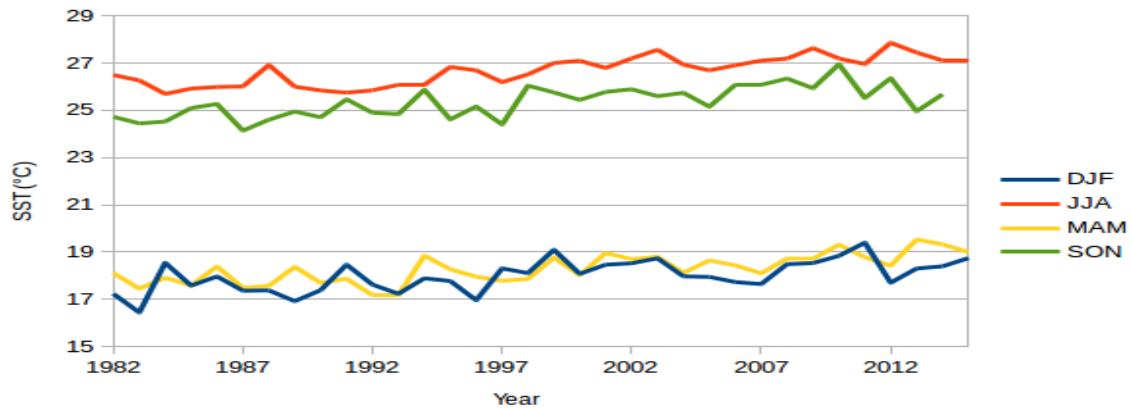


Figure 3. Annual seasonal average sea surface temperature change at the bay over the period 1982 to 2015.

34-year temporal SST average between maximum and minimum part at the Bay detected approximately 0.5 °C. Northeast part in region warmer than other parts of the gulf. The SST increased from north west to southeast parts of the Gulf (Figure 4).

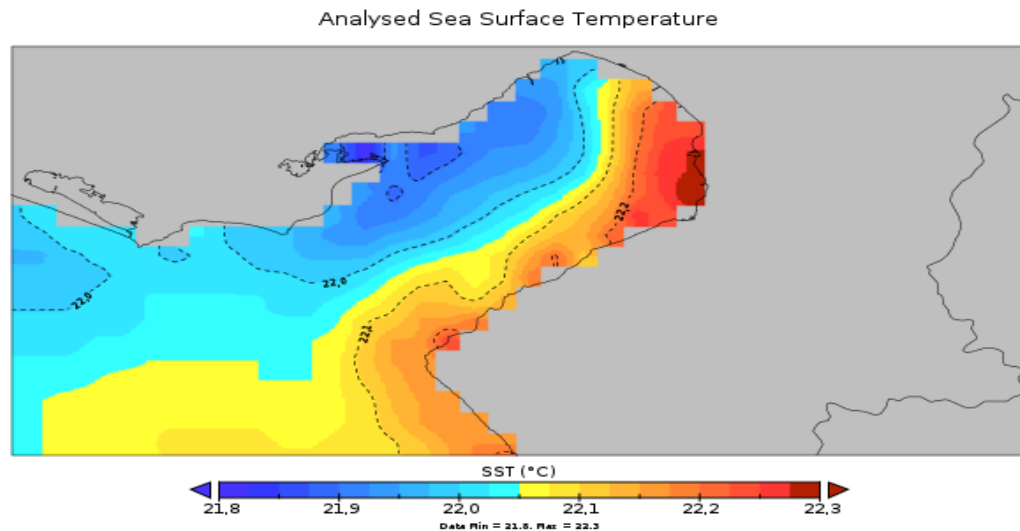


Figure 4. 34-year temporal average distribution of SST in the Gulf.

Figure 5 shows that the south part of the Gulf was warmer than the other parts during the study period. SST changes approximately between 17.4 °C to 18.9 °C in the Gulf of Iskenderun.

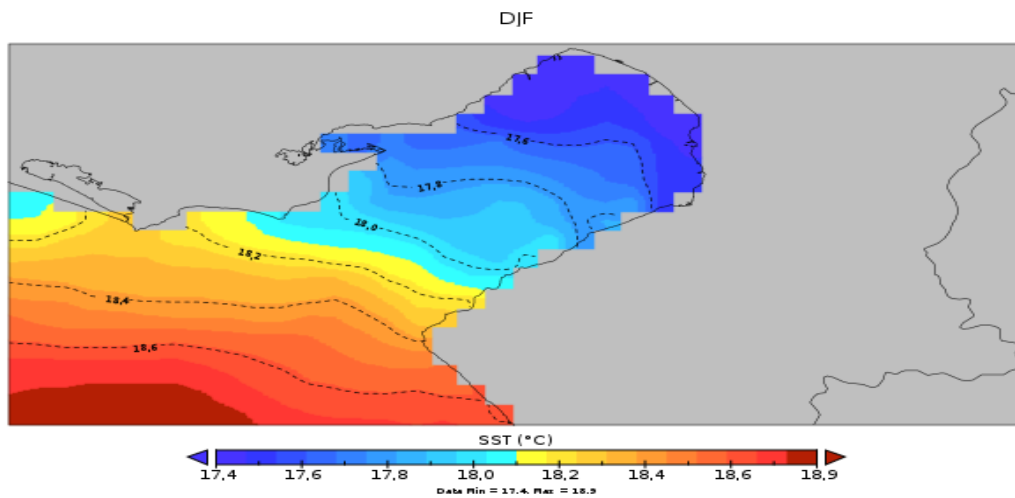


Figure 5. Spatial distribution of very high resolution (4x4 km) average over the period (1982-2015) SST for DJF (December-October-November) season in the Gulf of Iskenderun.

Southeast part warmer than the other part of bay. SST changes approximately between 15.5 °C to 16.6 °C in the Gulf of Iskenderun (Figure 6).

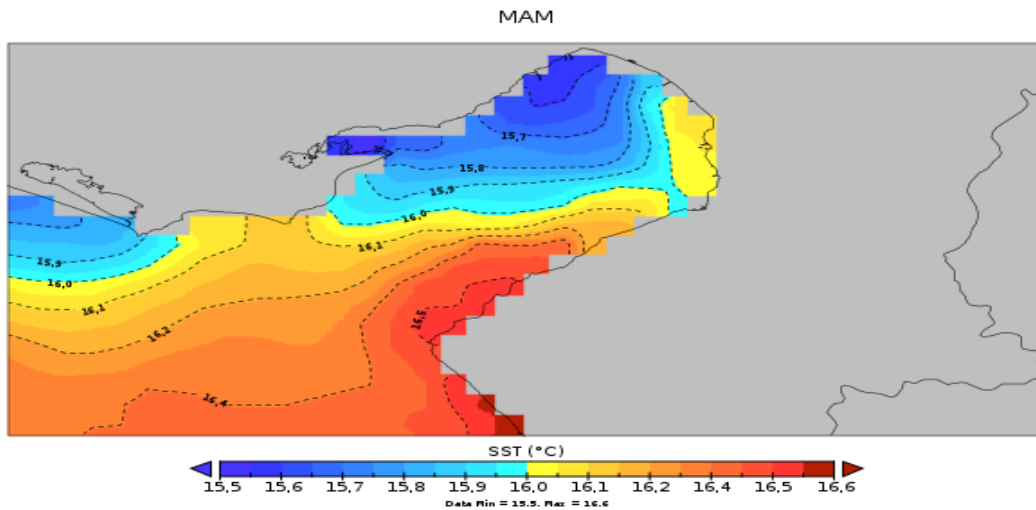


Figure 6. Spatial distribution of very high resolution (4x4 km) average over the period (1982-2015) SST for MAM (March-April-May) season at Iskenderun bay.

SST significantly raised in northeast region. The SST changes approximately between 24.1 °C to 25.2 °C in the Gulf of Iskenderun (Figure 7).

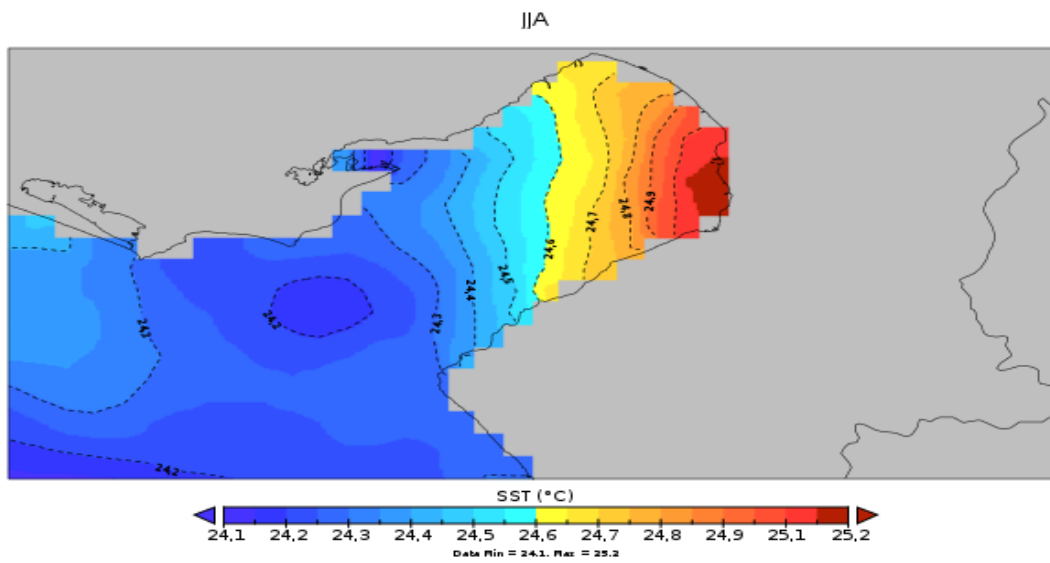


Figure 7. Spatial distribution of very high resolution (4x4 km) average over the period (1982-2015) SST for JJA (June-July-August) season in the Gulf of Iskenderun.

SST increased particularly in northwest part of the Gulf. The SST changes approximately between 27.5 °C to 28.3 °C in the Gulf of Iskenderun (Figure 8).

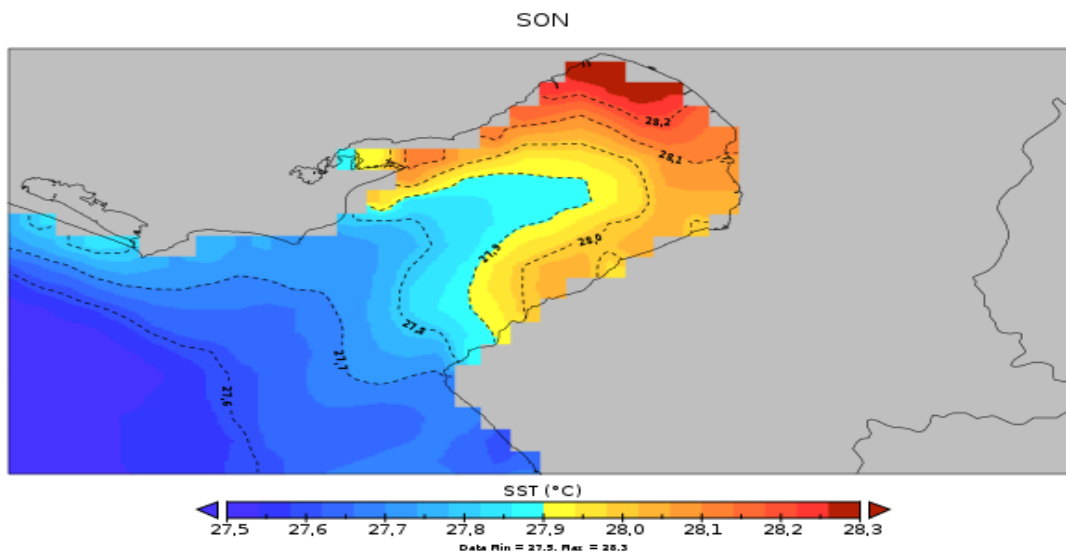


Figure 8. Spatial distribution of very high resolution (4x4 km) average over the period (1982-2015) SST for SON (September-October-November) season in the Gulf of Iskenderun.

Discussion

Since there is not a previous study for a comparison of the results of our study with, we can only compare our results with the results of the studies with larger regions as Mediterranean Sea.

In our study, we analysed an increase in SST about 0.5°C per decade in Gulf of Iskenderun. To compare of our results, the change of the SST in the Mediterranean Sea has been reported by Shaltout & Omsted (2014) and Nykjaer (2009) 0.24°C , 0.3°C per decade respectively. The differences between SST of the studies could be caused by the differences in spatial resolution and study field of the datasets. Our study is 36 and 16 times spatial resolution than other the two studies, respectively. Santoleri et al. (1994) indicated SST increased average 1.5°C of entire western Mediterranean for (1982-1990) using by satellite dataset of 18×18 km spatial and weekly temporal resolution. They also detected seasonal SST trends and found in summer, winter, spring and autumn increased annual mean 0.25°C , 0.16°C , 0.08°C , 0.13°C respectively in study period (1982-1990). However, we used 4×4 km spatial and daily temporal resolution dataset for the bay and analyzed of SST increased annual mean for summer 0.05°C , in winter 0.03°C , for spring 0.43°C and autumn 0.04°C in (1982-2015). The differences between properties of sea water circulation and power plants facilities in the gulf of Iskenderun could be caused change seasonal SST trends. Skliris et al. (2012) analyzed and compared satellite-derived (1985-2008) and in situ (1973-2008) SST dataset in the Mediterranean Sea. They reported both satellite and in situ derived SST dataset pointed out significantly warming of the Mediterranean Sea started early 1990's. They founded annual SST increased 0.037°C in all Mediterranean Sea. The study noted that increasing SST tendency westward to the eastward direction in Mediterranean Sea. They also indicated satellite SST data set shows stronger warming trends than in situ data set for same periods. However, we used only remote sensed SST data and founded annual SST rises at the bay 0.05°C . We analyzed the northern part of at bay warmer than other parts of the bay. This could be caused by Ceyhan river, which is the source of it located in the eastern Mediterranean region and discharge to central part in the bay. The quantity of water flow on the Ceyhan river changes substantially season by season (Ludwig et al., 2009). During the SON seasons, rains temporarily raise the water flow in the river probably decreased SST in middle regions of the bay. Because of snowmelt in the Taurus Mountains the water flow increases in the river, that could be caused decline SST in MAM season. On the other hand, water flow is the lowest range on river JJA season, this could not significantly impact SST variability western parts of at bay. Marbà et al. (2015) investigated SST change and their impacts on marine ecosystem period of (1980-2011). They also reported summer season average SST increased 1.15°C for the period. However, we analyzed the season of summer average SST rises about 1.6°C at the bay. Those differences could be based spatial and temporal datasets. Besides, during summer seasons, Ceyhan river has the lowest water flow which discharge in Gulf of Iskenderun. Turan et al. (2016) reported that increasing of SST one of the main reasons for rising rate of alien species invasion in the coasts of Turkey. Our results of SST increasing in the Gulf of Iskenderun were supported by Turan et al. (2016). Furthermore, Öztürk & İşinibilir (2010) pointed out that alien jellyfish species are clearly rises in the Mediterranean Sea which caused several negative effects on human health and regional tourism mainly because of increased SST. Moreover, Turan et al. (2015) and Gürlek et al. (2016) reported that lesepssian species have dramatically increased in Turkish marine waters since the last decades. It is important to mention that SST incerases may give rise to establish more lessepsian species in the Gulf of Iskenderun in the future.

Conclusion

Within this study, we indicated that SST was significantly increased mean annual, seasonal and monthly during period 1982 to 2015 in the Gulf of Iskenderun. It is important to mention that the Gulf of Iskenderun clearly affected by global warming and this case may be irreversible impacts in the marine ecosystems at the Gulf of Iskenderun.

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