Time Series Observations and Recent Anomalies of the Sea Surface Temperatures in the Cilician Basin

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Research Article

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Abstract

Sea Surface Temperature (SST) is one of the fundamental physical oceanographic parameters to understand, determine and predict ocean-atmosphere interactions. SST defines and influences local and global climate regimes, oceanic and atmospheric circulation, weather patterns, and regional phenomena.

Almost ninety per cent of the additional heat energy caused by greenhouse gasses is absorbed by the ocean. Compared to the pre-industrial era, the mean annual SST of the Mediterranean Sea is increased by about 1.0 °C, especially with a higher rate in the last decades. Since the 1990s, a gradually increasing trend of SST was observed in the Mediterranean Sea, while the highest SST warming was recorded in the Levantine Basin of the Eastern Mediterranean Sea.

The fifth-generation atmospheric reanalysis (ERA5) data sets of the European Centre of the Medium-Range Weather Forecast (ECMWF) and the time-series of observational meteorological data sets of the Kyrenia Meteorological Station are used. This study aimed to compare and validate the reanalysis and observational data sets and analyse SST trends in the southern Cilician Basin between 1995 and 2020.

Our results revealed about 1.1 °C of SST warming in the region during the last 25 years. The annual mean SST was calculated as ~ 22.20 °C. Continuous positive SST anomalies, recorded since 2010, are another significant outcome of the study, which shall be crucial for monitoring and predicting future climatic events.

1. Introduction

Sea surface temperature (SST) is one of the most essential and crucial physical oceanographic parameters and climatologic variables which define and influence regional and global climate regimes. At the interface of ocean and atmosphere, SST modulates the heat fluxes between the ocean and atmosphere, affects the oceanic and atmospheric circulations, properties of the seawater, biochemical processes, primary production, weather patterns and local phenomena such as severe storms, extreme precipitation and heat waves (Deser, Alexander, Xie, & Phillips, 2010; Pisano et al., 2020; Trenberth, 2009).

SST responds to anthropogenic and natural climate changes and variabilities in different time scales (i.e., seasonal, inter-annual, decadal and multi-decadal) (Deser et al., 2010; Pisano et al., 2020; Trenberth, 2009). The solar forcing, wind forcing, cloudiness, ocean-atmosphere interactions, and ocean-atmosphere circulations affect and modulate SST on different time scales (Gastineau & Frankignoul, 2015; Hurrell & Deser, 2009; Pisano et al., 2020; Rencurrel & Rose, 2020). However, in the last 50 years, greenhouse gas emissions caused by anthropogenic processes have changed the heat energy balance of the planet Earth on a global scale. About 90% of this additional heat energy generated by anthropogenic greenhouse gasses is absorbed in the ocean, resulting in a warming of the SST of the world ocean (Core Writing Team, Pachauri, & Meyer, 2015; Pastor, Valiente, & Palau, 2018; Stocker et al., 2013; Trenberth, Fasullo, & Balmaseda, 2014). Therefore, SST is a key and essential parameter for monitoring the ocean’s present state and predicting future climatic events.

Regionally, the Mediterranean Sea responding to climate change by continuous and rapid warming in the last few decades. The Mediterranean Sea warming trend is about twice the global ocean warming trend. Since the pre-industrial era, the annual mean SST of the Mediterranean Sea is increased by about 1.0-1.5 ℃, especially with a higher rate in the last decades, while the highest SST warming was recorded in the Levantine Basin of the Eastern Mediterranean Sea (El-Geziry, 2021; Macias, Garcia-Gorriz, & Stips, 2013; Pastor et al., 2018; Pisano et al., 2020; Samuel-Rhoads et al., 2013). This rapid and continuous SST warming trend of the Levantine Basin (ranging between 0.025–0.055 ℃/year) in the last few decades has been reported in several studies by using different methods (i.e., observational, model, reanalysis, and satellite) (El-Geziry, 2021; Macias et al., 2013; Pastor et al., 2018; Pisano et al., 2020; Samuel-Rhoads et al., 2013; Shaltout & Omstedt, 2014).

Despite their limitations (Jordà et al., 2017; Romanou et al., 2010), the fifth-generation atmospheric reanalysis (ERA5) data sets of the European Centre of the Medium-Range Weather Forecast (ECMWF) reanalysis (Hersbach et al., 2020) data sets are beneficial, powerful tools and widely used for climate analysis, especially due to the temporal and spatial difficulties of in-situ observations.

The SST, along with the salinity, is a fundamental parameter that affects and determines the physical oceanographic characteristics of the water masses in the Levantine Basin. The processes of local water mass formation in the region, i.e., Levantine Surface Water (LSW), Levantine Intermediate Water (LIW) and Levantine Deep Water (LDW), are well studied in the literature (Deliceırmak & Salihoğlu, 2020; Fach et al., 2021; Salihoglu et al., 2019; The LIWEX Group, 2003; The POEM Group, 1992).

This study aimed to evaluate and analyse SST trends in the southern Cilician Basin by observational time-series data sets of the Kyrenia Meteorological Station for 25 years between 1995 and 2020. ERA5 reanalysis and in-situ Conductivity – Temperature – Depth (CTD) measurements are used to compare and validate the data sets.

2. Data And Methods

Three different data sets (i.e., observational time-series data sets of the Kyrenia Meteorological Station, ERA5 reanalysis data sets of the ECMWF, and in-situ CTD measurements from the Kibris Time Series “the KTS”) studies are used in this study.

The observational time-series data set of the Kyrenia Meteorological Station is used to analyse SST trends. ERA5 data sets of ECMWF and in-situ CTD data of the KTS studies are used to compare and validate the observational and reanalysis of SST data sets in the southern Cilician Basin between 1995 and 2020.

Observational time-series data sets are obtained from the Meteorological Office of the Turkish Republic of Northern Cyprus (TRNC). The SST data is measured at the entrance of the Port of Kyrenia on a daily basis by the Kyrenia Meteorological Station (Fig. 1). Monthly means, annual means and trends are calculated and drawn using Sigma Plot software.

ERA5 reanalysis data sets “ERA5 hourly data on single levels and ERA5 monthly averaged data on single levels” between 1995–2020, are downloaded from the Copernicus Data Store (CDS) through the ECMWF and plotted by using Ocean Data View (ODV) software (Fig. 1). The SST units are given in Kelvin (K) and shall be converted to Celsius (°C) by subtracting 273.15.

In-situ CTD data sets of the KTS studies (Deliceırmak & Salihoğlu, 2020; Salihoglu et al., 2019) are compared to analyse and validate the observational data sets of the Kyrenia Meteorological Station between October 2015 and June 2018.

3. Results

Analyses of the annual mean SST and annual mean SST trend of the observational time-series data sets of the Kyrenia Meteorological Station between 1995 and 2020 are shown in (Fig. 2). The annual mean SST from 1995 to 2020 are calculated as 22.20 °C. Linear trend calculations revealed an increasing trend in the annual mean SST by a rate of about 0.043 °C/year and, in total, 1.08 °C during the 25 years investigated period (Fig. 2).

Annual mean SST anomalies between 1995 and 2020 are shown in (Fig. 3). Analysis of the annual mean SST data sets revealed continuous and consecutive positive anomalies in the region since 2010, except in 2013 (-0.1 °C). The highest positive annual SST anomaly was recorded in 2018 with 1.1 °C, and the highest negative SST anomaly was recorded in 1996 with 0.9 °C (Fig. 3).

Analysis of monthly SST and monthly SST trends of the observational time-series data sets of the Kyrenia Meteorological Station between 1995 and 2020 are shown in (Fig. 4). The minimum monthly mean SST was recorded in February at 16.2 °C (red coloured in Fig. 4), and the maximum monthly mean SST was recorded in August at 29.3 °C (grey coloured in Fig. 4). The coldest monthly mean SST was recorded in February 1996 at 15.1 °C, while the warmest monthly mean SST were recorded at 30.3 °C in August 1998 and August 2010 (Fig. 4).

Linear trend calculations of monthly mean SST revealed an increasing trend every month except June. Decreasing SST trend was recorded in June by -0.023 °C/year, 0.57 °C in total between 1995 and 2020 (pink coloured in Fig. 4). Between 1995 and 2020, the highest increasing trend of monthly mean SST was observed in November (dark yellow coloured in Fig. 4) and December (dark pink coloured in Fig. 4) by 0.099 °C/year (~ 2.48 °C in total) and 0.091 °C/year (~ 2.28 °C in total), respectively. The highest positive monthly SST anomaly was observed with 2.6 °C and 2.5 °C, respectively, in November and December 2018. On the other hand, the lowest increasing trend was recorded in July and May with 0.019 °C/year (~ 0.48 °C in total) and 0.021 °C/year (~ 0.53 °C in total), respectively (Fig. 4).

Observational monthly mean SST data of the Kyrenia Meteorology Station (Fig. 5) compared with the ERA5 monthly averaged and hourly data on a single level from 1995 and 2020 (Fig. 6). Although there were slight differences in maximum and minimum SST values, a comparison of these two data sets revealed consistent results, especially on temporal distribution, peaks, and trends. Furthermore, the monthly mean SST data of the Kyrenia Meteorology Station was compared with the in-situ CTD measurements of the Surface Mixed Layer temperature of the KTS studies between October 2015 and June 2018. Comparing these data sets revealed consistent and very similar SST values during the analysed period (Fig. 7) (Delicеırmak & Salihoğlu, 2020; Salihoglu et al., 2019).

4. Discussion

In this study, observational time-series data sets of the Kyrenia Meteorological station are evaluated and compared with the ERA5 reanalysis data sets and in-situ CTD measurements to analyse and validate the observational SST data. The comparison between the data sets seems to be consistent and satisfactory.

The results revealed that the SST of the southern Cilician Basin was in an increasing trend with 0.043/year between 1995 and 2020. The annual mean SST was calculated as 22.2 °C. These results were consistent and within the range of several recent studies conducted in the Levantine Basin (El-Geziry, 2021; Pastor et al., 2018; Pisano et al., 2020; Samuel-Rhoads et al., 2013; Shaltout & Omstedt, 2014). However, one of the most significant differences between this study and the studies mentioned above is the seasonal differences in the SST increases. Contrary to the studies mentioned above, in which the highest SST warming was observed in the summer seasons, in this study, the lowest SST warming was observed in the late spring and summer seasons. Even in June, decreasing SST with a rate of -0.023 °C/year was recorded during the investigated period. The highest SST increases were observed in late autumn (November and December) during the analysed period. Between 1995 and 2020, about 0.099 °C/year (2.48 °C in total) and 0.091 °C/year (2.28 °C in total) of SST warming were observed in November and December, respectively. It is well known in the literature that the SST in late autumn and early winter is crucial for winter mixing processes and forming of local water masses (i.e., Levantine Intermediate Water and Levantine Deep Water). Cooling of the SST in November and December is the precondition of these processes (Deliceırmak & Salihoğlu, 2020; Fach et al., 2021; Salihoglu et al., 2019; The LIWEX Group, 2003; The POEM Group, 1992). Therefore, excessive warming recorded in these months shall be investigated and monitored to understand the effects of the warming SST on the physical properties of the seawater.

Another significant outcome of this study is the continuous and consecutive positive SST anomalies recorded in the region since 2010. These results are consistent with the several studies which predict the SST will continue to increase even if the greenhouse gas emissions are reduced or limited in the short term (Deser et al., 2010; Pastor et al., 2018; Pisano et al., 2020; Stocker et al., 2013; Trenberth, 2009).

5. Conclusion

Analyses of the available best data infer that the increasing trend of SST is not going to slow down in the near future. Therefore, the effects of warming SST on the biosphere shall be carefully monitored, investigated and well understood. Climatological time-series observations, model simulations and remote sensing are crucial in understanding and predicting climatic events, especially in ocean sciences.

References

1. Core Writing Team, Pachauri RK, Meyer L (2015) *IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. *IPCC*. Gian-Kasper Plattner. Retrieved from http://www.ipcc.ch
2. Delicеırmak Ç, Salihoğlu İ (2020) Physical oceanographic features of the Cilician Basin and wastewater dumping at the coastal zone of Kyrenia. *Desalination and Water Treatment*, *177*(May 2019), 290–296. https://doi.org/10.5004/dwt.2020.25182
3. Deser C, Alexander MA, Xie S-P, Phillips AS (2010) Sea Surface Temperature Variability: Patterns and Mechanisms. *Http://Dx.Doi.Org/*10.1146/*Annurev-Marine-120408-151453*, *2*(1), 115–143. https://doi.org/10.1146/ANNUREV-MARINE-120408-151453
4. El-Geziry TM (2021) Long-term changes in sea surface temperature (SST) within the southern Levantine Basin. Acta Oceanol Sin 40(3):27–33. https://doi.org/10.1007/s13131-021-1709-2
5. Fach BA, Orek H, Yilmaz E, Tezcan D, Salihoglu I, Salihoglu B, Latif MA (2021) Water Mass Variability and Levantine Intermediate Water Formation in the Eastern Mediterranean between 2015-2017. *Journal of Geophysical Research: Oceans*, *2*. https://doi.org/10.1029/2020jc016472
6. Gastineau G, Frankignoul C (2015) Influence of the North Atlantic SST variability on the atmospheric circulation during the twentieth century. J Clim 28(4):1396–1416. https://doi.org/10.1175/JCLI-D-14-00424.1
7. Hersbach H, Bell B, Berrisford P, Hirahara S, Horányi A, Muñoz-Sabater J, Thépaut JN (2020) The ERA5 global reanalysis. Q J R Meteorol Soc 146(730):1999–2049. https://doi.org/10.1002/qj.3803
8. Hurrell JW, Deser C (2009) North Atlantic climate variability: The role of the North Atlantic Oscillation. J Mar Syst 78(1):28–41. https://doi.org/10.1016/j.jmarsys.2008.11.026
9. Jordà G, Von Schuckmann K, Josey SA, Caniaux G, García-Lafuente J, Sammartino S, Macías D (2017) The Mediterranean Sea heat and mass budgets: Estimates, uncertainties and perspectives. Prog Oceanogr 156(July):174–208. https://doi.org/10.1016/j.pocean.2017.07.001
10. Macias D, Garcia-Gorriz E, Stips A (2013) Understanding the causes of the recent warming of Mediterranean waters. How much could be attributed to climate change? PLoS ONE 8(11). https://doi.org/10.1371/journal.pone.0081591
11. Pastor F, Valiente JA, Palau JL (2018) Sea Surface Temperature in the Mediterranean: Trends and Spatial Patterns (1982–2016). Pure appl Geophys 175(11):4017–4029. https://doi.org/10.1007/s00024-017-1739-z
12. Pisano A, Marullo S, Artale V, Falcini F, Yang C, Leonelli FE, Nardelli BB (2020) New evidence of Mediterranean climate change and variability from Sea Surface Temperature observations. Remote Sens 12(1):1–18. https://doi.org/10.3390/RS12010132
13. Rencurrel MC, Rose BEJ (2020) The efficiency of the Hadley cell response to wide variations in ocean heat transport. J Clim 33(5):1643–1658. https://doi.org/10.1175/JCLI-D-19-0334.1

14. Romanou A, Tselioudis G, Zerefos CS, Clayson CA, Curry JA, Andersson A (2010) Evaporation-precipitation variability over the Mediterranean and the black seas from satellite and reanalysis estimates. J Clim 23(19):5268–5287. https://doi.org/10.1175/2010JCLI3525.1
15. Salihoglu I, Tugrul S, Gucu AC, Salihoglu B, Kocak M, Tezcan D, Temel O (2019) Determination of the influence of anthropogenic and natural processes on the Cilician Basin (Between the Turkish Republic of Northern Cyprus and Turkey) marine ecosystem. Kyrenia, Mersin
16. Samuel-Rhoads Y, Zodiatis G, Nikolaidis A, Hayes D, Georgiou G, Konnaris G, Nikolaides M (2013) Climate change impacts sea surface temperature in the eastern Mediterranean, Levantine basin. In *First International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2013)* (Vol. 8795, 8795). https://doi.org/10.1117/12.2028329
17. Shaltout M, Omstedt A (2014) Recent sea surface temperature trends and future scenarios for the Mediterranean Sea. Oceanologia 56(3):411–443. https://doi.org/10.5697/oc.56-3.411
18. Stocker TF, Qin D, Plattner GK, Tignor MMB, Allen SK, Boschung J, Midgley PM (2013) Climate change 2013 the physical science basis: Working Group I contribution to the fifth assessment report of the intergovernmental panel on climate change. *Climate Change 2013 the Physical Science Basis: Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, *9781107057*, 1–1535. https://doi.org/10.1017/CBO9781107415324
19. The LIWEX Group (2003) The Levantine Intermediate Water Experiment (LIWEX) Group: Levantine basin—A laboratory for multiple water mass formation processes. J Phys Res 108(C9):8101. https://doi.org/10.1029/2002JC001643
20. The POEM Group (1992) General circulation of the Eastern Mediterranean. Earth Sci Rev 32(4):285–309. https://doi.org/http://dx.doi.org/10.1016/0012-8252(92)90002-B
21. Trenberth KE (2009) An imperative for climate change planning: tracking Earth's global energy. Curr Opin Environ Sustain 1(1):19–27. https://doi.org/10.1016/J.COSUST.2009.06.001
22. Trenberth KE, Fasullo JT, Balmaseda MA (2014) Earth's energy imbalance. J Clim 27(9):3129–3144. https://doi.org/10.1175/JCLI-D-13-00294.1

Figures

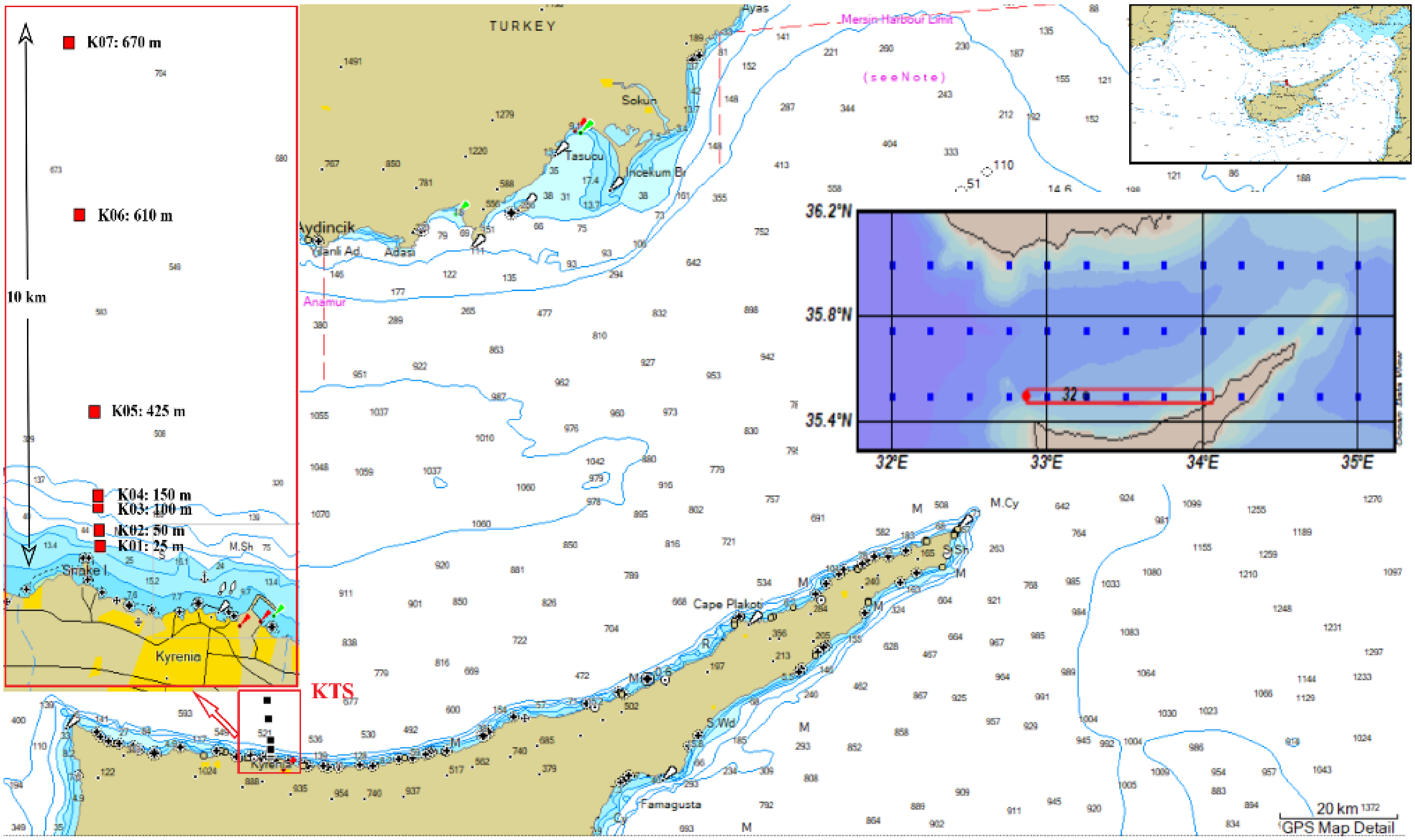

Figure 1

The map of the Cilician Basin. KTS stations are on the left. ERA5 stations on the right. The red section in the ERA5 map indicates the selected stations.

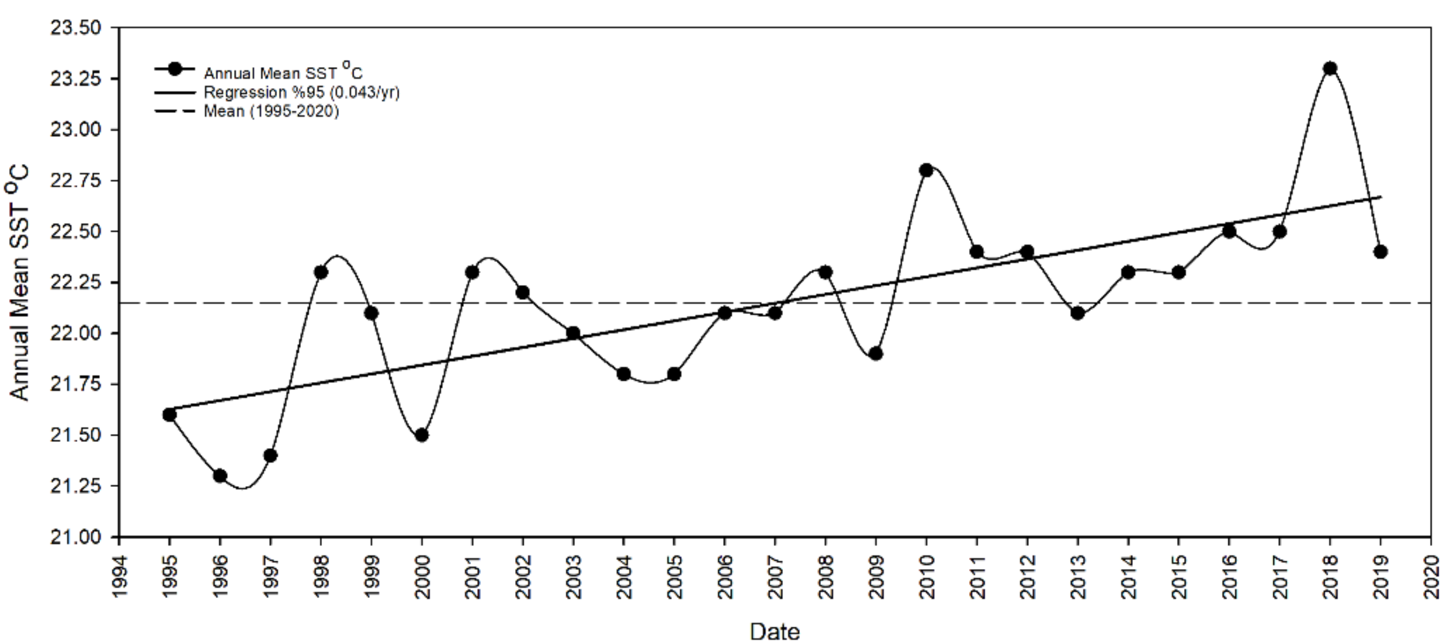

Figure 2

Annual mean SST of the observational time-series data of Kyrenia Meteorological Station between 1995 and 2020.

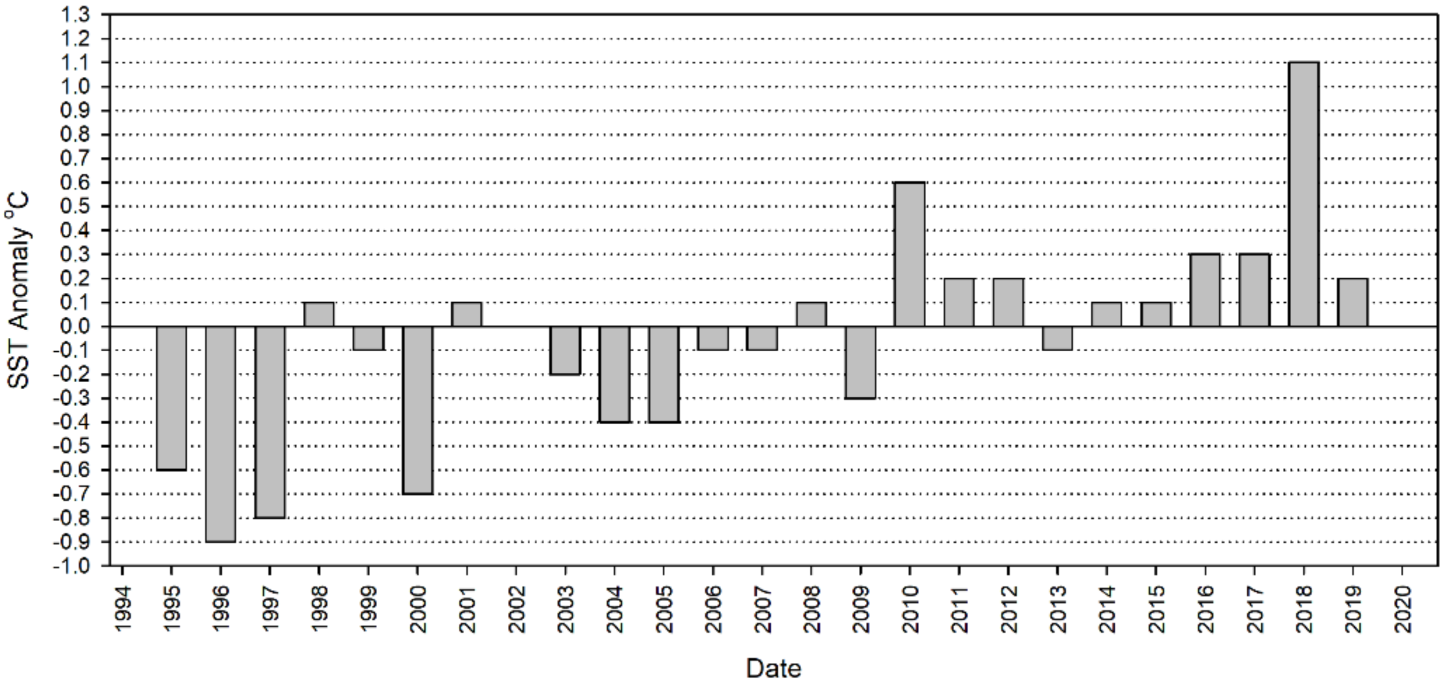

Figure 3

SST anomalies of the observational time-series data of Kyrenia Meteorological Station between 1995 and 2020. The anomalies are calculated by removing the annual mean value of the period.

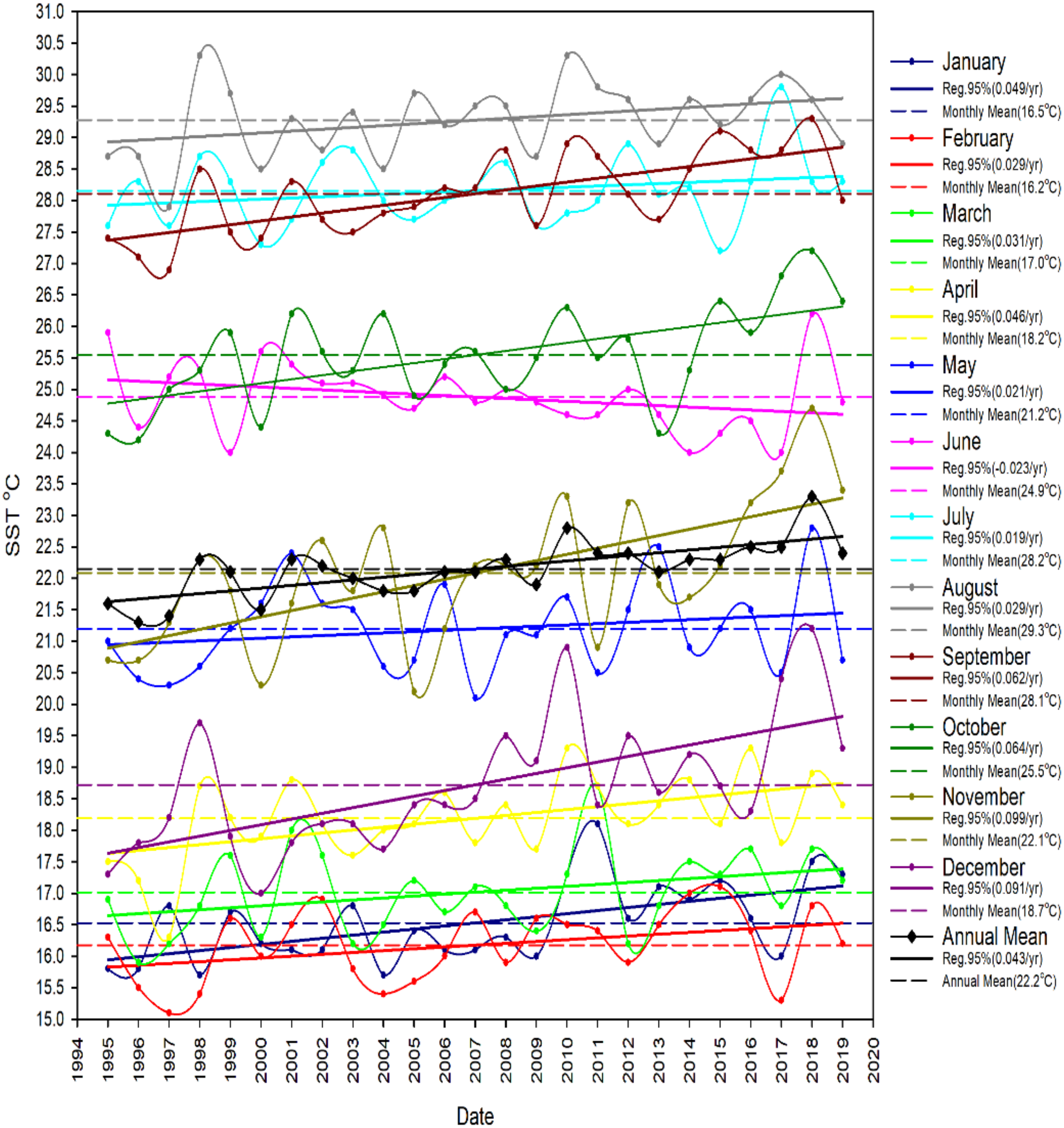

Figure 4

Monthly mean SST between 1995 and 2020. Each month is colour coded and shall be seen in the Legend. The black coloured plot is the annual mean. Solid lines are the regression 95%, and the dashed line is the mean SST. Trend and mean values shall be seen in the Legend

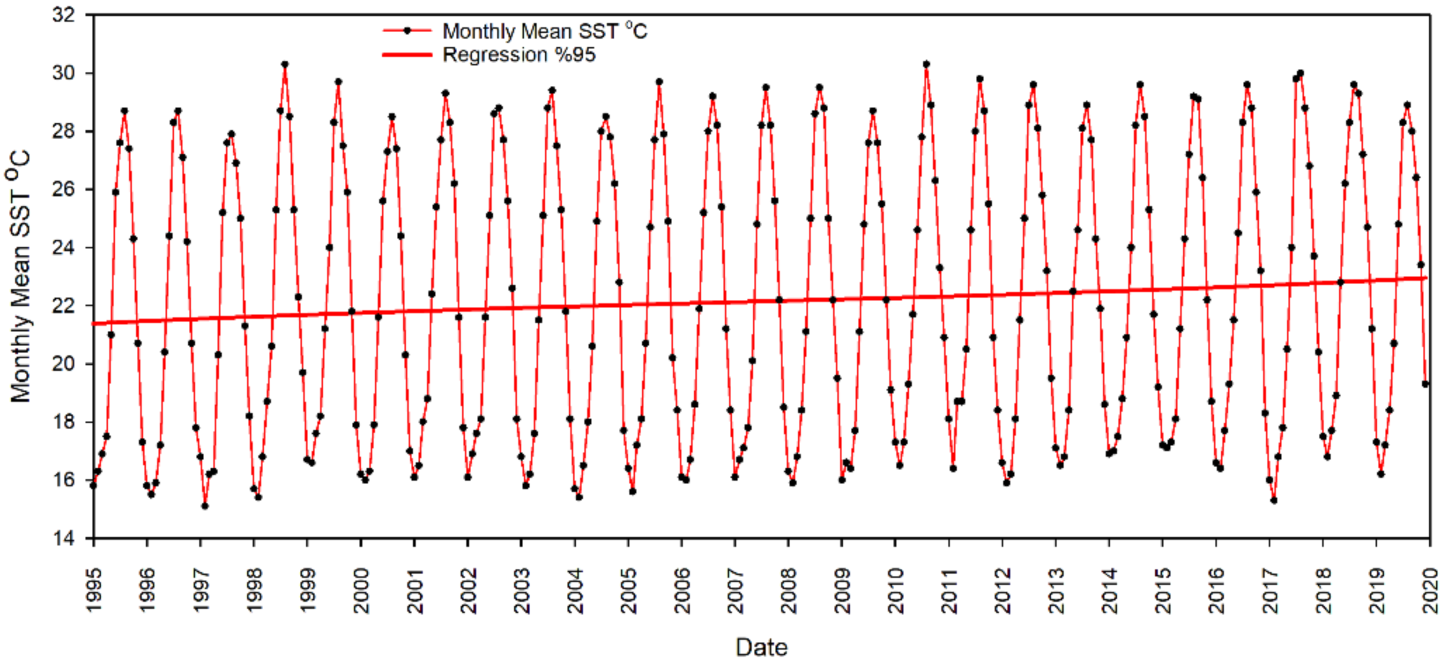

Figure 5

Time-series plot of monthly mean SST of observational data from 1995 to 2020. Black dots are the months, and the solid red line is the trend line.

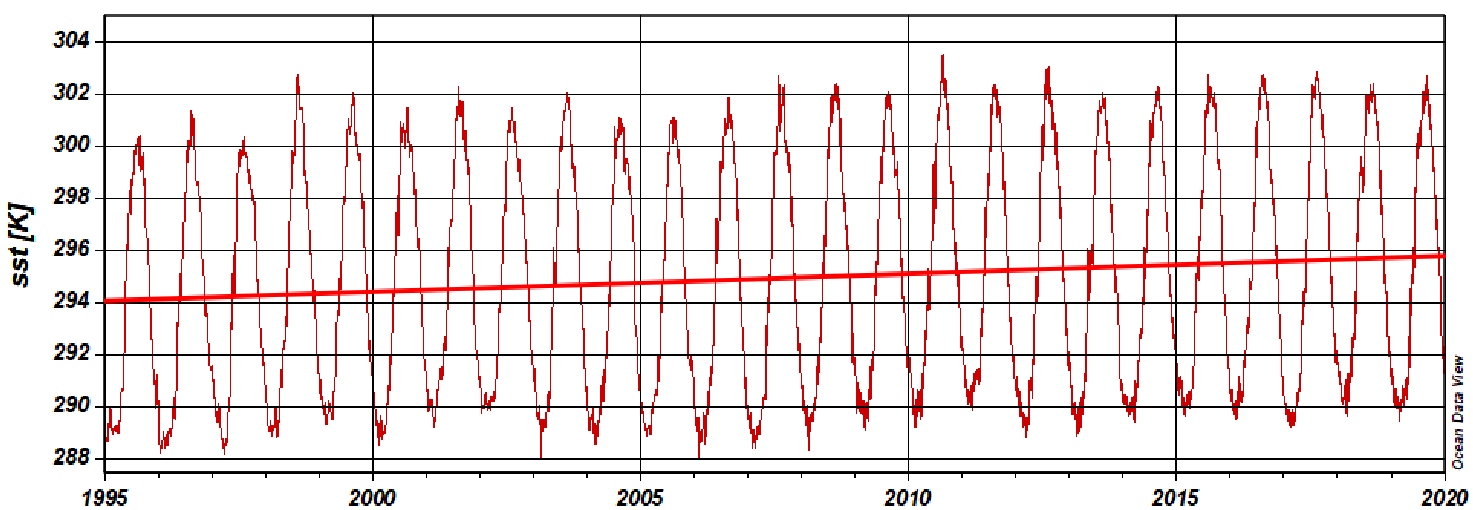

Figure 6

Time-series plot of monthly mean SST of ERA5 reanalysis from 1995 to 2020. The solid red line is the trend line. Selected stations shall be seen in Figure 1.

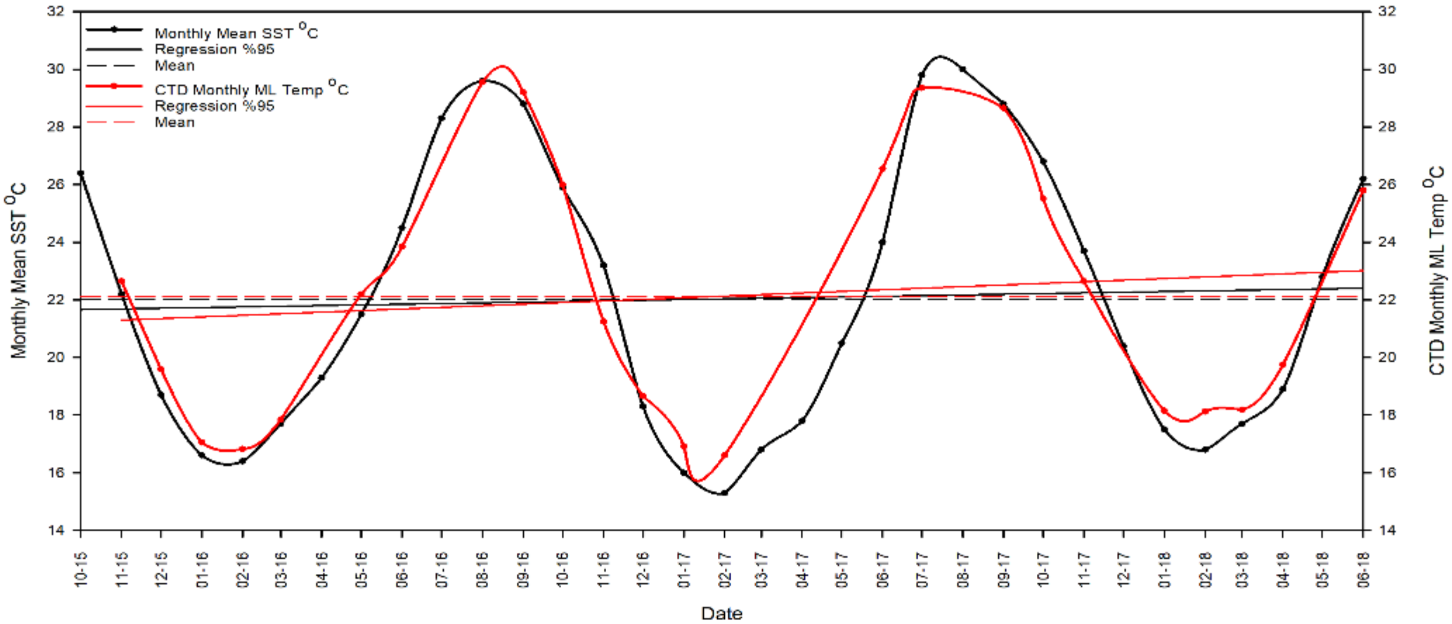

Figure 7

Monthly mean SST of the observational time-series data vs CTD monthly mean surface mixed layer temperatures between 10/2015 and 06/2018.