ROLE OF PHOTOACCLIMATION ON PHYTOPLANKTON'S SEASONAL CYCLE IN THE MEDITERRANEAN SEA THROUGH SATELLITE OCEAN COLOR DATA

M. Bellacicco [1,2], G. Volpe[1], S. Colella[1], J. Pitarch[1] and R. Santoleri[1]

[1] *Institute of Atmospheric Sciences and Climate (ISAC)-CNR, Via Fosso del Cavaliere 100, 00133 Rome, Italy, marco.bellacicco@artov.isac.cnr.it, gianluca.volpe@cnr.it, simone.colella@artov.isac.cnr.it, jaime.pitarchportero@artov.isac.cnr.it, rosalia.santoleri@artov.isac.cnr.it*
[2] *University of Naples "Parthenope", Via Amm. F. Acton 38, 80133 Naples, Italy, marco.bellacicco@artov.isac.cnr.it*

ABSTRACT

Photoacclimation changes the intracellular chlorophyll-a concentration (Chl), a process that is not currently taken into account by standard ocean colour algorithms. The cellular Chl production is an energy-demanding process, so that it occurs when nutrients are available and under light limiting conditions. Historically, Chl has been used as a proxy for marine algal biomass. This work aims at comparing Chl-based with Carbon-based estimates calculated from the particulate backscattering coefficient, b_{bp} (λ). Here, we define a regional model specifically for Mediterranean Sea using SeaWiFS time series 1998-2007, in order to describe the effect of photoacclimation process on the phytoplankton's seasonal cycle. Chl:C ratio is the footprint showing that phytoplankton cells enhance production of Chl to optimize photosynthesis under low light regime and high nutrients (e.g., winter and spring). We suggest that a new proxy for phytoplankton biomass is strongly needed, particularly for Mediterranean Sea, where Chl:C ratio varies significantly, clearly highlighting dominance of photoacclimation at seasonal and basin scales.

1. INTRODUCTION

The main aim of this work is to define algal biomass variability in space and time. As known, chlorophyll-*a* (Chl) is the most important photosynthetic pigment in phytoplankton cells and it is an energetically expensive molecule. In the Mediterranean Sea, Chl has a typical seasonal cycle with high concentration values in winter and spring seasons, while low values in summer. The photoacclimation is the adaptation of the phytoplankton cells to varying light and nutrients, the consequence of which is the increase or reduction of Chl. In satellite oceanography, Chl is the common proxy to define algal biomass concentration in the upper layer of water column, but Chl and other pigments cannot distinguish between intracellular and community dynamics variations. For this reason, an alternative index in terms of phytoplankton carbon (C) was proposed by [1] in 2005, based on particulate backscattering in seawater, b_{bp} (λ). Then, C is used to define the photoacclimation index Chl:C ratio. [1] used satellite monthly-mean data at global scale. The original equation was:

$$C = \left[b_{bp}(443) - b_{bp_{NAP}}(443) \right] SF \qquad (1)$$

In which C is algal biomass in terms of phytoplankton carbon (mg m^{-3}), $b_{bp}(443)$ is the particulate backscattering retrieved by satellite, b_{bpNAP} is the contribution of non-algal particles at the same wavelength and SF is a constant scalar factor equal to 13000 mg C m^{-2}. The core of the model is the b_{bpNAP} that is a constant value equal to 0.00035 m^{-1} obtained from a least square regression analysis between satellite Chl and b_{bp} (443). It represents a global estimate of backscattering due to heterotrophic and detritus particles.

2. DATA AND METHODS

Our study focus on Mediterranean Sea, divided into the bioregions proposed by [2]. We have selected the SeaWiFS sensor for the time series 1998 – 2007. We have used monthly-mean 1 km x 1 km data of Chl retrieved by the MedOC4 algorithm as defined by [3], and monthly-mean data of b_{bp} (λ) retrieved by the QAA_v5 algorithm [4]. In order to reduce the influence of other water constituents on the b_{bp}, only case 1 waters were selected. The selection of λ = 555 nm is motivated to remain coherent with the original definition of the scalar factor SF in [1]. At this wavelength, we have made preliminary trials and have found higher correlation between Chl and b_{bp} than using 443 nm, 490 nm, and 510 nm (results not shown).
The novelty of our Mediterranean Model (MM) is the definition of a non-algal particles contribution variable in space (each region) and time (each month). As a first estimate, we have applied the approach of [1] to our dataset and have found b_{bpNAP} = 0.001136 m^{-1}, that is, triple the finding of [1]. However, as reported by [5], in the Mediterranean Sea, non-algal particles vary in space and time. Thus, we have computed a specific b_{bpNAP} for each region and month.

3. RESULTS AND DISCUSSION

In this section, preliminary results of our approach are presented. We decided to show only a focus on the north-western Mediterranean Sea in April and May of 2005, in which the footprint of photoacclimation process is clear, so that it is needed another phytoplankton biomass proxy to describe this process. Indeed, the Chl map in April (Fig. 1A) shows the typical bloom patch that occurs in spring in north-west with maximum value equal to 3.5 mg m^{-3}. The phytoplankton carbon index (Fig. 1B) computed with the specific bioregion-monthly b_{bpNAP} shows a similar spatial distribution: both index are in accord. The Chl:C ratio (Fig. 1C) shows values between 0.02 and 0. 25.

In May, the bloom patch is reduced in intensity and extension (Fig. 2A), and Chl drops to a maximum value of 1.4 mg m^{-3} (less than half). In contrast, phytoplankton carbon biomass C computed with the MM persists in extension and magnitude (Fig. 2B). The resulting Chl:C shows a net decrease by a factor of two (Fig. 2C). The interpretation is that the intra-cellular Chl concentration is reduced while the algal biomass is conserved. In winter and early spring, phytoplankton cells enhance production of Chl to optimize photosynthesis under low light and high nutrients regime. Oppositely, minimum Chl:C ratio values are observed during summer when photo-inhibition is the dominant intracellular process (not shown here) because phytoplankton cells do not need to enhance photosynthetic pigment to catch the light. We have shown here the intermediate period.

4. CONCLUSIONS AND FUTURE PERSPECTIVES

Our combined use of the proxies Chl and C (the latter calculated using a novel approach) is able to capture the photoacclimation phenomenon, that dominates the phytoplankton seasonal cycle in the Mediterranean Sea, and is especially notable in the Gulf of Lion. The method is simple, general and extendable to other oceanic regions. Temporal and geographical coverage could be improved using merged multisensor data like CCI.

In order to refine the model, proper *in-situ* data is required for the broadest geographical range, including nutrients, water constituents and inherent optical properties.

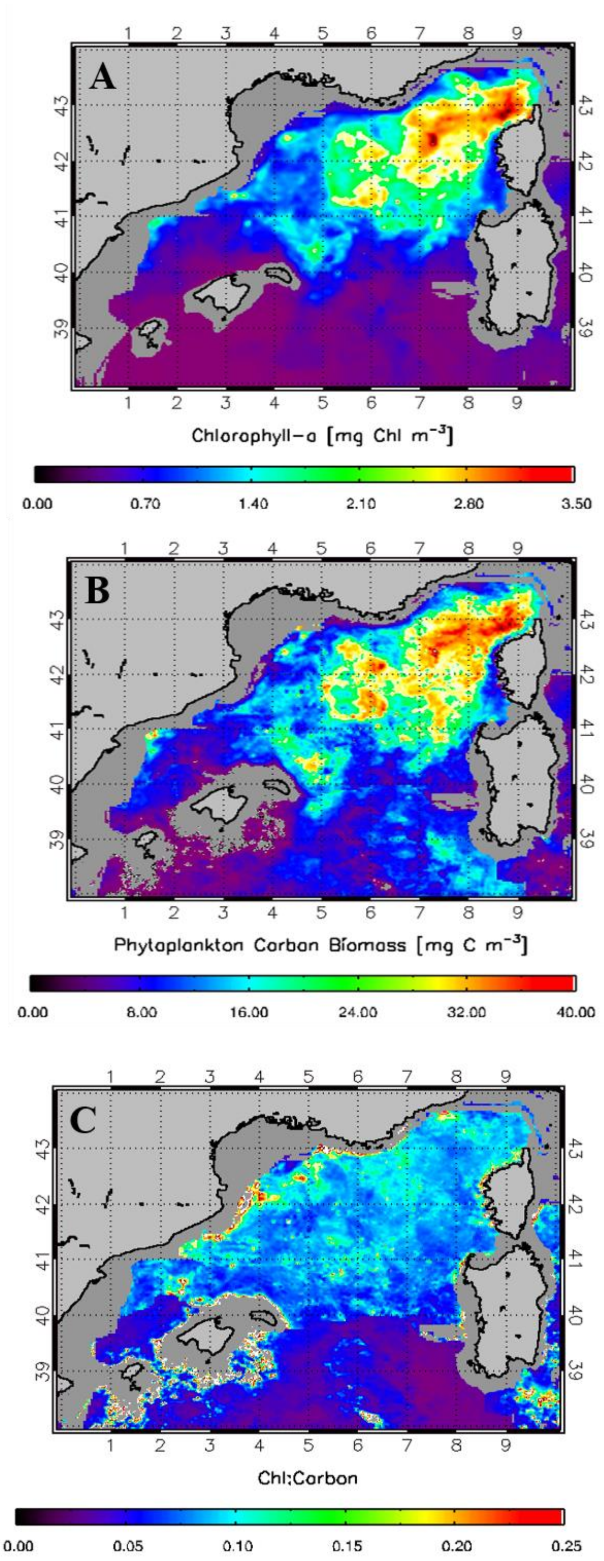

Figure 1: A) Chl (mg m^{-3}); B) Phytoplankton carbon biomass (mg m^{-3}), C) Chl:C ratio

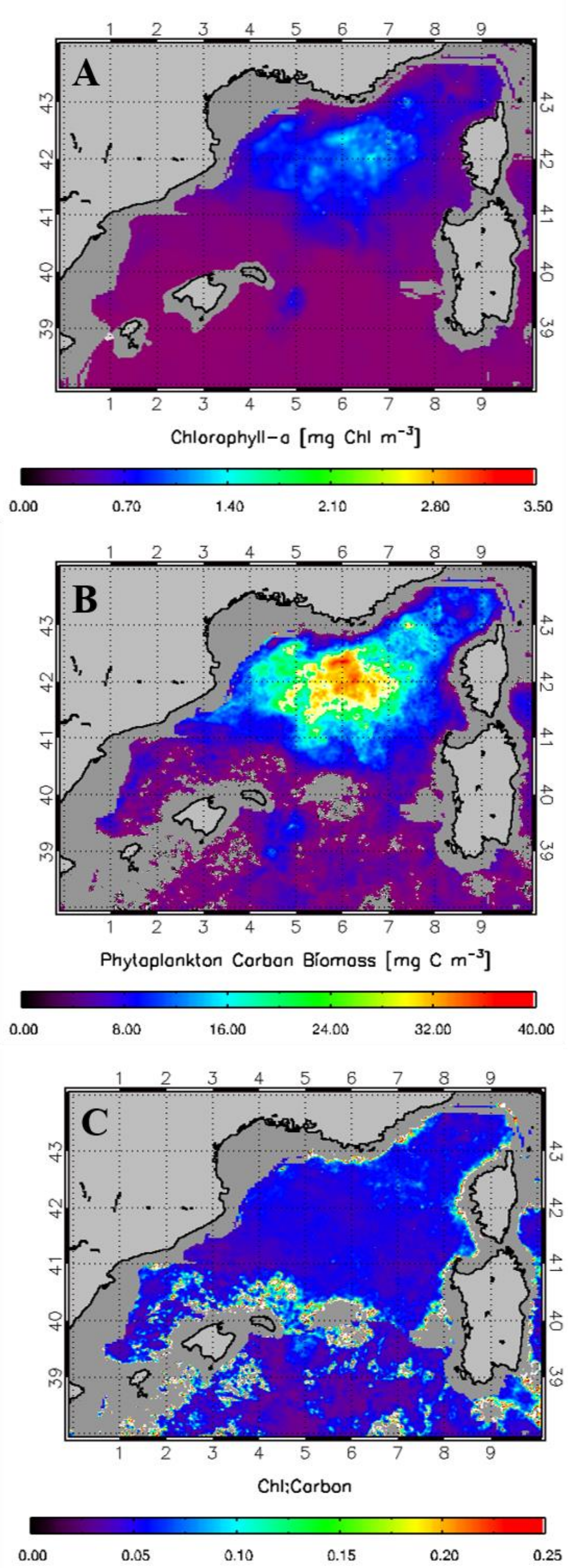

Figure 2: A) Chl (mg m^{-3}); B) Phytoplankton carbon biomass (mg m^{-3}), C) Chl:C ratio

5. REFERENCES

1. Behrenfeld, M. J., Boss, E., Siegel, D. a., & Shea, D. M. (2005). Carbon-based ocean productivity and phytoplankton physiology from space. *Global Biogeochemical Cycles*, **19** (1).

2. Lavigne, H., D'Ortenzio, F., Migon, C., Claustre, H., Testor, P., d'Alcalà, M. R., Prieur, L. (2013). Enhancing the comprehension of mixed layer depth control on the Mediterranean phytoplankton phenology. *Journal of Geophysical Research: Oceans*, **118** (7), 3416–3430.

3. Volpe, G., Santoleri, R., Vellucci, V., Ribera d'Alcalà, M., Marullo, S., and D'Ortenzio, F. (2007). The colour of the Mediterranean Sea: Global versus regional bio-optical algorithms evaluation and implication for satellite chlorophyll estimates. *Remote Sensing of Environment* **107**, 625-638.

4. Lee, Z., Carder, K. L., and Arnone, R. a. (2002). Deriving inherent optical properties from water color: a multiband quasi-analytical algorithm for optically deep waters. *Applied Optics*, **41** (27), 5755–72.

5. Siokou-Frangou, I., Christaki, U., Mazzocchi, M. G., Montresor, M., Ribera d'Alcalá, M., Vaqué, D., & Zingone, a. (2010). Plankton in the open Mediterranean Sea: a review. *Biogeosciences*, **7** (5), 1543-1586.

6. ACKNOWLEDGMENTS

This work has been funded by the Flagship Project RITMARE - The Italian Research for the Sea – coordinated by the Italian National Research Council and funded by the Italian Ministry of Education.
We thank at NASA-SeaDAS's team and MyOcean for satellite products.