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A two-decade record of temperature and chlorophyll "a" in surface waters within the Basque Country (southeastern Bay of Biscay)

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Abstract

Since 1986, physico-chemical and chlorophyll "a" data are obtained by means of CTD profiles and bottle samples at an offshore station located in the southeastern Bay of Biscay (43º 27' N, 1º 55' W). The station is considered to be non-impacted by anthropogenic influence due to its distance (13.1 km) from the main pollution sources in land, which makes it suitable for exploring the response of phytoplankton to oceano-meteorological forcing. Data series of temperature and chlorophyll "a", from surface waters, have been analysed to look for long-term temporal trends. Surveyed months and total number of surveys per year are very variable (from 2 to 12). In spite of the irregular sampling, a significant increasing trend in water temperature was detected. This was also observed at a neighbouring inshore station (Aquarium Donostia-San Sebastián), where daily records of temperature are available. In contrast, chlorophyll "a" did not present a significant trend of variation over the last two decades at the offshore station. Similarly, the chlorophyll "a" anomaly was studied as an indicator of the frequency of blooms and no significant trend of variation was observed. At this stage, the results obtained do not support the hypothesis that phytoplankton biomass is responding to changes in water temperature in the southeastern Bay of Biscay, at least in surface waters. However, the high variability that characterizes the concentration of chlorophyll at short-term scale can limit the conclusions based upon statistical analysis in this study. Further research is needed to determine the variation of chlorophyll "a" in the water column.

Keywords: Climate change, surface temperature, chlorophyll "a", Bay of Biscay

Introduction and objectives

Previous studies conducted in the Basque coastal waters have shown that sea surface temperature (SST) follows an increasing trend since 1985 (González et al., 2008; Goikoetxea et al. 2009). The objective of this study is to look for long-term trends in chlorophyll “a” concentration (Chl “a”) within the Basque coast that could be related to the changes observed in the seawater temperature.

Study area

Within the Basque coast (north of Spain), the longest time-series on Chl “a” and/or seawater temperature have been recorded at two stations: D2 and Aquarium (Figure 1). Both stations are in the southeastern Bay of Biscay. D2 is a station located 13.1 km offshore (43º 27’ N, 01º 55’ W), at 110 m water depth. Aquarium is an inshore station located at the Donostia-San Sebastián city (43º 19’ N, 02º 00’ W). These stations are not influenced by any important freshwater input.

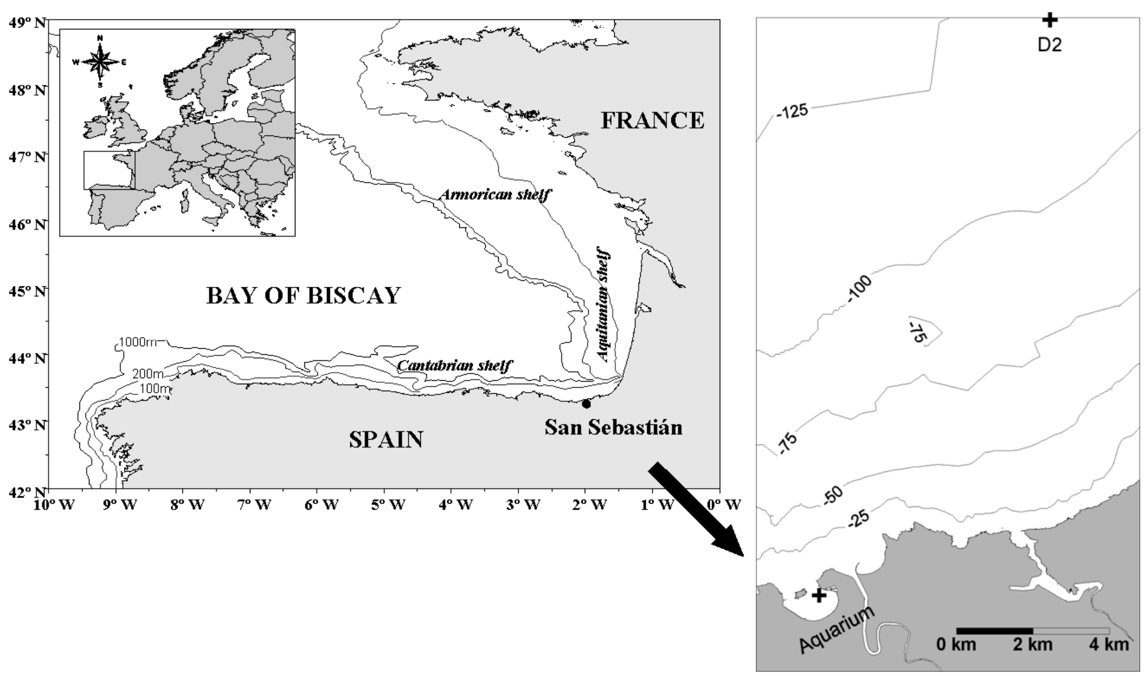

Figure 1. Map of the sampling stations (Aquarium and D2) within the context of the Bay of Biscay.

Methods

At D2, Chl “a” and seawater temperature have been recorded since 1986 up to 2008, which makes a total of 174 samples over 23 years. The sampling frequency has been very irregular, with 2-12 data points per year. From 1986 to 1990 Chl “a” was estimated in water samples taken at discrete depths (0, 5, 10, 20, 30, 50, 75, 100 m) by Niskin bottles. Water was filtered throughout Whatman GF/C filters and pigments were extracted in 90% acetone. The absorbance of the extract was read in a UV/VIS spectrophotometer (Shimadzu). Concentration was estimated according to the equations of Jeffrey and Humphrey (1975). Temperature was measured in the field, at similar depths, by specific sensors. Since 1991, fluorescence and temperature are being recorded by CTD at continuous vertical profiles. Fluorescence units are regularly calibrated against spectrophotometric measurements to acquire Chl “a” data. At Aquarium, SST has been measured since 1946, in a nearly daily basis at 10 a.m., by means of a thermometer.

In order to study long-term trends in Chl “a”, the data collected in surface waters (0-1 m) at D2 have been analysed. Firstly, simple linear regression analysis was applied to the data versus time expressed in Julian day basis. Then, simple linear regression analysis was applied to the annually averaged chlorophyll. Also, the annual average was calculated for two seasons separately. The two seasons involved the Chl “a” minima (warm months, from May to October) and the Chl “a” maxima (cold months, from November to April), respectively. Finally, the anomaly of the Chl “a” was studied as an estimate of the phytoplankton blooms. The anomaly was calculated as the difference between the measured value and the average, divided by the standard deviation; where the average and the standard deviation involve all the Chl “a” data set (N=174). Statistical modelling was also applied, following Pres et al. (1989) to the same Chl “a” data set. Furthermore, this method was applied to the SST from both stations. The statistical modelling method is based on the equation that describes the annual cycle. The equation is developed by a combination of cosines and predicts the value of the variable at each day along the average year. The predicted values were subtracted from the measured values and a linear regression analysis was applied to the resulting data set.

Results

The simple linear regression analysis conducted with chlorophyll in surface waters over surveyed days did not reveal a significant trend (Figure 2). The determination coefficient accounted for less than 1% of total Chl “a” variation; the slope was not significantly different from zero.

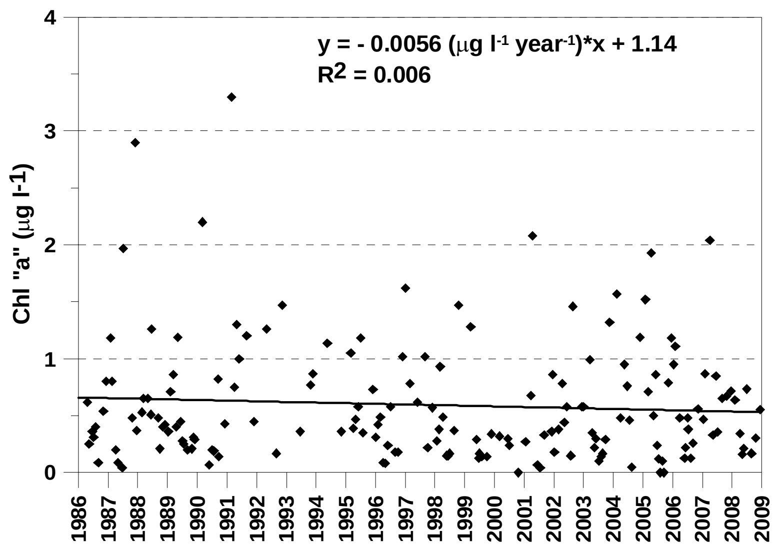

Figure 2. Linear regression between surface chlorophyll “a” at D2 station and time (Julian days). The best fit equation and the coefficient of determination are shown (N=174).

In order to analyse the change over time in the annually averaged Chl “a”, including the whole year and two specific seasons (the cold and the warm months, separately), further regression analyses were conducted (Figure 3). The cold season was defined from mid-autumn to mid-spring (from November to April). Monthly averaged SST ranged from 12.5 to 16.5 °C (Figure 7). In spite of the lower radiation expected during the cold season, Chl “a” was usually at the highest levels, with monthly averaged values ranging from 0.6 to 1.0 μg l^{-1} (Figure 5). The warm season was defined from mid-spring to mid-autumn (from May to October). During the warm season, the monthly averaged SST ranged from 15.6 to 22.7 °C (Figure 7) and Chl “a” was at the lowest levels, with monthly averaged values <0.5 μg l^{-1} (Figure 5).

The regression analyses conducted with the annually averaged Chl “a” values showed negatives slopes (Figure 3). The slope was more accentuated in the case of the warm season (data from May to October). However, again, only a low percentage of total Chl “a” variability (<10%) could be explained and the regression slopes were not statistically significant.

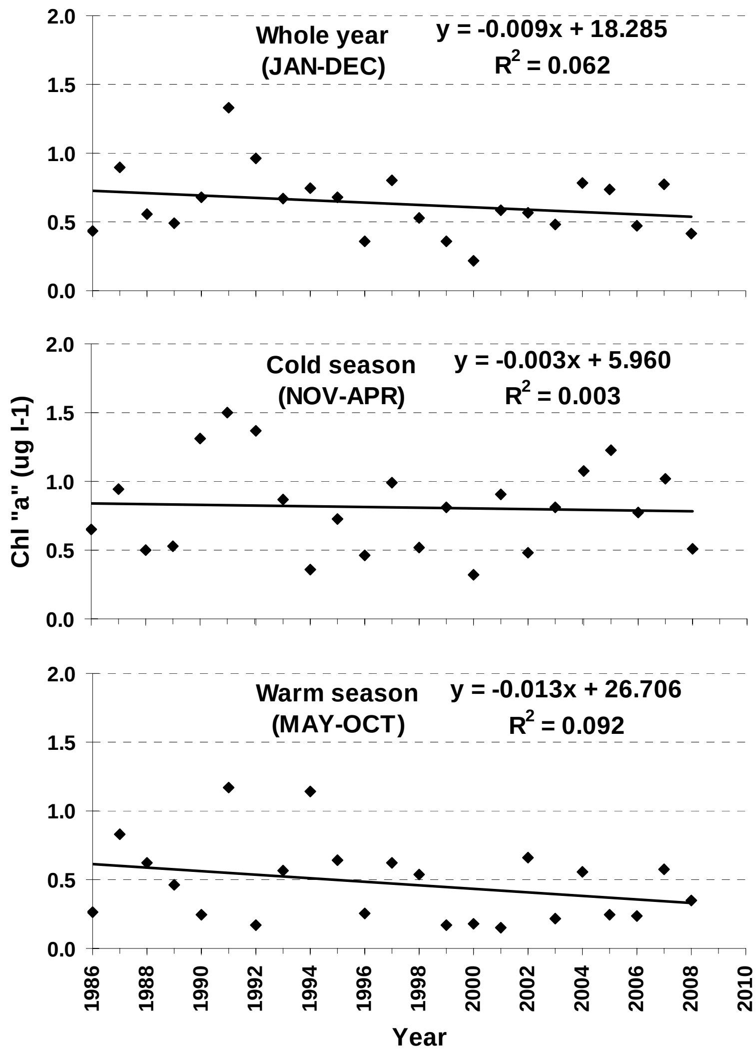

Figure 3. Regressions between chlorophyll “a” at D2 station and time expressed as years. Chlorophyll was averaged within each year. Upper panel: whole year; middle panel: cold season (from November to April); lower panel: warm season (from May to October). The best fit equations and the coefficients of determination are shown (N=23).

The anomaly of the Chl “a” was also studied to detect potential changes in the frequency and/or intensity of the phytoplankton blooms. The anomaly of the Chl “a” over the last 23 years ranged between -1.1 and 5.1 (Figure 4). Positive anomalies (values higher than the average) were less frequent than negative anomalies (values lower than the average), which is coherent with the usual dynamics of marine phytoplankton. Anomalies >1 could reflect phytoplankton bloom events, as these anomalies involved 14% of the data set and corresponded to 1.1±0.9 events year^{-1} (average ± standard deviation). The highest positive anomalies (>4) were found at the beginning of the time-series (December 1987 and March 1991), with two events that accounted for the Chl “a” maxima (2.9 and 3.3 µg l^{-1}, respectively). However, there was not a clear variation pattern in the frequency of anomalies >1 over time; blooms were observed throughout the whole time-series.

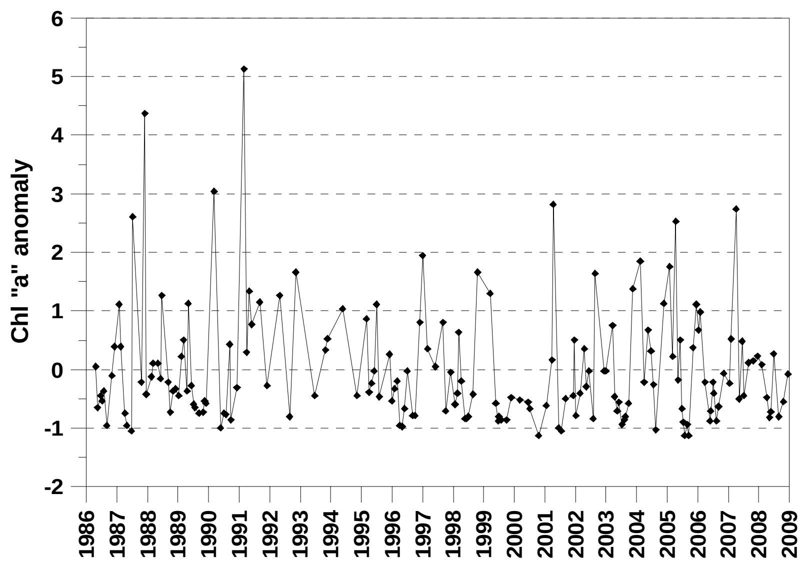

Figure 4. The variation of the chlorophyll “a” anomaly at D2 station from 1986 to 2008 (N=174).

Finally, statistical modelling methods were applied to both SST and Chl “a” data from surface waters at D2 station. Previously, the annual cycle was adjusted to a curve that predicts the values of the variable at any day of an average year (Figures 5 and 7). Then, predicted values were subtracted from measured values and the resulting data set was analysed by regression methods (Pres et al. 1989). The central trend indicated that Chl “a” changed very little (almost zero) in the long-term during the 1986-2008 period (Figure 6).

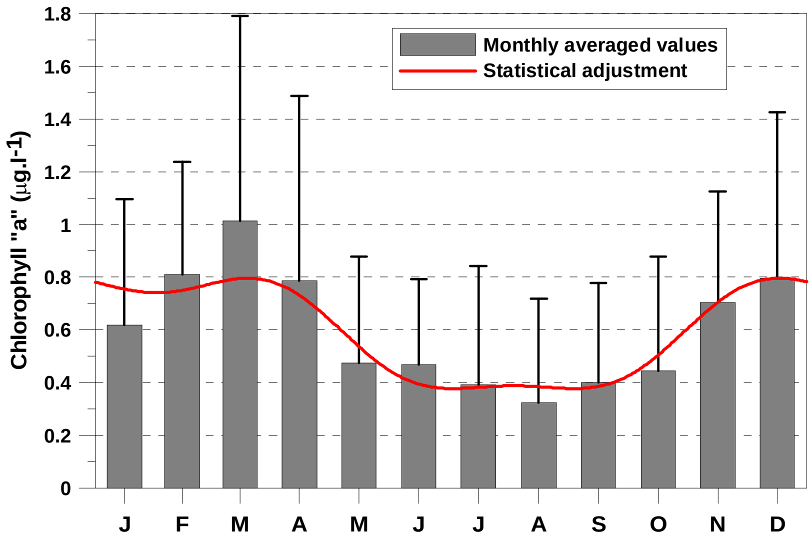

Figure 5. The annual cycle of chlorophyll “a” at D2 station. Bars represent the average and standard deviation calculated for each month. Continuous line represents the values estimated by the statistical adjustment, for each day, along an average year.

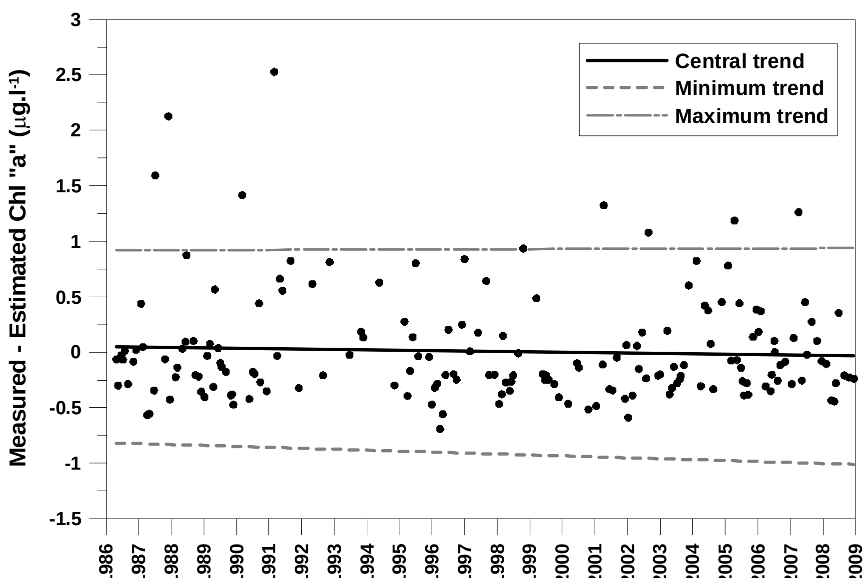

Figure 6. The temporal trend of chlorophyll “a” at D2 station from 1986 to 2008. Values are the difference between the measured data and the data estimated for an average year.

In contrast, the analysis conducted with temperature at D2 station showed an increasing trend (Figure 8). The slope of the central trend indicated a rate of change of 0.016±0.011 ºC $year^{-1}$.

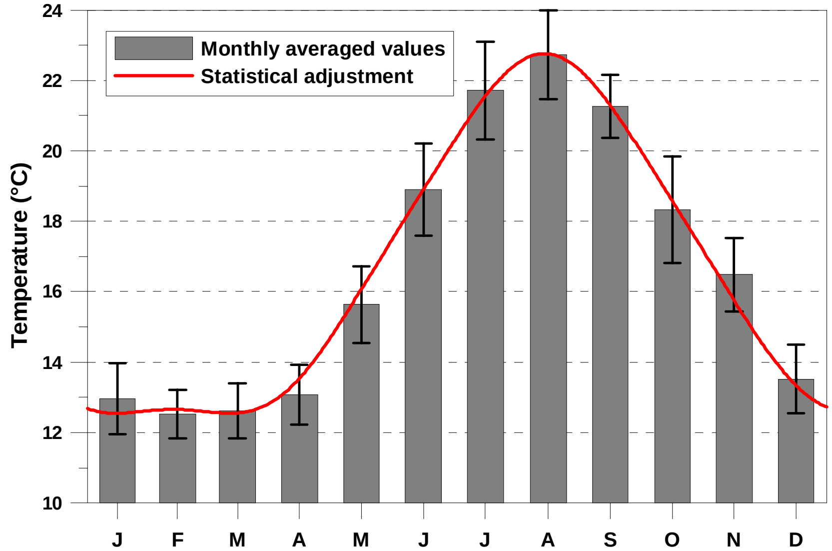

Figure 7. The annual cycle of surface temperature at D2 station. Bars represent the average and standard deviation calculated for each month. Continuous line represents the values estimated by the statistical adjustment, for each day, along an average year.

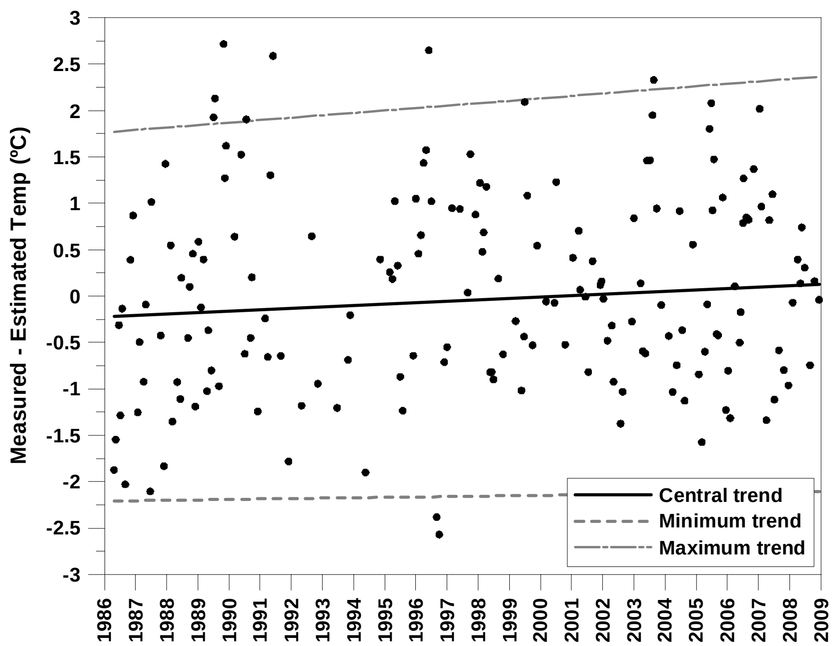

Figure 8. The temporal trend of temperature at D2 station from 1986 to 2008. Values are the difference between the measured data and the data estimated for an average year.

A similar analysis conducted with temperature data from inshore waters (Aquarium station), during the same period, also showed an increasing trend (Figure 9). In this case, the data set was much larger and the confidence limits of the regression coefficients were narrower (minimum, maximum and central trend coincided). In the Aquarium time-series, the slope of the regression (0.027 ºC $year^{-1}$) was within the limits of that observed in the offshore station.

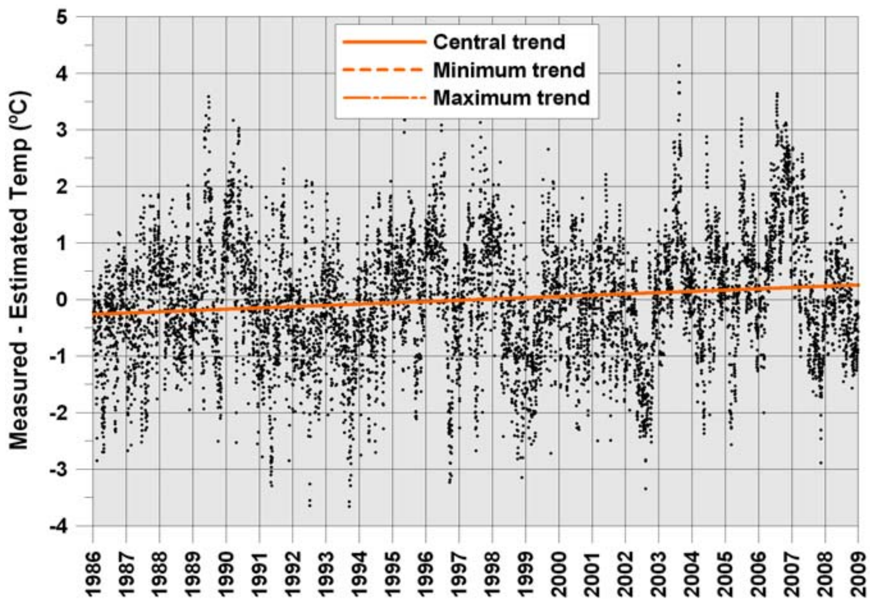

Figure 9. The temporal trend of temperature at Aquarium station from 1986 to 2008. Values are the difference between the measured data and the data estimated for an average year.

Conclusions

- No significant trends were found in surface chlorophyll over the last 23 years.
- Although chlorophyll presented a slight negative trend within the warm season (from May to October), it was not statistically significant.
- In contrast, a significant increasing trend (0.016±0.011 ºC $year^{-1}$) was found in surface temperature.

Recommendations

The lack of significant trends in the chlorophyll might be due to the intrinsic limitations of this time-series. The data set was probably small for the high short-term temporal variability that this biological variable presents. Therefore, for future studies, it is recommended to acquire data at a higher frequency and in a more regular basis. For example, fluorometers connected to oceano-meteorological stations or buoys could counteract these limitations.

Also, a more detailed study of this time-series should be advisable, for example, to look for trends in the subsurface chlorophyll maximum or in the vertically integrated water column concentrations.

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References

Goikoetxea N., Borja A., Fontán A., González M., Valencia V. 2009. Trends and anomalies in sea-surface temperature, observed over the last 60 years, within the southeastern Bay of Biscay. Continental Shelf Research 29: 1060–1069.

González M., Mader J., Fontán A., Uriarte A., and Ferrer L. 2008. Análisis de la tendencia de la temperatura superficial del agua del mar en Donostia-San Sebastián a partir del estudio de la serie del Aquarium (1946-2007). Revista de Investigación Marina 4: 7 pp. www.azti.es

Jeffrey S.W., and Humphrey GF. 1975. New spectrophotometric equations for determining chlorophylls a, b, c1 and c2 in higher plants, algae and natural phytoplankton. Biochem Physiol Pflanz 167:191–4.

Press H.W., Flannery B.P., Teulosky S.A., and Vettelrling W.T. 1989. Numerical Recipes. Cambridge University Press. Chapter 14. Modelling of Data, 498-546.