Mapping and Comparison of Different Sensors' Geophysical Products in the Eastern Black Sea Region

Mr. Abdulaziz Guneroglu(1), Dr. Ercan Kose(1), Dr. Fevzi Karsli(2), Dr. Muzaffer Feyzioglu(1) and Mrs. İlknur Kurt(1)

(1) Karadeniz Technical University, Faculty of Marine Science, 61530 Cambarnu/Trabzon, Turkey
(2) Karadeniz Technical University, Geodesy and Photogrammetry Department, 61080 Trabzon, Turkey

Abstract

In this study, final geophysical products of MERIS, MODIS and SeaWIFS were compared in the South Eastern Black Sea coastal and open waters. Chlorophyll-a (Chl-a) is widely accepted as a main component defining phytoplankton biomass in the Black Sea. Depends on season, circulation and mixing, typical Chl-a values range between 0.05 to 2 mg/m³ in open waters and up to 5-10 mg/m³ in coastal regions. Therefore, it is important to know, relative consistency between different ocean colour sensors by considering temporal and spatial variability. The SeaWIFS current default four–band algorithm (OC4v4) tends to over estimate Chl-a, whereas MERIS (algal I and algal II) and MODIS (OC3M) standard algorithms are expected to perform better in the Black Sea. Reasonable correlation (up to $R^2 = 0.80$) have been found between different sensors depending on time and location, which will be described. Additionally, the implications of developing a regional algorithm to derive Chl-a are discussed in relation to the local factors effecting the remotely sensed signal.

Keywords: Black Sea, Chl-a, MERIS

Introduction

The Black Sea ecosystem, suffering ecological deteriorations through long-term changes induced by natural and anthropogenic factors, needs to be continuously monitored for its environmental state and ecological processes. The most practical and appropriate parameter which can be used for monitoring the marine ecosystems is chlorophyll a concentration. Its level correlates well with primary production and it is widely accepted as an index of phytoplankton biomass. It has been monitored in the Black Sea for several decades and a large volume of data is available at present[1].

Water optical properties are the key factors to derive Chlorophyll over open and coastal oceanic waters. Especially in coastal waters due to coastal interactions scattering and absorption characteristics of these waters are much more complex than oceanic Case I waters. It is highly probable to see the failure of algorithms developed for Case I waters in Case II coastal waters.

The estimates of chlorophyll-a (Chla) concentration in ocean surface waters from the first ocean colour sensor, CZCS, were of poor quality due to its limited capabilities. The next generation of NASA ocean colour sensors, such as SeaWiFS (1997), Terra-MODIS (1999) and more recently Aqua-MODIS (2002), provides a quantitative time series of Chla concentrations due to higher spectral resolution, more stable calibration and more spectral bands[2]. Therefore they are more suitable for oceanographic applications but still they have some limitations due to spectral and spatial resolution for coastal zone applications. The particular requirements for a satellite sensor optimized for observations of coastal zones have driven the development of MERIS [3]. The aim of this study was to investigate how MERIS algal pigment data correlates to different sensors’ Chl-a values. The study is also important to test how reliable to substitute Chl-a data coming from different sensors in case lack of data set due to processing or binning and merging sensors’ data in Eastern Black Sea region. This is a preliminary study in frame of AO for Turkey project number:2457 and further results will be submitted by the time. Currently we are trying to complete our necessary field and laboratory equipment.

Chl-a in Black Sea

The available historical data implied that the Black Sea was in a ecologically well balanced and, thus, stable state in 1978–1986. The mean surface chlorophyll a concentration in the deep Black Sea for May–September interval over the 1964–1986 period was $0.15 \pm 0.04 \text{mgm}^{-3}$. Thereafter, its average value increased regularly at a rate of $0.06 \text{mgm}^{-3}/\text{year}$ during 1988–1991, and then increased rapidly to the peak value of $0.99 \pm 0.7 \text{mgm}^{-3}$ in 1992. After 1992, its value decreased down to $0.26 \pm 0.08 \text{mgm}^{-3}$ in 1993, and continued to decrease regularly at a rate of $0.02 \text{mgm}^{-3}/\text{year}$ during the 1993–1996 period[1]. As it is reported by some investigators the mean surface Chl values in the open Black Sea over 1998–2001 are equal to $0.46–0.50 \text{mgm}^{-3}$[4].
1996-2002 satellite derived surface chlorophyll time series shows a linear seasonal trend of decreasing Chl concentrations from peak values in November to minima in July followed by sharp increase from August to November every year. The phytoplankton production initiates every September, gradually intensifies and spreads over the basin in October, and finally attains its strongest phase in November. The peak is particularly pronounced in 1996, 1998, 2000 and 2001 with values around 0.9 mg m\(^{-3}\). The autumn bloom episode generally terminates in January as indicated by gradual reduction of chlorophyll concentrations to their minimum levels in winter months. It is also reported that May-June period (Chl) is inversely correlated with *Emiliania huxleyi* blooms [5]. CZCS derived similar patterns were also reported by other authors. [6]

Evaluation of SeaWIFS data set in different regions has been published recently. Among all of the basins, the Mediterranean/Black Sea region has the highest RMS for the SeaWiFS/in situ data comparisons and the lowest correlation. The SeaWiFS data set clearly overestimates the in situ data in this region across the entire range of chlorophyll observed, from 0.03 to 1.61 mg m\(^{-3}\). Where SeaWiFS estimates >1 mg m\(^{-3}\) and the corresponding in situ measurement shows the lowest value, 0.03 mg m\(^{-3}\), occurs in the pelagic Black Sea. Observations by other investigators (using previous versions of SeaWiFS data), confirm these findings attributed the overestimates in the Mediterranean to atmospheric correction (in particular, aerosols), while some others found reasonably good agreement with normalized water-leaving radiiances in the Black Sea, suggesting biooptical algorithm issues. It is suggested CDOM as a contributing influence, with the possibility of coccolithophore presence as well. It is also reported in some publications that high reflectances in the Black Sea due to coccoliths. Anomalous optical properties of the Mediterranean in general suggest that application of a regional bio-optical algorithm may yield better performance [7]. The Black Sea is also peculiar due to extremely high water stratification resulting from increased (as compared with other regions) input of freshwater with river discharge. Both seasonal cycles observed in these regions and the local variations of these cycles reveal the role of water stratification in the process of phytoplankton development [8].

**Material and Method**

In this study 5 MERIS, SeaWIFS and MODIS-Aqua images were processed by using tools (such as Beam3.2 and SeaDAS4.4) developed parallel to these scientific projects. Processed data is given in Figure 3. First the study area is classified to 3 regions (Figure 1). Classification was made mainly due to bathymetry and circulation regime. Because of high runoff by river outflow and circulation characteristic coastal areas have high nutrients and humic inputs which makes the study area optically complex. The study area is eastern part of Black Sea which is classified as an eutrophic for coastal regions and mixed type for the open part of the sea. The image data used is given in Table 1. Corresponding L2 SeaWIFS and Modis-Aqua images to MERIS L2 data were obtained from NASA ocean-color website. Satellite passing time is tried to be kept as close as it can be and all other factors effecting geophysical data retrieval such as meteorological or sensor specific are assumed to be the same. All available data was projected to same projection. Different regions of interest were selected in coastal and open part of Eastern Black Sea and Chl-a data derived by different sensors are correlated the basic statistics are given for some images in Figure 4. MERIS-Algal I was used for the open part of the basin and Algal II for the coastal regions of interest during the processing stage of MERIS data.

<table>
<thead>
<tr>
<th>MERIS</th>
<th>SeaWIFS</th>
<th>MODIS-Aqua</th>
</tr>
</thead>
<tbody>
<tr>
<td>MER_FR__2PNUPA20040323</td>
<td>S2004083092306.L2_MLAC</td>
<td>A2004083104000.L2_LAC</td>
</tr>
<tr>
<td>MER_FR__2PNUPA20040408</td>
<td>S2004099101533.L2_MLAC</td>
<td>A2004099104000.L2_LAC</td>
</tr>
<tr>
<td>MER_FR__2PNUPA20040418</td>
<td>S2004109102739.L2_MLAC</td>
<td>A2004109111500.L2_LAC</td>
</tr>
<tr>
<td>MER_FR__2PNUPA20040523</td>
<td>S2004144094346.L2_MLAC</td>
<td>A2004144101000.L2_LAC</td>
</tr>
<tr>
<td>MER_FR__2PNUPA20040614</td>
<td>S2004166095217.L2_MLAC</td>
<td>A2004166111000.L2_LAC</td>
</tr>
</tbody>
</table>
Since there is no in-situ data for the same real time and location, it is very difficult to comment about in-situ and satellite data correlation which is very crucial for any ocean color algorithm evaluation and validation study but as an approximation, an average surface Chl-a values for the same months from different datasets were given in Figure 3 for both coastal and deep part of the region. For the coastal region of south eastern part of the basin, monthly averaged Chl-a values for the March-June period were 1.16 mgm$^{-3}$ for the 1993-1994 and 0.69 mgm$^{-3}$ for the 2001-2002 period in average. For the deep eastern part of the basin the average value for the March-June period was 0.38 mgm$^{-3}$ 1984-1995 pooled data.

**Used Algorithms**

OC4V4, OC3M, Algal I and Algal II algorithms have been used in this study. OC4V4 is an empirical algorithm and uses the maximum band ratio blue (443,490 or 510nm) to green (555nm) to estimate Chl-a values. OC3M incorporates 443 and 488 nm and it uses maximum band ratio (551nm). The 443-551 ratio is always the maximum in low-chlorophyll (blue) waters, but as the chlorophyll concentration increases, reflectance in the
443-nm band diminishes due to the strong absorption of chlorophyll (and other organic matter). Eventually, the 488-551 ratio becomes the larger ratio. The form of this algorithm is similar to the OC4V4 algorithm, in that it uses a maximum reflectance ratio, but the OC4V4 also uses a third ratio involving the 510 nm band, which MODIS does not have [9]. It must be also noted the difference between OC4V4 and OC3M could be reach up to %25 in turbid waters [10]. Meris-Algal I is semi-analytical algorithm designed for Case I waters. It uses the ratio of absorption and backscattering (443nm to 555nm) to retrieve algal pigment index [11]. Meris-Algal II is based on inverse modeling technique (neural network) and designed for both Case I and Case II waters. It derives phytoplankton pigment, yellow substance and suspended matter by using directional water leaving radiance reflectance spectra [12].

Atmospheric correction and in-water bio-optical algorithms are the key components in processing satellite ocean color data. To date, ocean color algorithm development has focused largely on ocean waters for which simplifying assumptions about the optical properties can be made. Specifically, it has been assumed that over 90% of surface waters in the world oceans can be classified as Case I waters, in which phytoplankton and covarying material of biological origin are principal water constituents responsible for variations in ocean optical properties. In Case I waters, substances other than phytoplankton are either optically insignificant or correlated with phytoplankton. Although this idea oversimplifies the reality to some extent, it provided an essential stimulus for the advancement of ocean color remote sensing in recent decades. The Case I water assumptions imply that the ocean optical properties can be modeled as a function of chlorophyll concentration alone, which has led to algorithms for retrieving phytoplankton pigments from remotely sensed ocean color. The current satellite operational algorithms for retrieval of pigments and other bio-optical properties have been empirically derived from field data collected mainly in ocean waters that are assumed to be Case I [13]. But in natural environment, ocean colour is influenced by all coloured material in the water, principally phytoplankton and associated detritus, inorganic suspended particulate material (SPM) and colored dissolved organic material (CDOM) from land runoff. The OC4v4 algorithm is applicable only to those areas where the ocean colour is determined exclusively by material of phytoplankton origin (known as Case I waters). The approach is effective even though the blue band does not lie within the main region of absorption by chlorophyll-a (400–470 nm) because accessory pigments, mostly carotenoids, absorb throughout the blue part of the spectrum and these co-exist and co-vary with chlorophyll-a over most ocean provinces. A two band ratio algorithm such as OC4v4 will fail where the phytoplankton pigment assemblage is unusual, or where ocean colour is influenced predominantly by SPM and/or CDOM (so-called Case 2 waters), because it cannot distinguish the optical characteristics of carotenoids, CDOM or SPM from those of chl-a. [14].

**Discussion and Results**

It could be easily seen from Figure 3, that the meanders, filaments and some other mesoscale features are influenced by coastal freshwater input and show similar patterns for the same day and time. Due to high fresh water input, coastal waters are much more productive than inner basins because of the coastal production with high suspended matter and CDOM. All mentioned factors can be considered region-specific when developing local algorithms for all sensors in Eastern Black Sea.

Even though, the pigment data shows similar patterns inferred from previous studies in Black Sea they are single day images and they do not account for seasonal or annual mean which makes difficult to make further interpretation. Moreover, some discrepancies have been found among retrieved geophysical data for the same date and hour among different sensors. For instance, there were good correlations ($R^2=0.74-0.76$ for Modis-Meris, $R^2=0.76-0.79$ for Meris-SeaWIFS and $R^2=0.88-0.79$ for SeaWIFS-Modis in both coastal and open areas) on the date 144_2004 for all sensors’ algorithms and similar result for some other images but not for all of them. Discrepancies between different sensors final product comparison could be mainly due to atmospheric correction procedures applied in each sensor data processing schema to retrieve water leaving radiance ($L_w(\lambda)$). Daily meteorological conditions and sensor viewing geometry is also important. Sun glint is an another problem which may negatively effect the satellite data. Hence an extensive bio-optical measurement is needed to evaluate this problem for each sensor under clear sky conditions. Furthermore, according to previous studies it is well documented that OC4V4 and OC3M are tend to fail in Case II waters a strong correlation between these algorithms and Algal I or Algal II could be regarded as a hint to evaluate the performance of the algorithms. It is difficult to derive a conclusion whether or not MERIS algorithms are failed in Eastern Black Sea region but as it is reported by previous studies due to some peculiarities of the Black Sea a regional algorithm is needed to substitute for OC4V4 and OC3M.
Figure 3. Processed satellite data from three sensors.
Figure 4. Some sample plots and basic statistics for chosen areas from different sensors.
Acknowledgements

This work was supported by the Turkish Scientific and Technical Research Council (TUBITAK) NATO-A2 scholarship. We also would like to thank ESA and NASA-DAAC for the support and production and dissemination of MERIS, MODIS and SeaWIFS satellite data. The authors are grateful to Dr. S.J.Lavender (Universisy of Plymouth) for her helpful discussions. The part of the data used in this publication originates from the Data Base prepared in the framework of the NATO TU Black Sea Project.

References