Al-Mukhtar Journal of Basic Sciences 22 (1): 37-46, 2024
Doi: https://doi.org/10.54172/whj12t15

Research Article **Open Access**

The Effect of Wind Speed and Sea Surface Temperature on Chlorophyll –A Concentration in Sea Water Off the Libyan Coast

Haifa M. Ben Miloud[1] and Maha A. Alssabri[2]

***Corresponding author:** regcm00@yahoo.com Department of Atmospheric Science, Faculty of Science, University of Tripoli, Libya.

Second Author: m.alssabri@uot.edu.ly Department of Botany, Faculty of Science, University of Tripoli, Libya

Received:
05 August 2023

Accepted:
14 April 2024

Publish online:
30 April 2024

Abstract

The effect of winds and sea surface temperature on the concentration of chlorophyll-a, which is the primary source for phytoplankton to produce carbon through photosynthesis, is one of the climatic changes formed in the atmosphere and oceans that are the focus of current global studies. The study found a strong correlation between the concentration of chlorophyll-a and wind speed. The concentration of chlorophyll-a rises with increasing wind speed and reaches 0.85. Conversely, the relationship between sea surface temperatures and chlorophyll-a concentration is inverse, meaning that the higher the sea surface temperatures, the lower the concentration of chlorophyll-a. The inverse relationship approaches -0.798 in seawater. The intensity of chlorophyll-a concentration at sea and its relationship with wind speed and sea surface temperature explain why the percentage of the effect of variable wind speed and sea surface temperature on the concentration of chlorophyll-a is affected by (73.6%, 63.8%) on the concentration of chlorophyll-a, respectively.

Keywords: Libya, Climate change, Sea Surface Temperature, Wind speed, Chlorophyll-a.

INTRODUCTION

The Mediterranean region, which lies between two latitudes 30-40 N0, has mild, wet winters and warm to hot, dry summers (Lionello et al., 2006). The Mediterranean Sea's limited nutrient availability for phytoplankton growth which is enhanced from west to east makes it an oligotrophic marine environment (Kotta & Kitsiou, 2019; Turley et al., 2000). The Eastern Mediterranean Sea exhibits non-blooming traits, such as gradual increases in chlorophyll concentrations from summertime lows to wintertime highs (Kotta & Kitsiou, 2019).

Because phytoplankton form the base of the marine food web and account for half of the planet's primary production, they play a crucial role in Earth's system (Kotta & Kitsiou, 2019). Additionally, climate change has a significant impact on marine environment microorganisms. The composition of microorganisms in the ocean is impacted by temperature rises, and this causes changes in the distribution of these organisms. It also has an impact on chlorophyll concentrations, which are markers of phytoplankton abundance and their critical role in the global carbon cycle, influencing changes in production (Gregg et al., 2003; Hays et al., 2005).
Chlorophyll is impacted by heat, and wind currents, which carry water from the deep ocean to

the surface. Nutrient-rich water rises to the surface through a process known as spring and autumn inversion (Feng et al., 2015; Kahru et al., 2010; Katara et al., 2008), and this is one of the main dynamic factors that can drive nutrients from deep water to the surface, which can create wind-driven upward and enhance vertical mixing. Therefore, it can control the production of phytoplankton during the stratified season (Hopkins et al., 2021). However, the relationship between wind and phytoplankton biomass varies by region and is dependent on factors such as water depth, latitude, and other environmental factors. Consequently, further research is required to properly comprehend how wind affects phytoplankton, particularly in coastal oceans with complex environments (Lin et al., 2023). Rushing to the sea's surface is the process of moving a large body of water from the deep water column to the surface. This rise results in a decrease in sea surface temperatures and an increase in chlorophyll-a concentration, which boosts fishery productivity. The fishing season can be identified by two indicators: temperature and chlorophyll-a (Wirasatriya et al., 2018).

Libya is characterized by a long coastline, so some scholars have a major role in conducting some research on the Libyan coast. Statistical analyses show that the theoretical and experimental distributions of chlorophyll concentration for phytoplankton abundances obtained by the model in chlorophyll concentrations and compared with field data collected in twelve marine sites along the Cape Passero (Sicily)-Misurata (Libya) transect agree well. As a result, satellite remote sensing has emerged as a promising technique for large-scale ocean studies because of the wide spatial coverage offered by portable observation platforms in space (Valenti et al., 2017).

Study objectives

Find the effect of wind speed and sea surface temperature on chlorophyll-a, and know the strength of the correlation between the increase or decrease of chlorophyll in the Libyan coast with these factors.

MATERIALS AND METHOD

Area study and data sources

The search area is situated in Libyan waters across from the Mediterranean Sea, with latitudes of 30.36^0 to $35.54\ ^0$ and longitudes of 11.46^0 to 23.75^0 ,figure 1, From January 2003 through April 2023, the study used the Merrra-2 model for wind speed and the Aqua model for chlorophyll-a concentration and sea surface temperature. The data was obtained from Goddard Space Flight Center.

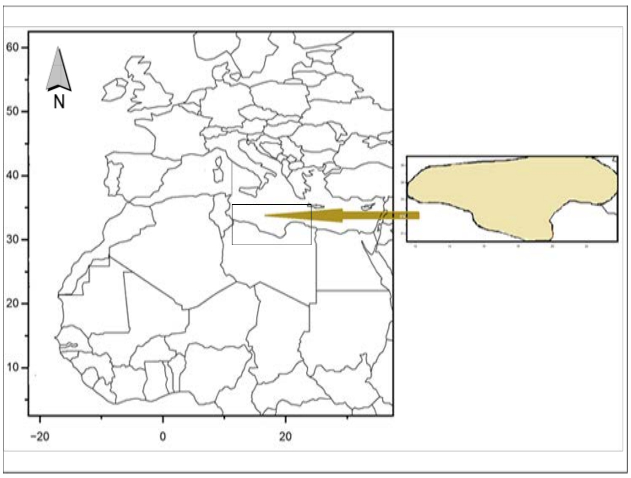

Figure (1): Area study (https:// gsfc.nasa.gov)

Climate data analysis

It is well known that the Mediterranean Sea has relatively low levels of chlorophyll, with levels rising in the west and falling in the east. By examining the concentration of chlorophyll-a, wind speed, and sea temperature from January 2003 to April 2023 and calculating the yearly average as presented in Figure 1, the Libyan shores are highly susceptible to temperature variations, as evidenced by the annual average temperature of the Mediterranean, which rises in the middle opposite the Libyan coast by approximately 22.5 C^0 and falls in the east by approximately 22 C^0 (see Figure 2,c). This is in contrast to the decrease in chlorophyll-a quantities in the middle opposite the Libyan coast by approximately 0.1 mg.m-^{3}, increases as we head west and reaches 0.25 mg.m-^{3}, and decreases to the east by a value of 0.13 mg.m-^{3}a look at Figures (2,a) and (2,b), where the wind speed measured in meters per second (m/s) increases by approximately 6.4–7 m/s, indicating a drop in temperature and an increase in levels of chlorophyll-a, and then drops to 6 m/s, indicating a rise in temperature and a decrease in chlorophyll-a.

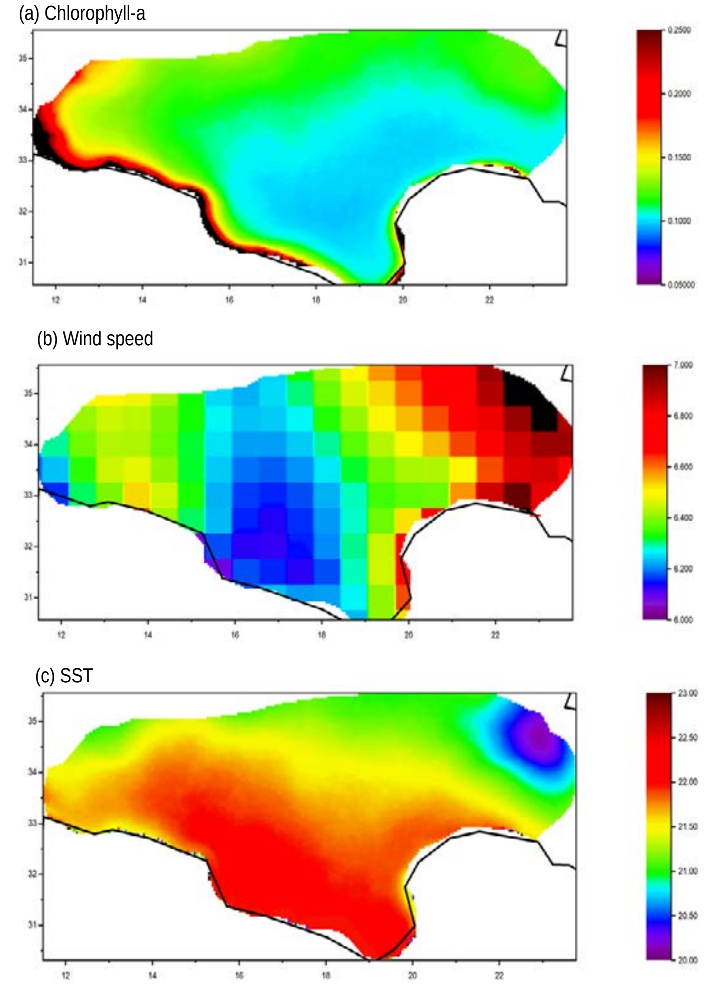

Figure (2): The annually average for (a) sea surface temperature (C^0), (b) wind speed ($m.s^{-1}$), and (c) chlorophyll-a concentration ($mg.m^{-3}$) from January 2003 to April 2023.

Statistical analysis of data and discussion

For clarification, statistical techniques were applied in the current study. To ascertain the kind and degree of correlation between the two variables wind speed ($m.s^{-1}$) and sea surface temperature (C^0) and the variable chlorophyll-a concentration ($gm.m^{-3}$) in the Mediterranean Sea close to Libya's coast. Table 1 displays the Pearson correlation coefficient that was used in this study. There is a strong direct relationship of approximately 0.858 between wind speed and chlorophyll-a, and a strong inverse correlation of approximately -0.799 between sea temperature and chlorophyll-a.

Table (1). Statistics

	Chlorophyll-a	
	Wind speed	Sea surface Temperature
Number of Points	244	244
Degrees of Freedom	242	242
Residual Sum of Squares	0.18706	0.25725
Pearson's r	0.85848	-0.79894
R-Square (COD)	0.73699	0.6383

From the above table, we find that the percentage effect of the independent variable wind speed - sea surface temperature on chlorophyll-a, the dependent variable, is equal to 0.737, 0.638, respectively, meaning that wind speed - sea surface temperature affects by (73.6%, 63.8%) on chlorophyll-a, respectively. And the square of the correlation coefficient R is used to find out the percentage change in the dependent variable and by which the variable can be predicted independently, see table 2.

Table (2). Summary

		Intercept		Slope	
		Value	Standard Error	Value	Standard Error
Chlorophyll-a	Wind speed	-0.1097	0.0092	0.03659	0.0014
	Sea surface Temperature	0.3463	0.0109	-0.0103	4.97E-4

Subsequently, the impact of wind speed and sea temperature on chlorophyll-a was examined by taking both factors into account (as an independent variable) on chlorophyll-a (as a dependent variable) and analyzing the data of the two variables during the period (January 2003 - April 2023) using a simple method for linear regression equation:

$y=a + b x$

Spread points between the two variables were plotted as follow:

To determine the significance of the model's quality, we used analysis of variance. Because we observed a linear relationship and a level of significance for F that is less than 0.05, which indicates that the independent and dependent variables are related and that the regression model is significant, we were able to reject the null hypothesis and accept the alternative. A significant figure whose outcomes are trustworthy is found in Tables 3, 4.

Table (3). Parameters

			Value	Standard Error	t-Value	Prob>|t|
Chlorophyll-a	Wind speed	Intercept	-0.10977	0.00919	-11.93848	3.86885E-26
		Slope	0.03659	0.0014	26.04061	3.90919E-72
	Sea surface Temperature	Intercept	0.34629	0.0109	31.75995	2.76827E-88
		Slope	-0.01026	4.965E-4	-20.66566	2.32116E-55

Chlorophyll: Slope is significantly different from zero (See ANOVA Table).

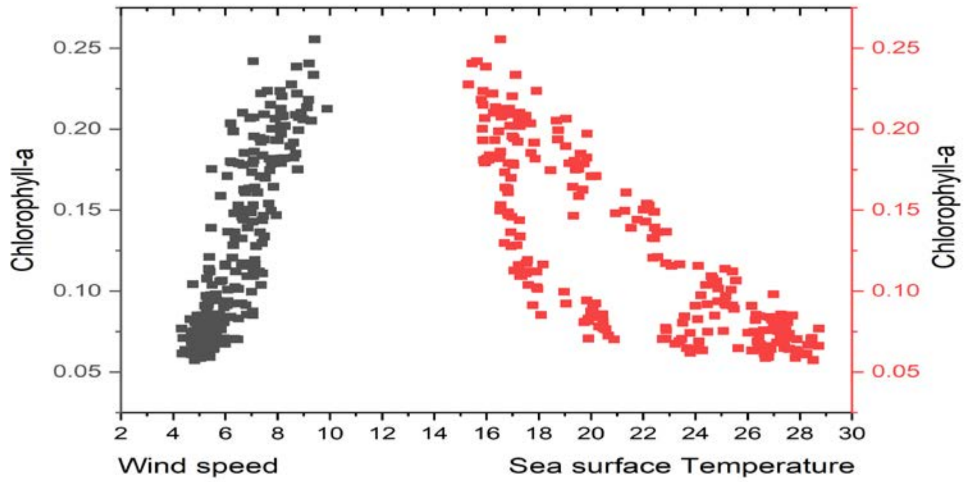

Figure (3). Scatterplot of red scatter sea surface temperature (C^0) - black scatter wind speed ($m.s^{-1}$) with chlorophyll-a ($mg.m^{-3}$).

Based on the ANOVA table 3. To test the significance of the regression we note that the value of F is equal to 678.1-427.06 respectively, with a probability of 0.0001 less than 0.05, which indicates the quality of the regression model and that it is statistically significant, and therefore the existence of a relationship between the two.

Table (4).ANOVA

			DF	Sum of Squares	Mean Square	F Value	Prob>F
Chlorophyll-a	Wind speed	Model	1	0.52417	0.52417	678.1132	<0.0001
		Error	242	0.18706	7.72982E-4		
		Total	243	0.71123			
	Sea surface Temperature	Model	1	0.45398	0.45398	427.06953	<0.0001
		Error	242	0.25725	0.00106		
		Total	243	0.71123			

Chlorophyll: At the 0.05 level, the slope is significantly different from zero.

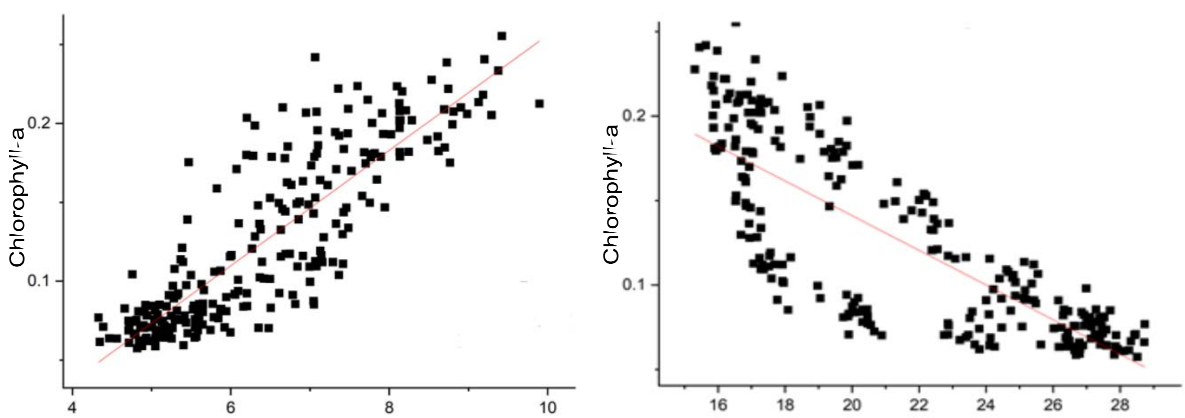

Figure (4). scatterplots for (a) wind speed ($m.s^{-1}$) and (b) sea surface temperature (C^0) , with the concentration of chlorophyll-a ($mg.m^{-3}$)

variables show figure 4. We notice that the points approach the line of the regression equation and that the residual residuals are distributed according to the normal distribution, which is a condition for applying the regression equation, as shown in the figure 5.

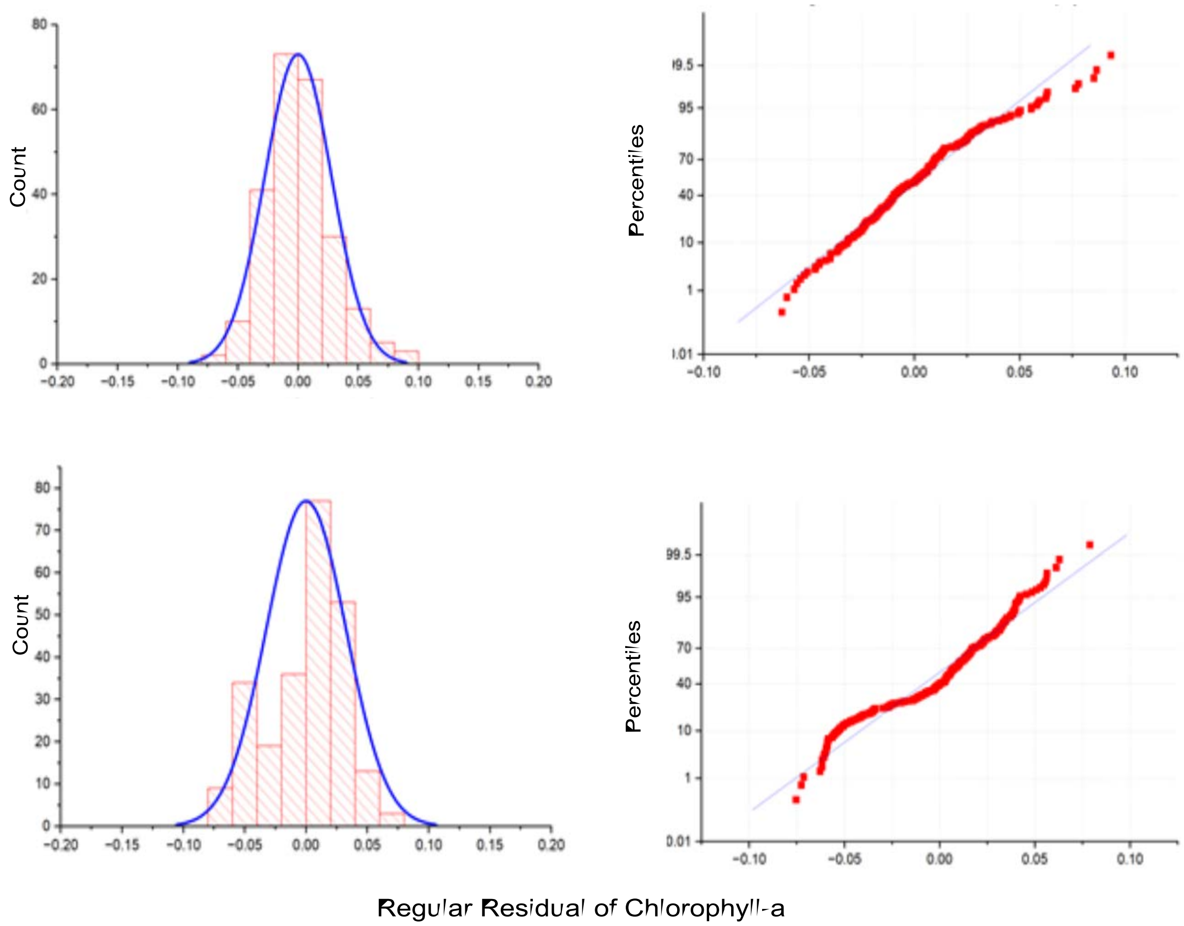

Figure (5). Normal plot of regression residual

As mentioned previously, the amounts of chlorophyll-a concentration in the Mediterranean are low, and this was evident in Figure 6 of the kernel density estimate analysis, which shows the chlorophyll –a concentration density with increasing or decreasing wind speed and temperature. The density of chlorophyll-a increases with increasing winds and reaches 1.08 when wind speed is 8 m/s^{-1} and amounts of chlorophyll-a are about 0.2 gm/m-^{3}, while the distribution of concentration density is large and reaches 1.7 when the chlorophyll-a is 0.1 gm/m^{-3}, where Its density in the sea against wind speed is 5.5 $m/s^{-1}$and the lowest density reaches 0.216, while the amounts of chlorophyll-a are about 0.29 gm/m^{-3} and the wind speed is about 10m/s^{-1}, as shown in the frequency histogram for each of the winds and the concentration of chlorophyll-a in Figure 6.a. The nucleus density of chlorophyll-a concentration reaches 1.16 in the two cases of chlorophyll-a, reaching 0.2 and 0.05 gm/m^{-3} against temperatures 5.17 and 27.5C^{0}, respectively, explaining the frequency histogram in Fig. 6b for both density concentration chlorophyll –a with increasing or decreasing with sea surface temperature.

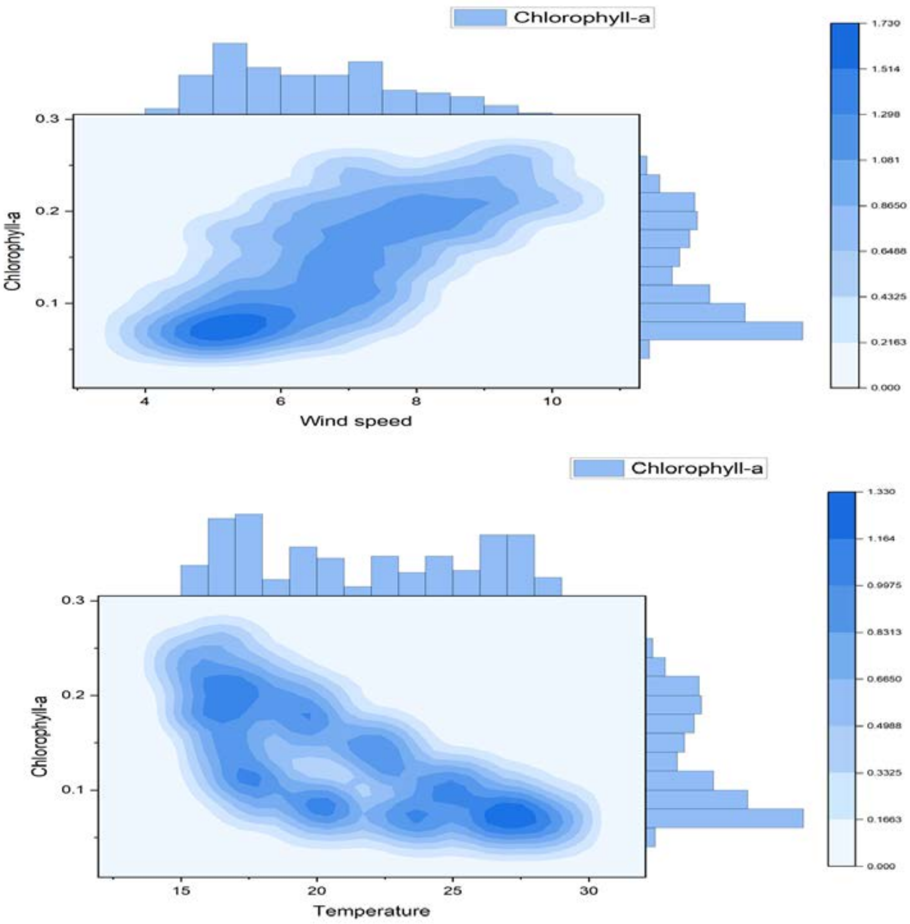

Figure (6). Kernel density estimate of the concentration of chlorophyll-a (gm/m^{-3}) with with (a) wind speed(m/s^{-1}), (b) sea surface temperature(C^{0}).

CONCLUSION

the world is currently bringing climate change in all land and ocean-related domains to light, and one of these changes is the effect of both sea surface temperature and wind speed on the concentration of chlorophyll-a, which is the main source of phytoplankton.

In this study, the relationship between wind speed and chlorophyll concentration is revealed. A is strong, as the wind speed increases, the concentration of chlorophyll-a increases and reaches 80.85, while the relationship is inverse between sea surface temperatures with the concentration of chlorophyll-a, as the higher the sea surface temperatures, the lower the concentration of chlorophyll-a in seawater and reaches The inverse relationship is about -0.798, and using statistical analysis and the use of Pearson correlation, we find that the percentage effect of wind speed and sea surface temperature on concentration chlorophyll-a, is affected by (73.6%, 63.8%) on the concentration of chlorophyll-a, respectively, and that there is a relationship between climate factors and chlorophyll-a concentration; the relationship between the sea's chlorophyll-a concentration's kernel density and its rise and fall with sea surface temperature and wind speed has been made evident, as the Mediterranean Sea typically has lower chlorophyll-a concentrations than other oceans.

ACKNOWLEDGEMENTS

Thanks to everyone who contributed to this work. We would especially like to express our gratitude to the anonymous reviewers who helped with revisions, and thanks to the website Giovanni of Satellite data used by NASA.

Duality of interest: The authors declare that they have/ have no duality of interest associated with this manuscript.

Author contributions: Example, A.B. developed the theoretical formalism, performed the analytic calculations and performed the numerical simulations. Both A.B and B.C. authors contributed to the final version of the manuscript. B.C. supervised the project.

Funding: A funding statement indicates whether or not the authors received funding (institutional, private and/or corporate financial support) for the work reported in their manuscript.

REFERENCES

Feng, J., Durant, J. M., Stige, L. C., Hessen, D. O., Hjermann, D. Ø., Zhu, L., Llope, M., & Stenseth, N. C. (2015). Contrasting correlation patterns between environmental factors and chlorophyll levels in the global ocean. *Global Biogeochemical Cycles, 29*(12), 2095-2107.

Gregg, W. W., Conkright, M. E., Ginoux, P., O'Reilly, J. E., & Casey, N. W. (2003). Ocean primary production and climate: Global decadal changes. *Geophysical Research Letters,* 30(15).

Hays, G. C., Richardson, A. J., & Robinson, C. (2005). Climate change and marine plankton. *Trends in ecology & evolution,* 20(6), 337-344.

Hopkins, J. E., Palmer, M. R., Poulton, A. J., Hickman, A. E., & Sharples, J. (2021). Control of a phytoplankton bloom by wind‐driven vertical mixing and light availability. *Limnology and Oceanography, 66*(5), 1926-1949.

Kahru, M., Gille, S., Murtugudde, R., Strutton, P., Manzano‐Sarabia, M., Wang, H., & Mitchell, B. (2010). Global correlations between winds and ocean chlorophyll. *Journal of Geophysical Research: Oceans, 115*(C12).

Katara, I., Illian, J., Pierce, G. J., Scott, B., & Wang, J. (2008). Atmospheric forcing on chlorophyll concentration in the Mediterranean. *Essential Fish Habitat Mapping in the Mediterranean*, 33-48.

Kotta, D., & Kitsiou, D. (2019). Chlorophyll in the eastern mediterranean sea: Correlations with environmental factors and trends. *Environments, 6*(8), 98.

Lin, L., Liu, D., Wang, Y., Lv, T., Zhao, Y., & Tan, W. (2023). Effect of wind on summer chlorophyll-a variability in the Yellow Sea. *Frontiers in Marine Science, 9*, 1104258.

Lionello, P., Malanotte-Rizzoli, P., Boscolo, R., Alpert, P., Artale, V., Li, L., Luterbacher, J, May, W, Trigo, R, Tsimplis, M. (2006). The Mediterranean climate: an overview of the main characteristics and issues (Vol. 4, pp. 1-26): Elsevier.

Turley, C., Bianchi, M., Christaki, U., Conan, P., Harris, J., Psarra, S., Ruddy, G., Stutt, E., Tselepides, A., & Van Wambeke, F. (2000). Relationship between primary producers and bacteria in an oligotrophic sea--the Mediterranean and biogeochemical implications. *Marine Ecology Progress Series*, *193*, 11-18.

Valenti, D., Denaro, G., Ferreri, R., Genovese, S., Aronica, S., Mazzola, S., Bonanno, A., Basilone, G., & Spagnolo, B. (2017). Spatio-temporal dynamics of a planktonic system and chlorophyll distribution in a 2D spatial domain: matching model and data. *Scientific reports*, *7*(1), 220.

Wirasatriya, A., Maslukah, L., Satriadi, A., & Armanto, R. (2018). Different responses of chlorophyll-a concentration and Sea Surface Temperature (SST) on southeasterly wind blowing in the Sunda Strait. IOP Conference Series: Earth and Environmental Science,