PHYTOPLANKTON RESPONSE TO PHYSICAL PROCESSES IN THE MEDITERRANEAN SEA: EOF ANALYSIS OF SATELLITE OBSERVATIONS

G. Volpe [1]*, B. Buongiorno Nardelli [1], P. Cipollini [2], R. Santoleri [1] and I. S. Robinson [2]
[1] ISAC-CNR Via Fosso del Cavaliere 100 - 00133 - Roma, Italy - g.volpe@isac.cnr.it
[2] NOCS Waterfront Campus European Way Southampton SO14 3ZH UK

Abstract

The relation between physical and biological processes affecting the Mediterranean Sea surface layer was investigated by means of different Empirical Orthogonal Function (EOF) decompositions over remotely sensed chlorophyll-a (CHL), sea surface temperature (SST) and Mediterranean Absolute Dynamic Topography (MADT) weekly time series (1998-2006). From the climatological point of view, there is an inverse relationship between CHL and SST, which is explained in terms of enhanced/reduced nutrient inputs to the surface layer as a result of the reduced/enhanced water column stratification. The correlation analysis over EOF results identified physical-biological interactions at both short and long term time scales, and from local to basin scales.

Keywords: Phytoplankton, Temperature, Sea Level

The relation between physical and biological processes affecting the Mediterranean Sea surface layer was investigated by means of different Empirical Orthogonal Function (EOF) decompositions over remotely sensed chlorophyll-a (CHL), sea surface temperature (SST) and Mediterranean Absolute Dynamic Topography (MADT) weekly time series (1998-2006). The EOF analysis generally requires complete time series of input maps, with no data voids. While respective data providers interpolated SST and MADT time series, CHL maps present several data voids due to the presence of persistent cloud cover. In this context, in order to fill in missing data, the Data INterpolating Empirical Orthogonal Functions (DINEOF) technique was applied to CHL images. A validation exercise, comparing 1304 *in situ* observations with space-time co-located satellite data, showed that, at weekly time scales, the DINEOF procedure improves data quality by filtering out the noise.

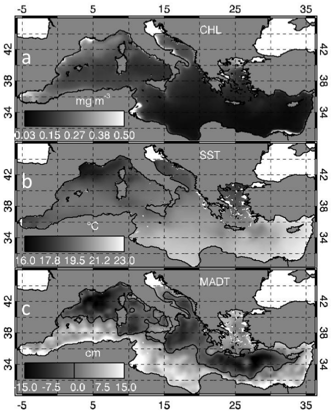

Fig. 1. Field climatologies (1998-2006) for CHL (a), SST (b) and MADT (c). Zero level contour line is superimposed onto the MADT map.

From the climatological point of view, a tight correlation exists between CHL and both SST and MADT (Fig.1). The basin and sub-basin scales inverse relationship between CHL and SST (r=0.64) is explained in terms of Behrenfeld hypothesis [1]: i.e., surface heating enhances water column stratification, which in turn prevents nutrient entrainment into the euphotic mixed layer, and vice versa. At more local scale, highly productive open-ocean areas are found to correspond with well-known and defined dynamical structures (as highlighted by the MADT field): in the WMED, these areas are represented by the cyclonic gyre in the Gulf of Lion, and all along the Algerian Current from the western Alboran Gyre down to the border between Libya and Tunisia across the southern sector of the Sicily Channel. In the EMED, this coupling appears in relation to the Ierapetra Gyre, though less clearly.

This analysis, on a side, provides enlightening insights on the physical-biological coupling, but on the other it is unable to investigate such a coupling on other than climatological time scales. The correlation analysis applied to EOF results, by exploring all time scales, helps giving deeper comprehension about these relationships. Results from the single EOFs, along with a cross-correlation analysis, identified physical-biological interactions at both short and long term temporal scales, and from local to basin spatial scales. In particular, the high correlation (r=0.9) between CHL and SST first modes describes the immediate response of phytoplankton concentration to the annual cycle of the water column stratification, at both basin and sub-basin scales. A completely different mechanism links the MED open ocean spring bloom to the DWF processes, in the north western MED. This is described by the 5.5 months phytoplankton delayed response to local surface cooling (as described by CHL and SST second modes). In fact, on one hand, the total amount of nutrients available in the offshore surface waters depends on the deep convection events occurring in late winter [2]. On the other hand, the DWF phenomena are characterized by a fundamental pre-conditioning phase, during which the surface stratification is significantly reduced.

Despite the good correlation between phytoplankton biomass variability and the temperature field at seasonal time scale, this analysis was unable to identify the co-variability between the two parameters at interannual timescale. We interpret this as due to the strong annual component, which definitely dominates the overall signal within both the first two EOF modes. In order to highlight then the presence of longer time scale signals and to investigate the covariance between the phytoplankton biomass and surface conditions at interannual timescales, the annual cycle and higher frequency signals have been removed from EOF data input. This data manipulation consisted in removing the weekly climatology from each weekly field of the time series, and then of applying a low-pass filter (one year moving average). This data filtering showed the link between phytoplankton biomass variability and two distinct interannual signals: a) the modified surface circulation pattern consisting in a northward shift of the Algerian current, along with its intensity increase, and the reduced cyclonic circulation in the whole eastern basin; b) to the surface heat content anomalies during 1998/1999 (particular cold winter) and 2003 (summer heat wave). This data filtering enabled to investigate the processes that influence the phytoplankton space and time distribution over longer time scales. In particular, the phytoplankton biomass variability was linked to two distinct interannual signals. The first is the modified surface circulation pattern consisting in a northward shift of the Algerian current, along with its intensity increase, and the reduced cyclonic circulation in the whole eastern basin (r=-0.87). One possible explanation is that the reduced advection of the relatively richer waters of Atlantic origin (in terms of nutrients and biomass) in the Tyrrhenian and Ionian Seas and its increased dispersal into the western WMED result in a progressive decrease of F-LCHL concentration in the central MED, creating the positive patch in the western WMED. The second is the surface heat content anomalies in 1998/1999 (particular cold winter) and 2003 (summer heat wave) (r=0.52), driving the phytoplankton dynamics in the central WMED, with few months delay. The observed impact of the water column stratification dynamics onto the phytoplankton biomass variability recalls the described simple model [3].

References

1 - Behrenfeld, M., O'Malley R.T., Siegel D., McClain C., Sarmiento J.L., Feldman G.C., Milligan A.J., Falkowski P., Letelier R. and Boss E., 2006. Climate-driven trends in contemporary ocean productivity, *Nature*, 444: 752-755, doi:710.1038/nature05317.

2 - Levy, M., Memery L. and Madec G., 1999. The onset of the Spring Bloom in the MEDOC area: mesoscale spatial variability, *Deep-Sea Res. I,* 46 (7): 1137-1160.

3 - Doney S.C., 2006. Plankton in a warmer world, *Nature,* 444: 695-696.