Vikas Nagar, Lucknow, INDIA
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Full paper available on: www.jeb.co.in

J. Environ. Biol.
32, 493-498 (2011)
ISSN: 0254-8704
CODEN: JEBIDP

The relationship between sea surface temperature and chlorophyll concentration of phytoplanktons in the Black Sea using remote sensing techniques

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Publication Data

Paper received:
25 October 2010

Revised received:
11 July 2011

Accepted:
20 July 2011

Abstract

Present work investigated the relationship between Chlorophyll (Chl), of phytoplankton biomass, and sea surface temperature (SST) of the Black Sea, using Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and Advanced Very High Resolution Radiometer (AVHRR) satellite imagery. Satellite derived data could provide information on the amount of sea life present (Brown algae, called kelp, proliferate, supporting new species of sea life, including otters, fish, and various invertebrates) in a given area throughout the world. SST from AVHRR from 1993 to 2008 showed seasonal, annual and interannual variability of temperature, monthly variability Chl from SeaWiFS from 1997 to 2009 has also been investigated. Chl showed two high peaks for the year 1999 and 2008. The correlation between SST and Chl for the same time has been found to be 60%. Correlation was significant at $p<0.05$. The information could also be useful in connection with studies of global changes in temperature and what effect they could have on the total abundance of marine life.

Key words

Sea surface temperature, Remote sensing, SeaWiFS, AVHRR, Black Sea

Introduction

As an enclosed sea the Black Sea has countless economic activities (mainly tanker traffic and fisheries) and recreational activities, with the consequence of being threatened by dramatic dangers and pollution. As an important heat reservoir, the Black Sea should be studied extensively using remote sensing techniques.

Phytoplankton also affects carbon dioxide levels when they die. Phytoplankton, like plants on land, is composed of substances that contain carbon. Dead phytoplankton can sink to the ocean floor. Other material sinking to the ocean bottom soon covers the phytoplankton. In this way, the ocean act as a sink, a place to dispose of global carbon, which otherwise would accumulate in the atmosphere as carbon dioxide. Other global sinks include land vegetation and soil. However, the carbon sinks are frequently returned to the atmosphere as carbon dioxide by burning or decomposition. Deforestation contributes to the accumulation of carbon dioxide in the atmosphere by reducing the removal of carbon dioxide. Carbon dioxide acts as a 'greenhouse' gas in the atmosphere, and therefore an increase in its concentration may contribute to global warming. The increase of carbon dioxide means less long-wavelength energy emitted from the Earth can escape to space. This would lead to a gradual warming of the Earth.

If we can set up a relationship between photosynthesis and temperatures, satellites could aid in determining the amount of sea life present in any given area throughout the world. The information could also be used to explain global changes in temperature and what effect they could have on the total abundance of marine life.

Hood *et al*. (1990) led a two-day cruise in which he collected both satellite thermal data as well as biological data off the coast of Northern California. His team found two distinct waters masses, one hot and one cold, which were divided by a front. On the landward side of the front, they found that there was a sharp decline in SST as well as an abundance of phytoplankton biomass. On the seaward side of the front, they observed an increase in SST as well as a decrease in the amount of phytoplankton biomass. However, Robinson *et al*. (1993) who performed another study in the mid

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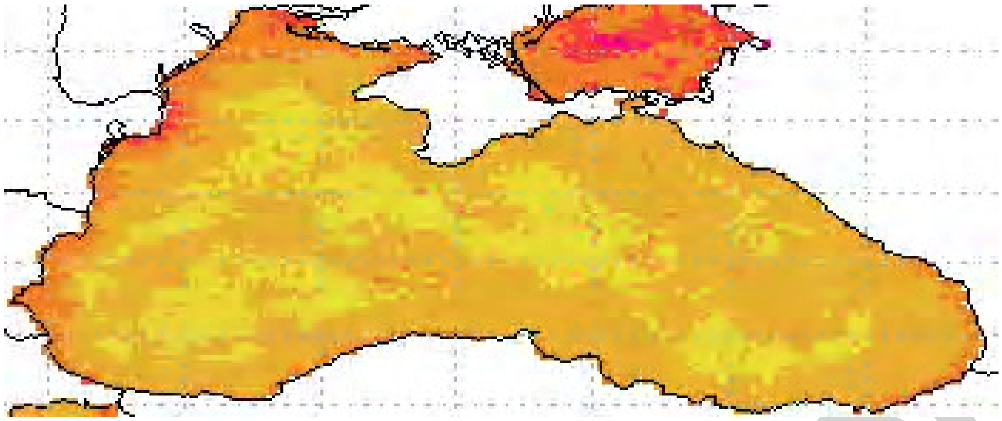


Fig. 1: Ocean color data generated from Ocean color web site (http://reason.gsfc.nasa.gov/OPS/Giovanni/ocean.swf8D.shtml)

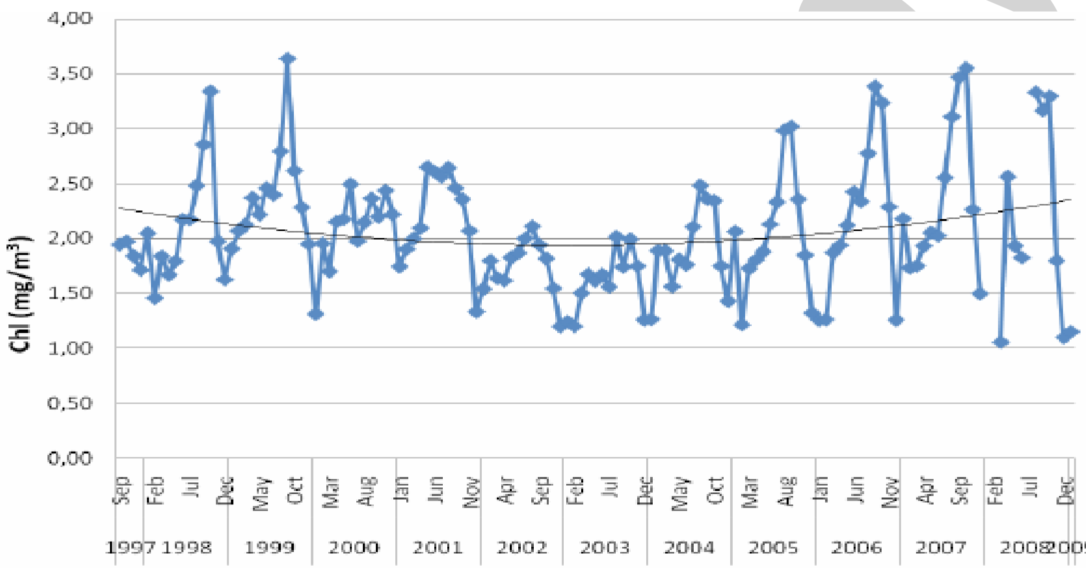


Fig. 2: Showing monthly chlorophyll pigment concentration of the Black Sea from 1997 to 2009

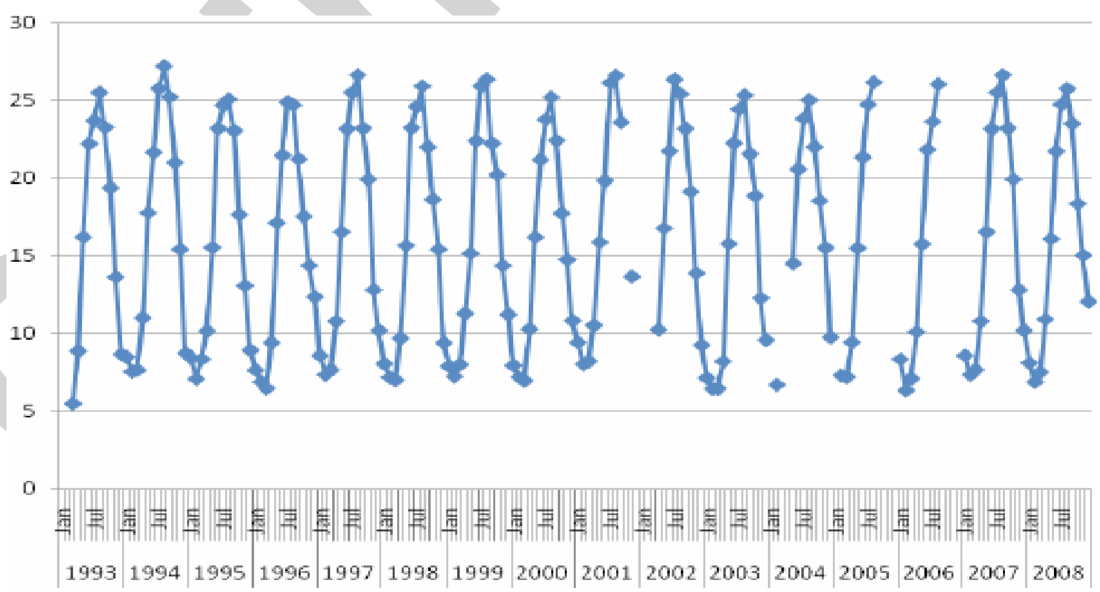
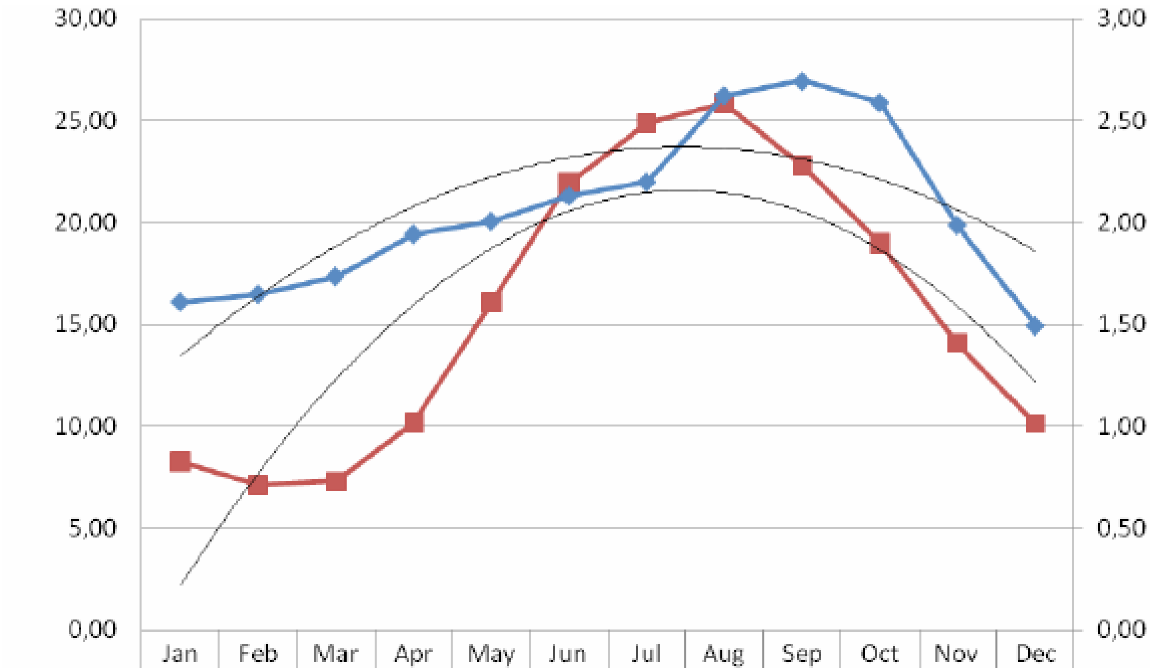


Fig. 3: Showing monthly SST variation of the Black Sea from 1993 to 2008



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SSTºC	8,24	7,13	7,29	10,14	16,07	21,93	24,88	25,84	22,83	18,99	14,09	10,11
CHL	1,61	1,65	1,74	1,94	2,01	2,13	2,20	2,62	2,70	2,59	1,99	1,49

Fig. 4: Showing monthly average chlorophyll pigment concentration and SST whole averaged data

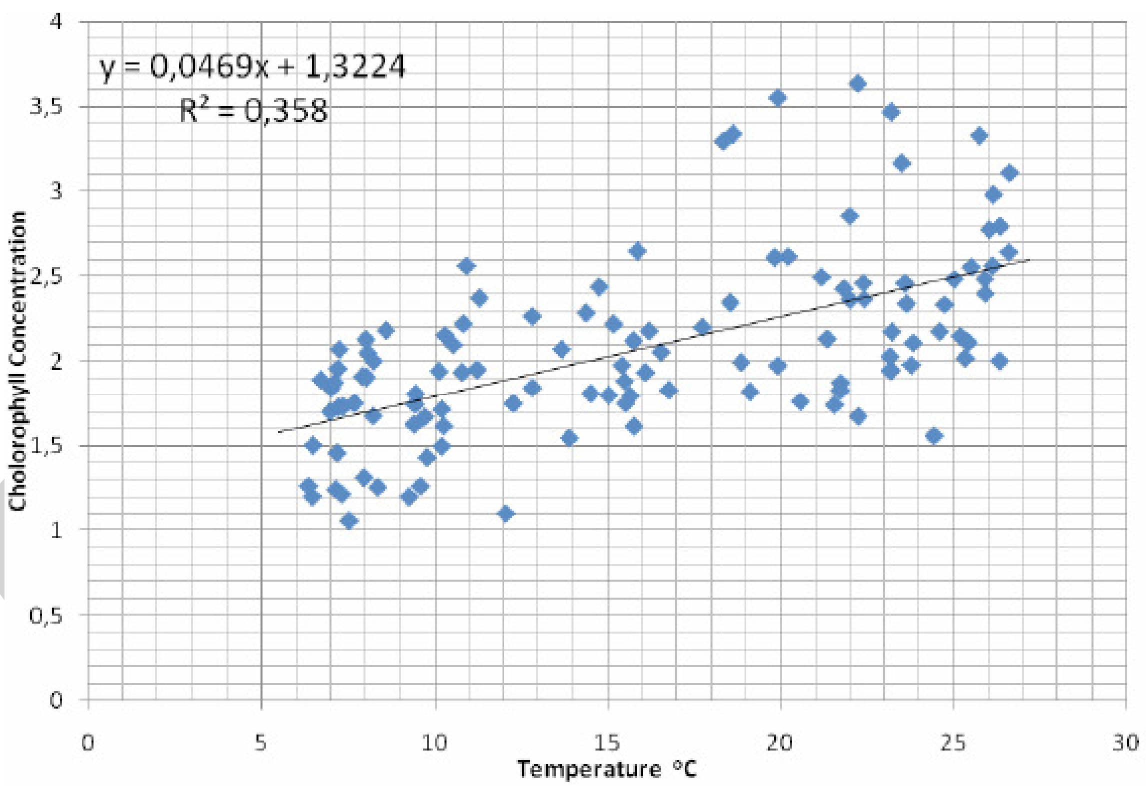


Fig. 5: Cross-plot of monthly averaged point's chlorophyll pigment concentration and SST of Whole basin SST versus Chlorophyll concentration

1980's in the British Antarctic did not support the hypothesis that SST directly affects the amount of Chl concentration. Correlation between SST and Chl pigment concentration has also been investigated by Nykjaer *et al*. (1989) on a Northwest African upwelling area. Nykjaer *et al*. (1989) used ten simultaneous pair of Coastal Zone Color Scanner (CZCS) and National Oceanic and Atmospheric Administration Global Area Coverage (NOAA GAC) images and the images were analyzed with respect to: Describing the relationship between SST and total pigment concentration in terms of similarities, discrepancies and spatial variability. Identifying different water masses through the relationship between SST and Chl.

Inferring concepts of upwelling events based on the SST/ Chl relationship, They did not find a linear correlation between pigment concentration and temperature on the surface. Fox *et al.* (2005) studied Chl and SST of Gulf of Maine using AVHRR, SeaWiFS and buoy data by dividing the region into five regions; they found significant difference on the slope than the other regions which they attributed to warm core ring (WCR) in the region.

First Empirical Orthogonal Function (EOF) contained 95% and 46% variance of SST and Chl respectively. Wang *et al*.(2006) studied Miles *et al* (2010) SST and Chl imagery for the South Atlantic Bight (SAB) using MODIS data for 6 year period to identify their spatial and temporal variability on monthly averaged data using EOF analysis. Characteristic of Chl in the Sulu Sea, the variation of Chl and SST were associated with the seasonally reversing monsoon, they also observed one peak during the northeast monsoon each year. SST's have significant negative correlation with Chl concentration; *i.e.*, high and uniformly distribution in summer but lower with an obvious tongue of cold waters southward in the central basin in winter. Ginzburg *et al.* (2002) traced eddies using SST (AVHRR) and Chl fields (SeaWiFS) data in the northwest of the Black Sea. Kopelevich *et al.* (2002), investigated Chl concentration using CZCS and scientific cruse data between 1978-1986 and found significant difference in Chl concentration between the western shelf regions on the open part of the Black Sea, particularly in warm season. Abigail *et al.* (2008) used 8 yr SeaWiFS Chl data to investigate spatio-temporal patterns and variability in the Black Sea particularly between riverine-influenced Northwest shelf and open Black Sea to explore potential role of climate in the Black Sea recovery. Oguz and Ediger (2006) studied the impact of phytoplankton bloom on the suboxic layer and compared *in situ* and satellite derived Chl pigment concentration in the western Black Sea during May-June, 2001. According to this paper the SeaWiFS chlorophyll algorithm overestimated surface Chl concentration by a factor of 4 with respect to *in situ* measurements within four different regions of the Black Sea.

The pigment pattern of the Black Sea has also been studied from space using the CZCS by Barale and Murray (1995) and Barale and Schlittenhardt (1994) Their findings in all of the CZCS images (they considered composited images) available, showed that major rivers such as the Danube, Dnestr and Dnepr, the Don in the Sea of Azov, as well as other minor rivers, mostly along the western and southern coast of the Black Sea, produce distinct plumes interacting with the marine environment. Within the range of plumes, as with coastal runoff in general, it is often impossible for the CZCS to distinguish the signature of biogenic pigments from that of the total load of dissolved and suspended materials present in the water. Also concurrent bio-optical in situ measurements performed at the time of the CZCS overpasses are rarely available. They also pointed out that the number of images available for compositing varies from a maximum of 18 to 24 images year^{-1} in the south-western part of the basin, to a minimum as low as 6 to 12 images year^{-1} in the north-eastern part.

The main feature of the Black Sea appearing in the OCEAN time series of composite images is the high pigment concentration. This could possibly be related to the combined effect of coastal runoff, strong stratification and circulation in general, on the presence and abundance of suspended and dissolved matter in surface waters. The impact on the surface color field of river discharges along the western coast can readily be evaluated (Barale *et al*., 1999)

As an enclosed basin, the Black Sea has different features (such as motion, inflow waters, biological and chemical properties) from the open oceans and might show a correlation between SST and chlorophyll pigment concentration. For instance, a current would change the temperature of the region, or again, the current may transport the phytoplankton to another location. Fresh inflow waters carried by rivers are rich in nutrients and therefore would increase the phytoplankton population. So an increase parameter on one region would increase the average of whole basin's average.

Present work investigated long term Chl pigment concentration (Fig. 2), sea surface temperature variability (Fig. 3) and their correlation (Fig 4 and Fig. 5) for the whole Black Sea.

Materials and Methods

Chlorophyl data: SeaWiFS 8 Day Global 9 km Chl images were downloaded from (http://reason.gsfc.nasa.gov/OPS/Giovanni/ocean.swf8D.shtml) the Ocean Biology Processing Group (OBPG) by selecting the Black Sea (Fig. 1). This site also gives an option to obtain 8 day averaged Chl concentration of whole basin as an ascii file. So 8 day composite Chl concentration of whole basin from 28/09/1997 to 090/2/2009 was downloaded as an ascii file. Monthly mean generated from 8 day averaged Chl of whole basin.

The processing of SeaWiFS data for Chl concentrations involves the standard four-band OC4v4 algorithm (O'Reilly, 2000) using the four available visible bands (443, 490, 510, 555 nm). The resulting Chl concentrations differ by a factor of two when compared to the estimates derived from a local algorithm (Suetin *et al*., 2001). In the final processing, Chl concentrations from the OC4v4 algorithm were thus divided by two to give their more conservative estimates. Even in the case of such local corrections, Chl concentrations may still have some level of uncertainty (Cokacar *et al.,* 2004).

Sea surface temperature: The monthly MCSST data with the resolution of 1 km AVHRR from March 1993 to December 2008 was downloaded from (http://eoweb.dlr.de:8080/servlets/template/welcome/entryPage.vm) Earth Observation on the WEB interface (EOWEB). The SST values are stored as follows: Greyvalue "0" is reserved for "LAND", greyvalue "255" is reserved for "CLOUD" and no "NO DATA" The temperature range starts with 0.0°C and is referred to greyvalue "1". The radiometric resolution is 0.125°C; greyvalue 254 is therefore referred to 31.75°C (maximum temperature). Images were containing whole Europe, so to study the area of interest (The Black Sea) whole images were imported to ERMapper 5.2 (www.erdas.com). Then the SST of each month for whole basin was calculated excluding flagged pixels.

The images and data used in this study were acquired using the GES-DISC Interactive Online Visualization and Analysis Infrastructure (Giovanni) as part of the NASA's Goddard Earth Sciences (GES) Data and Information Services Center (DISC).

Result and Discussion

Variability of Chl plot (Fig. 2) from 1997 to 2009 showed that 1999 had highest value than other years, then tended to decrease or was stabilized up to the year 2004, then a slow increase with four peaks up to 2009. The considerable points of these peaks are that they are occurring in September and October months. Therefore, for the Black Sea , this time of year would be appropriate to study Chl pigment concentration.

Long term variability of SST (Fig. 3) for 15 years showed temperature variation of the Black Sea. Temperature draws a sine curve with the summer times maximum and winter times minimum. The temperature was a bit higher than the *in situ* measurements of Altman *et al.* (1987) since satellite measures skin temperature (about 20µm) of the Sea (Walsh, 1976). Monthly averaged SST (°C) and Chl (mg m^{-3}) of Fig. 2 and Fig. 3 are shown on Fig. 4

A decrease in Chl concentration from November to February and increase from January to September was observed. On the other hand, SST was minimum in February then reached maximum in August. From fig 4 we could say that Chl was one month behind SST. La Violette *et al.* (1994), using similar data for the North Adriatic region, found that the highest values of Chl pigment concentration occured in winter months. High Chl pigment concentration in winter could be due to less-stratified (better-mixed by winter winds) water that is more likely to be rich in nutrients.

Correlation between SST and Chl was calculated using the same time of the years, that was available for both (1997-2008) (Fig. 5)

Correlations between SST and Chl was found to be 60% and was significant at $p<0.05$. Which means that SST and Chl pigment concentration do not behave differently from each other. Although the present work does show correlation, as mentioned, on the previous works, other factors must be taken into account in determining biomass growth. Such as surface flow zones, substrate concentration, temperature gradients, oxygen abundance, and other factors are important (Tran *et al.,* 1993).

There is no unique algorithm for case 1 waters (those waters for which phytoplankton and their by-products play the dominant role in determining the optical properties of the water body) and case 2 waters (sediment dominated waters) as it seems to be dependent on geographic locations. Thus different waters require different algorithms (Singh. 1992). As Bowers *et al.* (1996) indicated, inorganic sediment concentration has to be known in order to derive chlorophyll concentration from a blue-green ratio measured by satellite to obtain more accurate results. Bowers *et al.* (1996) suggested using a three channel algorithm or the use of fluorescence or the chlorophyll absorption peak in the red.

Present work was conducted at the whole Black Sea, however, it would be interesting to use Landsat data where inflow waters are present, Landsat data is available on USGS (United States Geological Survey) web site for free of charge.

Sea surface temperature of the Black Sea was correlated with chlorophyll pigment concentration by 60%. This result could be useful in connection with studies of global changes in temperature and what effect they could have on the total abundance of marine life. Also, if chlorophyll pigment concentration of the Black Sea to be studied the best times is September and October months as the concentration of chl is at the top.

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