SATellite-Derived Seasonal Variability of Sea-Surface Temperature and Chlorophyll in the Aegean Sea

Gkanasos A., N. Skliris, A. Mantziafou, Sofianos, S.
University Of Athens, Ocean Physics and Modelling Group, thgan@oc.phys.uoa.gr

Abstract

Long-term Satellite derived data of Sea Surface Temperature and Chlorophyll are used to investigate the key processes affecting their spatial and temporal variability. Monthly and seasonal climatologies are computed from daily Satellite Data. Climatological maps show that Black Sea cold and Chlorophyll-rich waters enter through the Dardanelles Strait and they are accumulated in the north-eastern part of the Aegean Sea, stirred by the Samothraki anticyclone. Moreover, SST climatological fields reveal strong upwelling during summer along the eastern coasts of the basin, due to stronger northerly winds.

Keywords: Aegean Sea, SeaWiFS, Surface chlorophyll, AVHRR, SST.

1. Introduction

The Aegean Sea displays prominent hydrodynamic features such as mesoscale eddies, hydrological fronts, strong baroclinic currents and upwelling zones. All the above play an important role in regulating primary productivity in the region. Large gradients of primary productivity have been observed. The open (Oceanic) waters of the Aegean Sea have been classified as “oligotrophic”, the offshore waters as “mesotrophic” and the inshore waters as “eutrophic” (Ignatiades, 2005).

In this study, 8-year time series of Advanced Very High Resolution Radiometer (AVHRR) derived sea surface temperature (SST) and Sea-viewing Wide Field-of-view Sensor (SeaWiFS) derived chlorophyll data are used to investigate the spatial and temporal variability of these parameters in the Aegean Sea and to assess their impact on the plankton ecosystem processes.

2. Methodology

The daily ocean colour data from November 1997 to November 2005 with 9-km spatial resolution, became available from the Distributed Active Archive Center (DAAC) at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) (http://oceancolor.gsfc.nasa.gov). The construction of SST maps for the Aegean Sea is based on a re-analysis of AVHRR Oceans Pathfinder (version 5.0) SST timeseries of the Mediterranean Sea (Marullo et al., 2006). A complete dataset of the 1985-2005 period consisting of optimally interpolated declouded daily SST maps at a 1/16° resolution-grid over the whole Mediterranean region is provided by the Gruppo Oceanografia da Satellite (GOS) of the CNR - ISAC (Istituto di Scienze dell’Atmosfera e del Clima) (http://gos.ifa.rm.cnr.it).

The available long-term series of both satellite data types will allow us to capture the dominant space/time features of the Aegean Sea ecosystem and to assess the physical/biological coupling. 8-day mean, monthly and seasonal climatologies of SST and chlorophyll concentration, are computed from daily data to enable the dominant patterns to be identified.

3. Results

The temporal mean distribution of SST during 1997-2005 period, shows a North to South increasing pattern of SST, with minimum values near the Dardanelles straits and the northeastern part of the Aegean Sea, whereas maximum values appear at the southern parts of the basin (Fig. 1.a). Cold Black Sea waters entering through the Dardanelles Strait create a thermohaline front
with a strong baroclinic current. In this current, a bifurcation is produced with a northern branch of the current entering the northeastern part of the basin contributing to a permanent anticyclone around the island of Samothrace. This circulation pattern results in the accumulation of cold Black Sea waters in the northeastern part of the basin a feature that is clearly evident in the SST fields. Another smaller branch follows a southwestward route, finally contributing to the generally cyclonic circulation of the Aegean Sea transporting cold waters along the eastern coasts of the basin. The SST spatial mean shows a stable seasonal cycle, with a maximum value of about 25°C in the middle of August and a minimum value of about 15°C in the middle of February (Fig. 2.a).

The spatial pattern of the mean surface chlorophyll (Fig. 1.b), reveals an extremely oligotrophic environment for the major part of the southern and central basins with surface chlorophyll mean values lower than 0.1 mg/m³. Much higher mean values (>0.3 mg/m³) are encountered in the northeastern Aegean as well as in coastal areas with large river/anthropogenic nutrient load, mainly located in the northern basin such as the Thermaikos Gulf. Chlorophyll-rich Black Sea waters enter the Aegean through the Dardanelles and following the path of the Samothraki anticyclone are accumulated in the northeastern part of the basin. The standard deviation of chlorophyll concentration in this area is also increased, suggesting strong variability. The spatial mean of surface chlorophyll concentration during the 1997-2005 period (Fig. 2.b), shows a strong seasonal cycle with a maximum value in early March and a minimum value in late August.

Finally, the 8-day mean time-series of SST and chlorophyll are strongly (negatively) correlated (r=-0.81, statistically significant at the 95% confidence level) denoting a close relationship between the seasonal cycles of the two parameters. There is a 1-month lag between the maximum chlorophyll values (i.e. obtained in mid-February) and the minimum SST values (i.e. obtained in mid-March).
In order to further analyze the seasonality of SST and surface chlorophyll, monthly and seasonal mean climatological maps are constructed (Fig. 3). The spatial variability of SST seems to be affected by the Black Sea water entering through the Dardanelles Strait and the Levantine warm waters entering through the eastern Cretan straits, as well as by the upward transports of deep cold water due to turbulent mixing and upwelling processes. Time variations of all these inputs are superimposed on the thermal seasonal cycle. Analysis of the climatological maps reveals two distinct periods of SST spatial variability throughout the year characterized by different large scale spatial gradients which are induced by different processes regulating the dynamics in this region. From October to May there is an increasing SST gradient from north to south. The northeastern basin presents the lowest temperatures as it is filled with colder waters of Black Sea origin, whereas the southern basin presents the highest values due to the intrusion of warmer waters of Levantine Sea origin. From June to September the influence of the two external water masses is diminished and the increasing SST gradient is now from east to west. Low temperatures are found all along the Turkish coasts probably related with the upwelling favourable strong northerlies (etesian winds) which become stronger in the region during summer.

Climatological maps of surface chlorophyll show a decreasing southward gradient with much larger chlorophyll concentration values in the North Aegean throughout the climatological year (Fig. 4).

During summer extremely low surface chlorophyll values (<0.1 mg/m³) are found in the major part of the Aegean except from the area of the hydrological front in the North Aegean and coastal areas with important river/anthropogenic nutrient load mainly located in the northern basin. It is interesting to note that in contrast with SST the summer variability mode characterized by an east-west gradient is not present in the chlorophyll climatology. In such oligotrophic area, the main factor controlling primary production is the upper-water column nitrate content, which in turn is related to the intensity of turbulent mixing and/or wind induced upwelling. The surface chlorophyll maximum is obtained in late winter where the phytoplankton consumes the large amounts of nutrients transported in the upper layer by the intense winter mixing. The phytoplankton stock in the surface layer is then gradually depleted by nutrient limitation and grazing and a pronounced subsurface maximum is formed. Other factors favouring the formation of Deep Chlorophyll Maximum and could be added are the intense photo-degradation process in summer and the higher sustainable sinking velocities in the stratified waters. The sub-surface maximum follows the depth of the nutricline and reaches about 100m depth in late summer (Skliris et al., 2006). Therefore during summer both nutricline and sub-
surface chlorophyll maximum are found at much deeper layers than the thermocline so that nutrient/ chlorophyll rich deep waters need larger mixing and/or stronger and more persisting upwelling in order to be transported in the surface layer. During summer strong upwelling-favorable wind events occur but they are very sporadic associated with mesoscale variability (time scales of a few hours to a few days) so that they are largely smoothed out in the monthly climatological maps.

3. Conclusions

SST and chlorophyll climatologies of the Aegean Sea are computed using satellite-derived data. The key factor regulating the SST and chlorophyll distribution in the area are found to be the Black Sea cold and chlorophyll rich water entering through the Dardanelles strait. At the eastern part of the Aegean Sea, during summer, the upwelling due to Northerlies is the most important feature affecting the SST, while from October to May there is an increasing North to South SST gradient. Surface chlorophyll concentration presents an increasing North to South gradient during the entire climatological year. Relatively large chlorophyll concentrations are encountered in coastal regions affected by enhanced anthropogenic and/or river nutrient inputs such as the Thermaikos Gulf.

Fig. 3: Seasonal Variation of SST (°C).
Fig. 4: Seasonal Variation Of Surface Chlorophyll (mg/m³).

4. References

