Scientific Reports in Life Sciences 3 (1): 1-8
DOI: https://doi.org/10.5281/zenodo.6512092

Scientific reports in life sciences
http://www.scientific-reports.com

Satellite indicators of sea surface temperature, chlorophyll-a, and the diffuse attenuation coefficient for the Izmir Bay: A study for descriptive and temporal evaluation

A. Hüsnü Eronat
Dokuz Eylül University, Institute of Marine Sciences and Technology
Email: husnu.eronat@deu.edu.tr

Received: 9 January 2022 / Revised: 15 February 20212/ Accepted: 26 February 2022 / Published online: 04 March 2022.

How to cite: Eronat, A.H. (2022). Satellite indicators of sea surface temperature, chlorophyll-a, and the diffuse attenuation coefficient for the Izmir Bay: A study for descriptive and temporal evaluation, Scientific Reports in Life Sciences 3(1), 1-8.
DOI: https://doi.org/10.5281/zenodo.6512092

Abstract
One of the most important challenges in the world is climate change causing the warming of oceans and its direct and indirect impacts on ecosystems. This fact makes it important to have and utilize regular data sets to increase understanding. This study, it is aimed to understand the descriptive properties of outer Izmir Bay by using alternative data sets from satellite technology. Remotely sensed data sets of the sea surface temperature, chlorophyll-a, and attenuation coefficient through satellite technology were analyzed over a long time period, between 01/2004 and 12/2021. Results showed stable properties of these variables and a significantly weak increasing trend in chlorophyll-a and attenuation coefficient. Even though no significant trends were detected in sea surface temperature, months from winter to summer showed a significant increasing trend for the temperature. Seasonal warming trends can be the cause of the successful settlement of warm-water species in Izmir Bay, as it is maybe the case in other parts of the Mediterranean Sea.
Keywords: Descriptive, trend, physical and optical properties, Izmir Bay

Introduction
Various data sources provide important information about global warming, which is one of the most important challenges for the world ecosystem. Systematic changes in the physical and chemical properties of ocean water all over the world (Doney et al. 2012 and references therein) concluded there is serious pressure on the components of the marine ecosystems. These pressures can be the reason for the collapse of the system or lead to altering structures and functions in a system (Doney et a. 2012). According to Jin et al. (2018), thermal stratification delivers an important impact on water quality as well as particle circulation and sinking mechanism, besides physiological stress on the organisms (Doney 2012).

According to Bengil (2020), the Mediterranean Sea has significant documentation on the trend of global warming over the last three decades, which indicated consistent warming for the entire Basin (Pisano 2020) and some sub-regions, including the Aegean Sea (Nykjaer 2009, Skiliris et al. 2011, Bengil and Mavruk 2019). Evaluations on interannual patterns of chlorophyll concluded with trends in spatial variation in trends (Colella et al. 2016, Bengil and Mavruk 2018). The utilization of various data sources in marine studies has become popular in the last decades. The effectiveness of these sources was discussed and various evaluations on their utilization success were provided for the Mediterranean Sea, especially for the Aegean Sea (Bengil et al. 2021). Data from freely available medium-scale satellite remote sensing data are advantageous for long-term evaluation of the properties of certain marine areas since there are systematically available time series data sets that lack data gaps (e.g. OceanColor and Giovanni). Sea surface temperature and chlorophyll are available globally in time series due to being retrievable data from satellite technology (Bengil 2020).

Izmir Bay, as a semi-closed part of the Aegean Sea, is located on the west coast of the Anatolian Peninsula (Fig. 1). The geographical location of the bay is in the middle of the Aegean Sea. It is known as one of the biggest bays in the Mediterranean Sea (Sipahioglu, 2014). As a result of its morphology and physio-chemical features, Izmir Bay can be classified into three sub-regions; outer, middle, and inner bay. Chemical pollution is one of the main challenges in the bay of intense industrial growth and urbanization (Lemenkova, 2016). Additionally, current systems and water masses are well known in Izmir Bay (Sayın 2003, Sayın et al. 2006). However, long-term evaluation of the properties is still scarce and further information on the inter-and intra-annual properties of its sub-regions is required. This study, therefore, aims to understand, characterize, and describe inter-and intra- annual properties of sea surface temperature, chlorophyll, and attenuation coefficient of the light, in the outer sub-region of Izmir Bay.

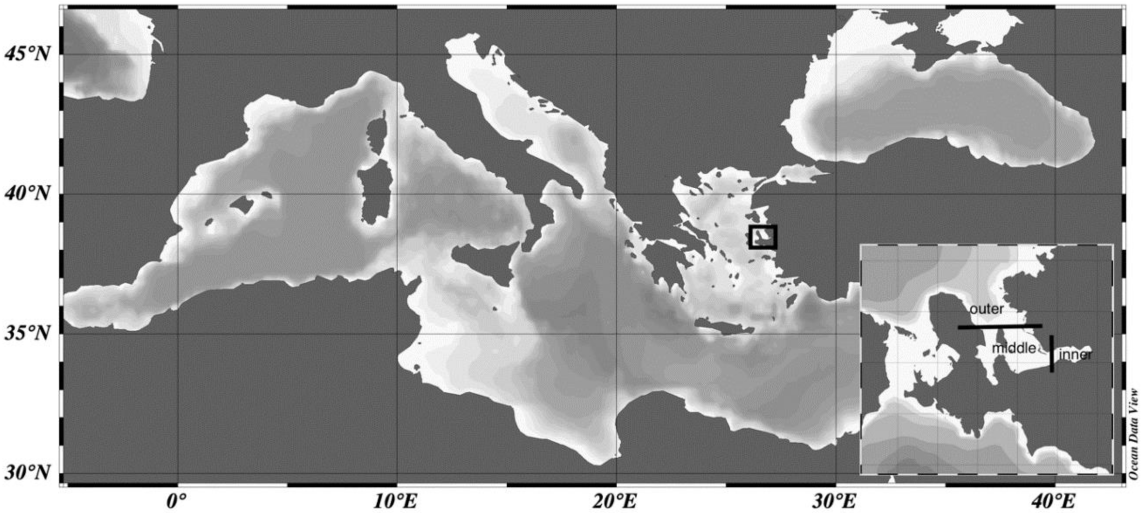

Figure 1. The study area. The black box shows Izmir Bay, and black lines separate sub-regions in Izmir Bay. The outer region was used for further analysis

Material and methods

Three adjacent regions that represent the inner, middle, and outer parts are recognized in Izmir Bay. The outer part of the bay was chosen for further analysis in this paper (Figure 1). Datasets that represent estimated monthly values of sea surface temperature (SST), chlorophyll-a (Chl), and diffuse attenuation coefficient (Kd) were used in this study. The data sets were extracted from the Giovanni online data system; developed and maintained by the NASA GES DICS (Acker and Leptoukh 2007). Relevant data sets were obtained from the MODIS Aqua level four products, which have 4 X 4 km spatial resolution and the temporal period from 01/2004 to 12/2021. Further information about the products of the data sets is available on the Ocean Color website (https//ocean-color.gsfc.nasa.gov). The minimum, maximum, average, and range of each variable were calculated to designate the descriptive properties of the study area. Additionally, linear fittings with monthly time frames were applied to evaluate trends of SST, Chl, and Kd during the time period of the study. The intercept and slope of linear trend lines with a 95% confidence interval (ci) were estimated by using linear regression. Slope values and their ci were used to evaluate trends in different time periods.

Results

Descriptive characteristics

The annual average of SST was found to be 18.92 ^{o}C in the outer part of Izmir Bay. The overall range of SST was 12.41 ^{o}C, and the overall minimum SST was 13.57 ^{o}C as the overall maximum was 25.98 ^{o}C. It should be also noted that the minimum value was observed in 2006 and the maximum was in 2010. On the other hand, the coolest summer was in 2013 (23.37 ^{o}C) and the warmest winter was in 2021 (15.49 ^{o}C). Interannual variation showed the widest range in 2010 as 10.90 ^{o}C, while the narrowest range was 8.95 ^{o}C in 2020. Regarding intra-annual characteristics, the minimum temperature was found to be in January and February, and the maximum temperature was detected in July. Intra annual variation showed the widest range in July with 3.04 ^{o}C, while the narrowest range was 2.22 ^{o}C in May. Descriptive values of the data set are presented in Table 1. The overall average of Chl was 0.52 mg/m^3 in the study area. Intra-annual averages fluctuated from 0.31 mg/m^3 (2008) to 0.91 mg/m^3 (2018). On the other hand, the overall range was found to be 3.61 mg/m^3 from 0.31 mg/m^3 in 2008 to 3.28 mg/m^3 in 2019. While maximum observation dispersed from 0.48 mg/m^3 (November 2008) to 3.76 mg/m^3 (February 2019), observations with the minimum values over the time period were found to be between 0.15 mg/m^3 (July 2009) and 0.48 mg/m^3 (May 2019). Interannual characteristics of Chl indicated a sinusoidal pattern from winter months, mostly in February to summer months, which was mostly in June and July. Parallel to this, the widest interannual range was found to be in February (3.39 mg/m^3), while the narrowest range was found to be in June (0.33 mg/m^3). Descriptive parameters of Chl data set are given in Table 1.

Table 1. Descriptive parameters of data sets (MAX: maximum, MIN: minimum).

SST (ºC)				
Months	Average	MAX	MIN	Range
January	14.61	15.83	13.57	2.26
February	14.73	16.05	13.57	2.47
January	15.63	17.04	14.61	2.44
February	18.44	20.19	17.50	2.68
January	22.24	23.25	21.04	2.22
February	23.74	25.06	21.76	3.30
January	24.18	25.98	22.19	3.79
February	22.66	24.23	21.06	3.16
January	20.46	22.40	19.35	3.04
February	18.33	19.56	16.59	2.97
January	16.70	18.38	15.08	3.30
February	15.32	16.56	13.90	2.67
All year	18.92	19.70	18.04	1.66
Chl (mg/m^3)				
	Average	MAX	MIN	Range
January	0.64	1.33	0.36	0.96
February	0.98	3.76	0.36	3.39
January	0.82	1.97	0.35	1.63
February	0.60	1.29	0.23	1.06
January	0.30	0.59	0.17	0.42
February	0.28	0.50	0.17	0.33
January	0.32	0.52	0.15	0.37
February	0.36	0.59	0.19	0.40
January	0.36	0.65	0.22	0.42
February	0.47	1.04	0.22	0.82
January	0.61	1.10	0.37	0.74
February	0.54	0.81	0.35	0.46
All year	0.52	3.76	0.15	3.61
Kd (m$^-$)				
	Average	MAX	MIN	Range
January	0.08	0.12	0.06	0.06
February	0.10	0.29	0.06	0.23
January	0.09	0.16	0.05	0.11
February	0.07	0.11	0.04	0.07
January	0.05	0.06	0.03	0.03
February	0.04	0.06	0.03	0.03
January	0.05	0.07	0.03	0.04
February	0.05	0.07	0.04	0.03
January	0.05	0.08	0.04	0.03
February	0.06	0.10	0.04	0.06
January	0.08	0.11	0.06	0.05
February	0.07	0.09	0.06	0.03
All year	0.07	0.09	0.05	0.04

The average from the total data set of Kd was 0.07 m^- for the outer part of Izmir Bay. Intra-annual averages were between 0.05 m^- in 2008 and 0.09 m^- in 2019. Additionally, the overall range of Kd was 0.26 m^-, dispersed from 0.03 m^- in 2008 to 0.29 m^- in 2019. As maximum annual Kd was 0.29 m^- from 2019, while the maximum annual observation was dispersed to 0.07 m^- in 2007. On the other hand, the minimum annual Kd was 0.03 m^- in 2004, 2008, 2009, 2015, and 2021 and it dispersed up to 0.06 m^- in 2019. The interannual characteristic of Kd data set showed the highest maximum value in February, while the lowest minimum was in May, June, and July. Interannual ranges of Kd were scattered from 0.03 m^- in May, June, August, September, and December, to 0.23 m^- in February. Details on Kd data set are presented in Table1

Trend analysis

Linear fitting of overall data sets over the time period showed no significant trend in SST, while there were significant positive trends in Chl and Kd ($p<0.05$). The annual trend was 0.0102 mg m^{-3} $year^-$ for Chl 0.0008 m^- $year^-$ for Kd. Interannual analysis showed a significant trend of SST in the months from February to June, August, and December ($p<0.05$). Significant trends were April, July, August, September, and October for Chl, and months from August to October and April for Kd ($p<0.05$). Trend results from the linear fitting analysis are presented in Table 2.

Table 2. Significant trends in time frames of data sets. Slope and its confidence limit (95%).

Time frame	Variable	Trend (slope)	Lower confidence interval	Upper confidence interval
April	**Chl**	2.39E-02	1.80E-03	4.59E-02
July		1.07E-02	3.91E-03	1.75E-02
August		1.76E-02	1.18E-02	2.34E-02
September		1.12E-02	2.84E-03	1.96E-02
October		2.40E-02	1.39E-02	3.41E-02
Overall		8.53E-04	6.83E-05	1.64E-03
April	**Kd**	1.75E-03	2.05E-04	3.30E-03
August		1.36E-03	8.37E-04	1.89E-03
September		8.57E-04	4.57E-05	1.67E-03
October		2.03E-03	1.28E-03	2.79E-03
Overall		6.70E-05	1.04E-05	1.24E-04
February	**SST**	8.29E-02	5.07E-02	1.15E-01
March		6.61E-02	2.46E-02	1.08E-01
April		9.85E-02	5.72E-02	1.40E-01
May		6.65E-02	3.06E-02	1.02E-01
June		8.06E-02	2.86E-02	1.33E-01
August		7.39E-02	3.69E-03	1.44E-01
December		5.33E-02	2.62E-03	1.04E-01

Discussion

There are various detailed studies on biological (Sunlu et al. 2012), chemical (Lemenkova 2016), and physical properties (Sayın 2003, Sipahioglu 2014) of the Izmir Bay, this study is the first documentation for evaluation of the properties over a wider time period. A comparison with an in-situ data set from Sayın (2003) showed very similar properties in data distribution in temperature measurement for the bay. Similarly, a comparison by Kontas et al (2004) for the outer part of Izmir Bay resulted that alternative data sources, such as satellite remote sensing, have a similar chlorophyll-a data set distribution for the region. This fact encourages the use of alternative data sets for further evaluations in Izmir Bay. On the other hand, it should be noted that data properties in the middle and inner part of Izmir Bay are remarkably different in in-situ data sets (please see, Kontas et al. 2004, Kucuksezgin et al 2006), therefore, utilization of alternative data sets in these sub-regions should be questioned and verified before further analysis.

Even though there has been no study on diffuse attenuation coefficient variations in Izmir Bay, some evaluations on light parameters are available. Sayin et al. (2007) investigated spatiotemporal changes in light transmission percentage and secchi disk variation. They highlighted that the wastewater treatment system in the bay impacted positively at the beginning of the 2000s. Contrary, this study showed a significant increasing trend in attenuation coefficients from 2003 to 2021 in the outer part of Izmir Bay. However, the trend value of the attenuation coefficient, 0.0008 m^{-} per year is very small over the time period. Thus, it can be concluded that the wastewater treatment system has provided stable physical system properties regarding the light distribution of the bay.

Previous studies on seawater temperature reported an increasing trend in the Aegean Sea (Skliris et al 2011, Bengil and Mavruk 2019). Additionally, Skliris et al (2011) reported that the Aegean Sea has the lowest trend properties in seawater temperature among regions in the Mediterranean Sea. This study resulted that no significant warming trend has been found in the outer part of Izmir Bay over the time period of this study. Even though annual evaluation does not show a significant trend in sea surface temperature, winter, spring, and summer months showed a significant increasing trend over the time period of the study. Seasonal warming trends can be the cause of successful settlement of warm-water species in Izmir Bay, as in various other parts of the Mediterranean Sea. Lastly, in terms of previous studies on chlorophyll-a trend showed very weak or insignificant trends in most of the sub-regions of the Mediterranean Sea (Coppini et al. 2013, Collela et al., 2016, Bengil and Mavruk 2018). Bengil and Mavruk (2018) particularly reported an insignificant trend in chlorophyll-a throughout the Aegean Sea. Parallel to these studies, a very weak trend of chlorophyll-a was detected in the outer part of Izmir Bay. In conclusion, this study provided descriptive and long-term trends for physical and bio-optical properties of the outer part of Izmir Bay. While descriptive properties showed stable and consistent results with studies from previous years or data sets, trend analysis showed slightly different properties than the Aegean Sea. These results encourage the utilization of data sets from satellite technologies to proceed toward future aims.

References

Bengil F., Mavruk S. (2018). Bio-optical trends of seas around Turkey: An assessment of the spatial and temporal variability. Oceanologia, 60(4), 488–499. https://doi.org/10.1016/j.oceano.2018.03.004

Bengil F., Mavruk S. (2019). Warming in Turkish seas: comparative multidecadal assessment. Turkish Journal of Fisheries and Aquatic Sciences, 19(1), 51–57. https://doi.org/10.4194/1303-2712-v19_1_06

Bengil, F., 2020. Temporal Characteristics and Patterns of Sea Surface Temperature and Chlorophyll in the Ligurian Sea (NW Mediterranean). Sci. Reports Life Sci. 1, 29–37. https://doi.org/10.22034/sris.2020.137097.1001

Bengil, F., Mavruk, S., Kızılkaya, Z., Bengil, E.G.T., Alan, V., & Kızılkaya, İ.T. (2021). Descriptive Capability of Datasets as Proxy of Sea Water Temperature in Coastal

Systems: An Evaluation from the Aegean Sea. Turkish Journal of Fisheries and Aquatic Sciences, 21, 627-635. http://doi.org/10.4194/1303-2712-v21_12_05

Colella S., Falcini F., Rinaldi E., Sammartino M., Santoleri R. (2016). Mediterranean Ocean Colour Chlorophyll Trends. PLoS One 11, e0155756. https://doi.org/10.1371/journal.pone.0155756

Coppini G., Masina S., Pinardi N. (2019). Mediterranean Sea Analysis and Forecast (CMEMS MED-Currents 2016- 2019) [Data set]. https://doi.org/10.25423/CMCC/MEDSEA_ANALYSIS_FORECAST _PHY_006_013_EAS4

Doney S.C., Ruckelshaus M., Emmett Duffy J., Barry J.P., Chan F., English C.A., Galindo H.M., Grebmeier J.M., Hollowed A.B., Knowlton N., Polovina J., Rabalais N.N., Sydeman W.J., Talley L.D. (2012). Climate Change Impacts on Marine Ecosystems. Ann. Rev. Mar. Sci. 4, 11–37. https://doi.org/10.1146/annurev-marine-041911-111611

Juxiang J, Scott A. Wells, Defu Liu, Guolu Yang; Thermal stratification and its relationship with water quality in the typical tributary bay of the Three Gorges Reservoir. *Water Supply* 1 May 2019; 19 (3): 918–925. doi:https://doi.org/10.2166/ws.2018.142

Kontas, A., Kucuksezgin, F., Altay, O., Uluturhan, E. (2004). Monitoring of eutrophication and nutrient limitation in the Izmir Bay (Turkey) before and after wastewater treatment plant. Environment International 29, 1057-1062.

Kucuksezgin, F., Kontas, A., Altay, O., Uluturhan, E. and Darilmaz E. (2006). Assesment of marine pollution in İzmir Bay: Nutrient, heavy metal and total hydrocarbon concentrations. Environment International, 32, 41-51.

Lemenkova, P. (2016). Chemical Pollution of Coastal Waters in the Izmir Bay, Aegean Sea. International Scientific Conference in honor of O.G. Kusakin: “Biodiversity and Evolution”, A. V. Zhirmunsky Institute of Marine Biology, Far Eastern Branch of Russian Academy of Science (RAS), Oct 2016, Vladivostok, Russia. pp.121-126, 10.6084/m9.figshare.7210214 . hal-01986700

Nykjaer L. (2009). Mediterranean Sea surface warming 1985–2006. Clim. Res. Clim Res 39, 11–17. https://doi.org/10.3354/cr00794

Pisano A., Marullo S., Artale V., Falcini F., Yang C., Leonelli F. E., Santoleri R., Buongiorno Nardelli B. (2020). New Evidence Of Mediterranean Climate Change And Variability From Sea Surface Temperature Observations. Remote Sensing, 12(1). Https://Doi.Org/10.3390/Rs12010132.

Sayin, E. (2003). Physical features of the İzmir Bay. *Continental Shelf Research 23*, 957-970.

Sayin, E., Pazi, İ., & Eronat, C. (2006). Investigation of water masses in İzmir Bay, Western Turkey. *Turkish Journal of Earth Sciences*, *15*, 343-372.

Sipahioglu, G. (2014). Water Exchange between Aegean Sea and İzmir Bay. Master thesis, Graduate School of Natural and Applied Sciences of Dokuz Eylül University, 60 pp.

Skliris N., Sofianos S. S., Gkanasos A., Axaopoulos P., Mantziafou A., Vervatis V. (2011). Long-term sea surface temperature variability in the Aegean Sea. Advances in Oceanography and Limnology, 2(2), 125– 139. https://doi.org/10.1080/19475721.2011.601325

Sunlu S., Sunlu, U., Buyukisik, B Kükrer, Serkan A., Uncumusaoğlu. (2012). Nutrient and Chlorophyll a Trends after Wastewater Treatment Plant in Izmir Bay (Eastearn Aegean Sea). Journal of Animal and Veterinary Advances. 11. 113-123. 10.3923/javaa.2012.113-123.