Monitoring chlorophyll concentrations with POSEIDON system's optical instruments

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Abstract

In a specially designed experiment optical data from the POSEIDON system Cretan Sea station, above water surface reflectance measurements and in-situ chlorophyll-a profiles were collected and combined in order to evaluate the existing remote sensing chlorophyll retrieval algorithms. It was found that both SeaWiFS and MODIS global algorithms overestimate the chlorophyll concentration by >35%, but another more interesting finding was that the algorithms, developed specifically for the Mediterranean, underestimate the concentration by a similar factor. Further investigation is under way.

Keywords: ocean optics, remote sensing, operational oceanography

1. Introduction

Algal biomass distribution is an important factor for the assessment of marine environment condition. Traditionally, a proxy to this distribution is chlorophyll concentration, which in turn can be estimated with the implementation of optical methods. More specifically, this is achieved either by monitoring the stimulated fluorescence of chlorophyll or simply the effect it has in the colour of the ocean. Satellite-collected ocean colour data provide a cost effective way for this purpose provided that the chlorophyll retrieval algorithms have been validated for the region of interest. Drakopoulos *et al*. (2003) found that for the Cretan Sea oligotrophic Case I waters, the global SeaWiFS algorithm overestimates in-situ chlorophyll by ~37%. In time new empirical relations tuned to the Mediterranean waters have been developed (MedOC4 for SeaWiFS, and MedOC3 for MODIS; Volpe *et al*., 2007, Santoleri *et al*., 2008).

In order to monitor algal biomass for the needs of the prognostic system Poseidon, optical sensors have been installed at an operational level on the multi-parameter observation platform (E1-M3A) in the Cretan Sea (Nittis *et al*., 2010). This platform is moored in 1400 m depth, 20 miles north of Iraklion, at exactly the same location that the SeaWiFS global chlorophyll retrieval algorithm was investigated 10 years ago. The availability of new optical measurements and the lack of proper validation of ocean colour products for that region led us to undertake this relevant experiment. Its scope was oriented towards assessing the performance of the newly developed local algorithms. It was executed during the regular maintenance visit to the E1-M3A platform in March 2011. The purpose of this paper is to report the preliminary results.

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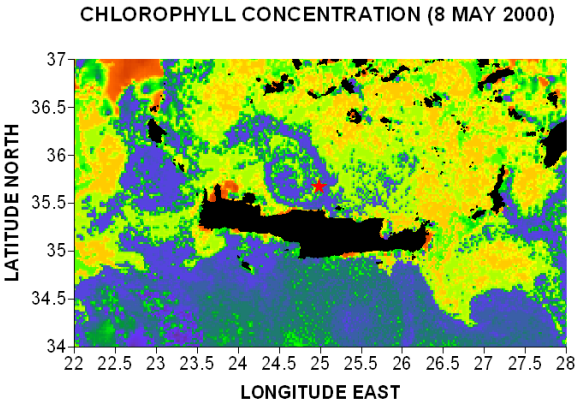

Figure 1 Location of the E1-M3A platform.

2. Instruments

The basic optical instruments installed on the multi-parameter observation platform E1-M3A and utilised in this experiment are (Drakopoulos *et al*. 2009):

- OCR-507 irradiance meter monitoring solar irradiance at seven wavelengths 412, 443, 490, 555, 665, 683, 705 nm. It is installed 2.2 m above sea surface and is equipped with an anti-fouling shutter.
- OCR-507 radiance meter monitoring water leaving radiant flux over the above mentioned seven wavelengths. It is installed at a depth of 40 cm below the sea surface and is equipped with an anti-fouling shutter.
- LI-193SA PAR photometers and FLNTU fluorometers installed at depths 25, 50, 75, 100 m.

In addition an Ocean Optics HR4000 portable spectroradiometer was utilised. The radiance measurements were performed with an 8° FOV Gershun tube attached to the end of the fibre. For downwelling irradiance estimation, the diffuse reflectance of a calibrated Spectralon plate was measured. Complimentary data included in-situ vertical profiles obtained with an SBE25 CTD equipped with PAR, transmittance and fluorescence sensors. Chl-*a* concentration profiles were calibrated against concurrent water samples from six visits on location during 2010–2011.

3. Methods

The remote sensing chlorophyll concentration is given by (e.g. D'Ortenzio *et al*., 2002):

$$C = 10^{(a_0 + a_1 R + a_2 R^2 + a_3 R^3 + a_4 R^4)} \quad (1)$$

where the *a* coefficients are algorithm-dependent and *R* is related to the ratio of blue to green remote sensing reflectances. This concentration is comparable to the weighted in-situ concentration:

$$C_w = \frac{\int_0^{\tau} C(z)\exp(-2kz)dz}{\int_0^{\tau}\exp(-2kz)dz} \quad \text{where } \tau = \frac{1}{k_{\mathrm{PAR}}} = \frac{z_e}{4.6} \approx 19 \text{ m} \tag{2}$$

with the limit of integration (optical depth) during the experiment estimated from PAR profiles.

The above the water surface (Mobley 1999 protocol) and below surface remote sensing reflectance were calculated following:

$$R_{rs}(0+) = \frac{L_w(0+)}{E_d(0+)} = \frac{[L_u(0+) - \rho L_{\mathrm{sky}}(0+)]R_g}{\pi L_d(0+)}$$

$$R_{rs}(0+) = \frac{L_w(0+)}{E_d(0+)} = \frac{0.54L_u(0-)}{E_d(0+)} \tag{3}$$

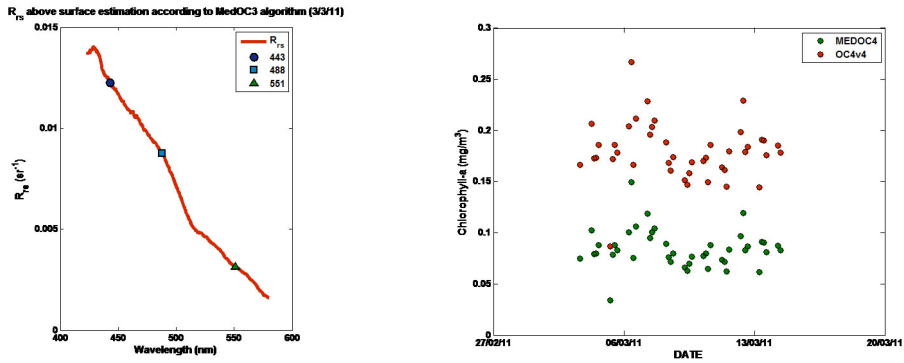

Figure 2 Left: Typical above surface remote sensing reflectance during the experiment. Right: Time series of chlorophyll concentration at the M3A location monitored by the OCR7 radiometers and estimated using the MEDOC4 (solid circles) and OC4v4 (transparent circles) algorithms. The starting date is 3 March 2011, which was the day of the experiment.

4. Results

The corresponding depth integrated weighted concentration was found to be:

$$C_w = 0.12(\pm 0.02)\ \mathrm{mg\,m^{-3}} \tag{4}$$

This value is also expected to be calculated by the radiance measurements (both above and below surface) provided that the retrieval algorithms used are properly tuned.

The tabulated results are in $\mathrm{mg\,m^{-3}}$. Both the above and under surface measurements gave comparable results. Undoubtedly, the global algorithms OC4v4 and OC3 overes-

timate concentration (~35%). Surprisingly enough, it was found that the regional algorithms for the Mediterranean Sea are also biased and underestimate the ground truth by a similar amount. This figure was also evident in concurrent MODIS pictures readily processed with the MedOC3 algorithm and archived in the site of CNR.

Algorithm	Above surface	Below surface	MODIS pictures	In-situ optically weighted
OC4v4	0.14	0.16		
MedOC4	0.06	0.07		0.12
OC3	0.13	-		
MedOC3	0.05	-	~0.06	

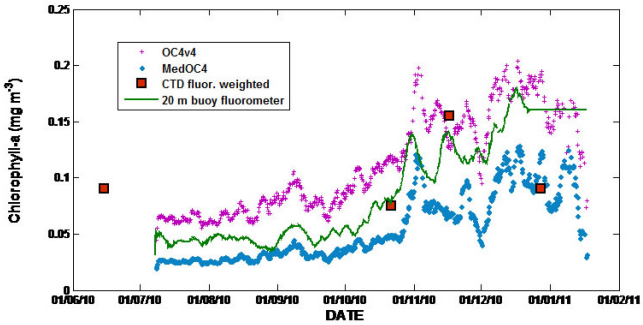

Figure 3 Available data before the current experiment. In-situ collected data fall, on average, in between the values obtained from buoy reflectance measurements evaluated according to the two different algorithms.

5. Conclusions

The main conclusion is that all global algorithms overestimate the chlorophyll concentration (35%) in the Cretan Sea. Moreover, the newly developed regional algorithms underestimate concentration (>35%) at least for concentrations of the order of 1 $mg\,m^{-3}$. The agreement with in-situ and remote sensed estimations points toward adequacy of atmospheric correction algorithms. The discrepancy can be attributed to the local phytoplankton community structure and distribution.

New visits to the site are scheduled for the near future, in order to accumulate enough data for estimating local empirical coefficients. Refined optical measurements, such as collection of profiles with a hyperspectral absorption-transmission meter, should aid the investigation towards explaining the causes behind the peculiarities of the local water colour.

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