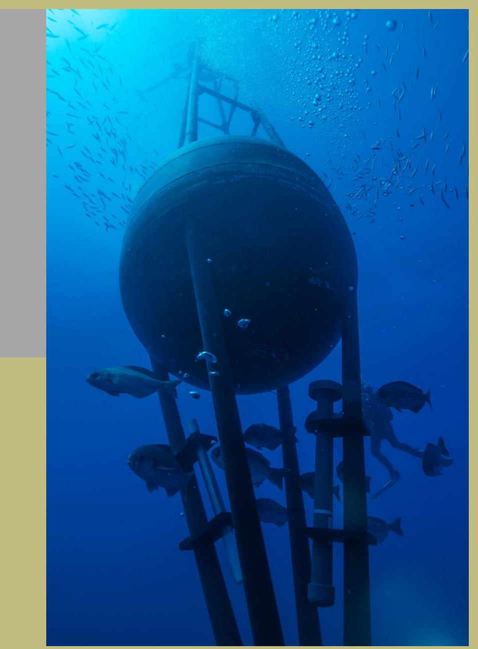
The BOUSSOLE bio-optics time series New developments in the frame of the BIOCAREX project



Melek Golbol[1], Vincenzo Vellucci[1], David Antoine[1,2], Malika Kheireddine[1], Emanuele Organelli[1], Morvan Barnes[1], Annick Bricaud[1], Jacqueline Boutin[3], Liliane Merlivat[3], Laurence Beaumont[4], Bernard Gentili[1], Grigor Obolensky[1], Francis Louis[1], Josephine Ras[1], Vincent Taillandier[1].

[1]*Laboratoire d'Océanographie de Villefranche (LOV), CNRS-UPMC, Villefranche-sur-Mer, France*
[2]*Now at : Department of Imaging and Applied Physics, Remote Sensing and Satellite Research Group, Curtin University, Perth, WA 6845, Australia*
[3]*Laboratoire d'Oceanographie et du Climat (LOCEAN), Paris, France*
[4]*Division Technique de l'INSU – CNRS, Meudon, France*

golbol@obs-vlfr.fr

The overall objective of the BIOCAREX project "BIOoptics and CARbon EXperiment" is to better understand the diel variability of optical properties and to use it as a proxy to biogeochemical information. BIOCAREX leverages the backbone of the BOUSSOLE activities and introduces new instrumentation and measurements dedicated to new research goals.

1. The BOUSSOLE Project

The project was initiated in 2000. The goal is to establish a **long-term time series of in situ bio-optical measurements** to support **calibration/validation of ocean color remote sensing observations** and fundamental **research in bio-optics**.

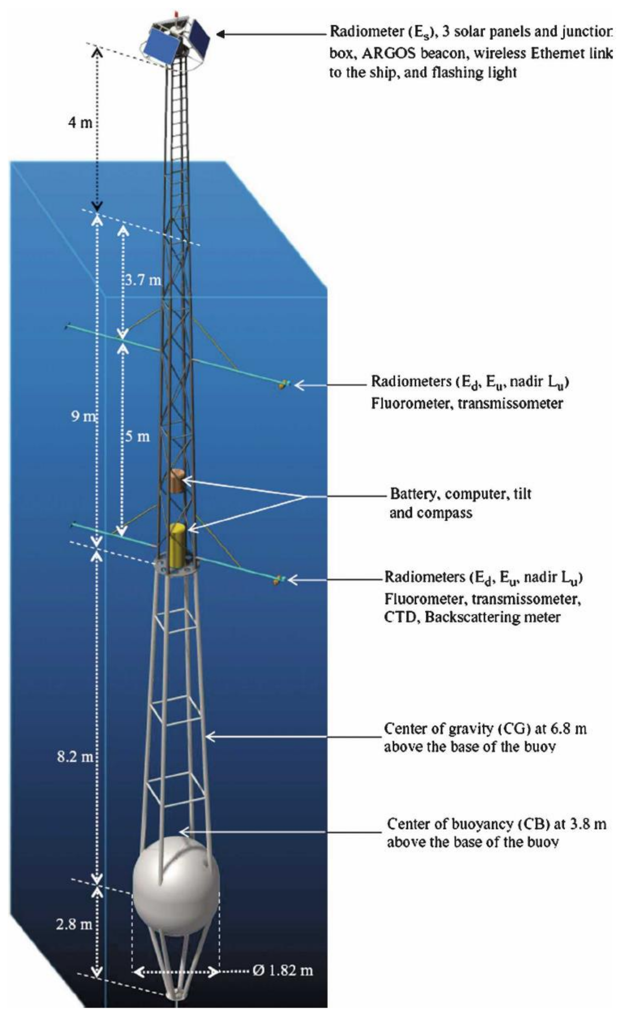


Fig. 1: Schema of the BOUSSOLE buoy structure.

Since September 2003, **the BOUSSOLE mooring** is collecting AOPs and IOPs in the NW Mediterranean Sea at high frequency (1' records every 15').

A program of **monthly cruises**, started on July 2001, provides complementary measurements at the mooring site such as **optical profiles** and **CTD casts with water sampling** (phytoplankton pigments, total suspended matter, absorption by particulate and colored dissolved organic matter).

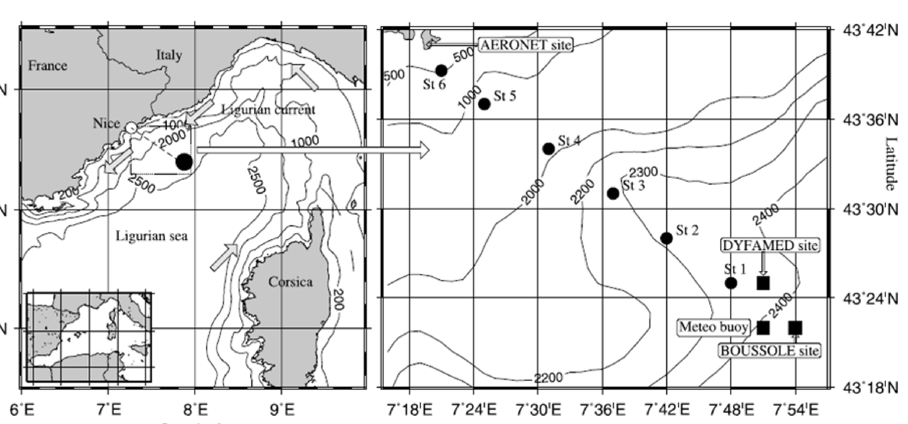


Fig. 2: Map of the Northwestern Mediterranean sea showing the location of the BOUSSOLE site (left) and a blow-up showing the six transect stations in the Ligurian sea (right).

2. BIOCAREX: New Instrumentation & Analyses

On the Buoy

- **Satlantic HyperOCR-IW** at 4 and 9 m measuring downwelling plane irradiance, $E_d(\lambda)$, between (300 and 800 nm with 3 nm resolution) (since January 2012).
- **pCO_2 CARIOCA sensors** at 3 and 10 m measuring carbon dioxide fugacity fCO_2 (operational since February 2013).
- **2 Seabird SBE 37** at 3 and 9 m measuring conductivity, temperature and pressure (since July 2012).
- **2 Anderaa F3835 optodes**, measuring oxygen concentration (O_2).

a) 

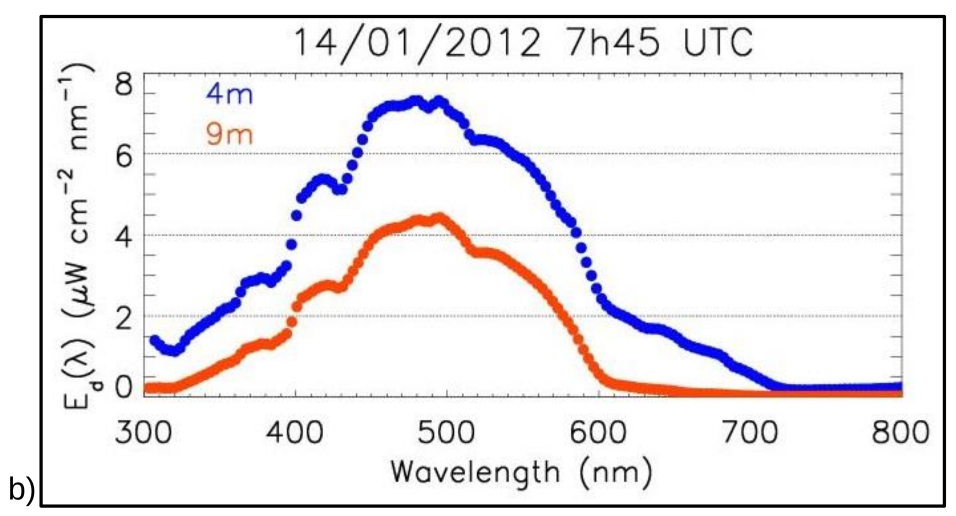
b) 

Fig.1: a) Hyperspectral radiometers on the buoy measuring Ed and Lu at 9m depth.
b) Exemples of data from hyperspectral radiometers at 4m and 9m: median Ed-spectra of 1 minute record.

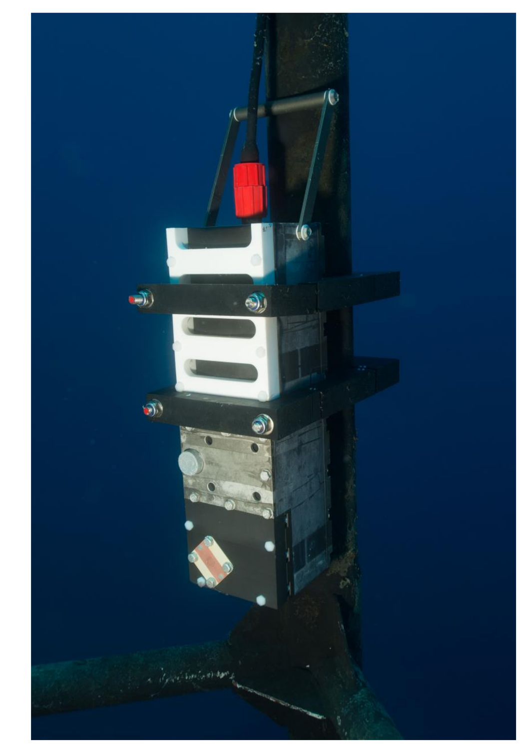


Fig.2: pCO_2 CARIOCA sensor.

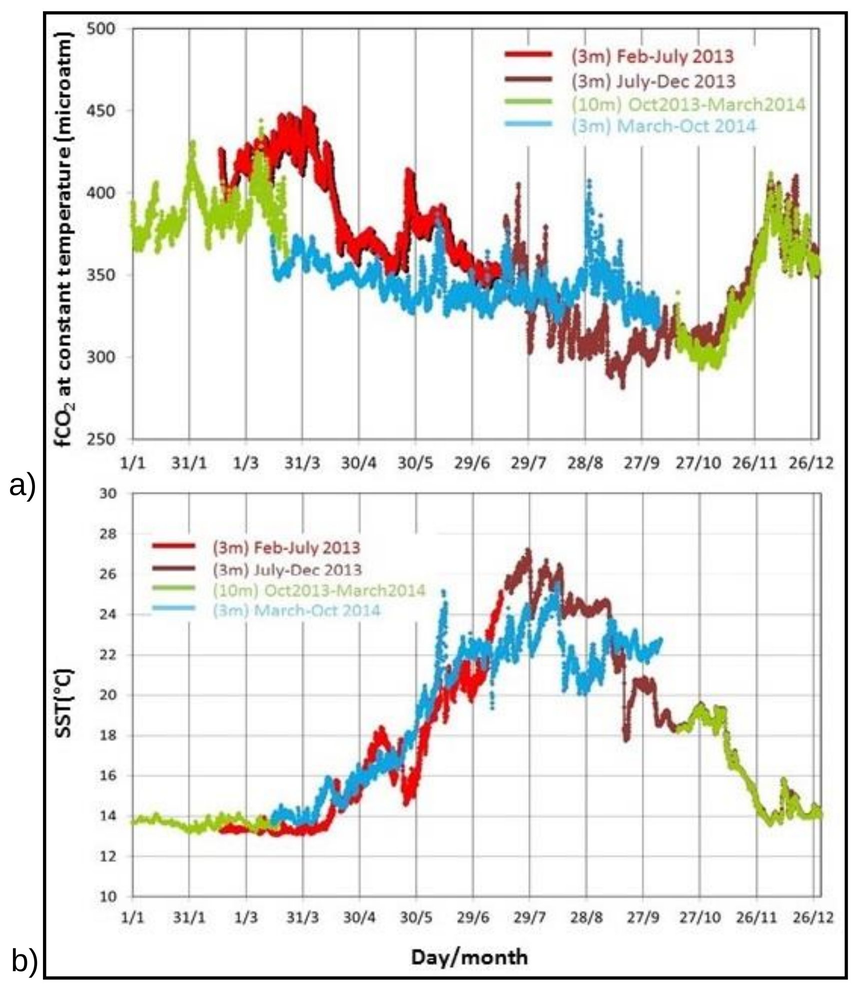
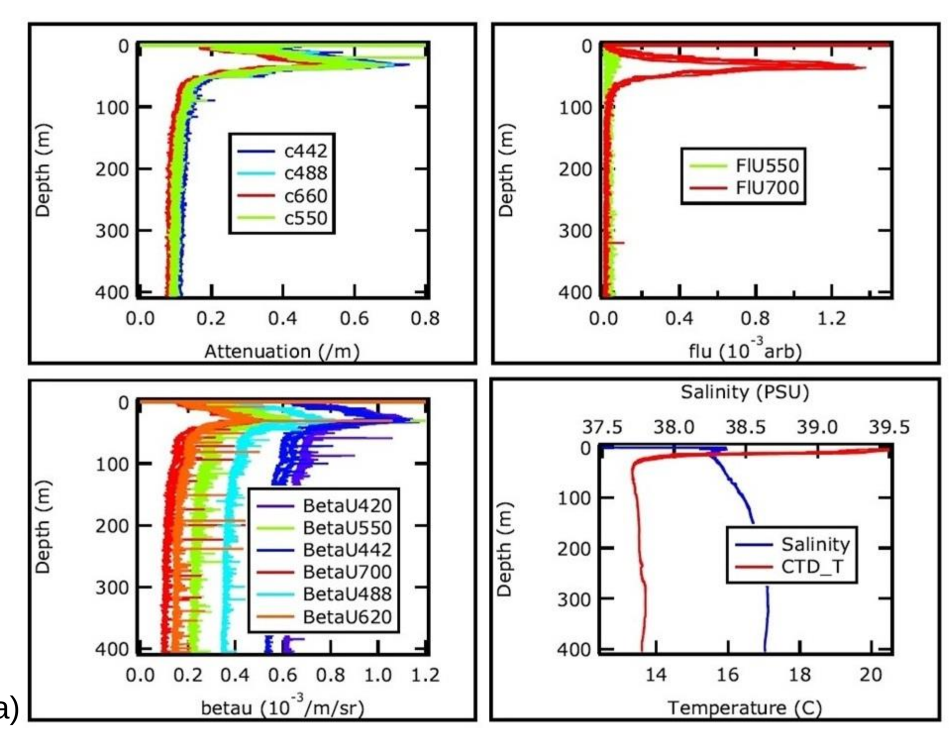


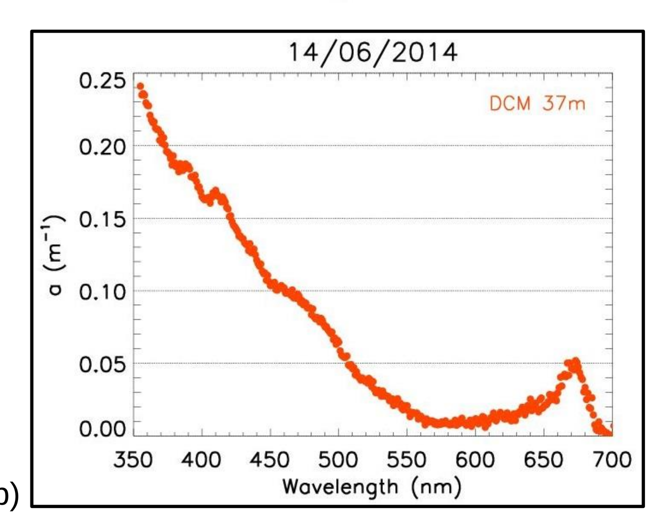
Fig.3: fCO_2 at constant temperature (a) and SST (b) from February 2013 to October 2014 (preliminary data at 3 m and 10 m depth). Main fCO_2 2013-2014 interannual variability related to (1) An earlier onset of the bloom in Spring 2014 (2) higher pCO2/colder SST in 2014 in August-September suggesting more intense mixing in 2014.

During the monthly cruise

- **A new IOPs package** has been deployed with the CTD Rosette (since December 2011):

a) 

- **Hobilabs *a*-Sphere** absorption coefficient net of water contribution (at-w) between 355 and 765 nm with 0.3 nm resolution.
- **Hobilabs Hydroscat-VI** : backscattering coefficient (b_b) at 420, 442, 488, 550, 620, 700 nm and fluorescence (F) at 550 and 700 nm.
- **Hobilabs Gamma-IV** attenuation coefficient net of water contribution (c_{t-w}) at 442, 488, 550 and 660 nm.
- **SeaBird SBE 49 Fastcat** : conductivity, temperature and pressure.

b) 

c) 

Fig.4: a) Exemples of IOPs package acquisition : attenuation, fluorescence, backscattering and CTD profiles (June 2014).
b) *a*-Sphere absorption spectra measured at 37m (June 2014).
c) IOP package fixed under the CTD rosette deployed at the BOUSSOLE site.

- Water sampling for **analyses of particulate organic carbon** and **flow cytometry** were performed during 2 years (between October 2011 and December 2013).

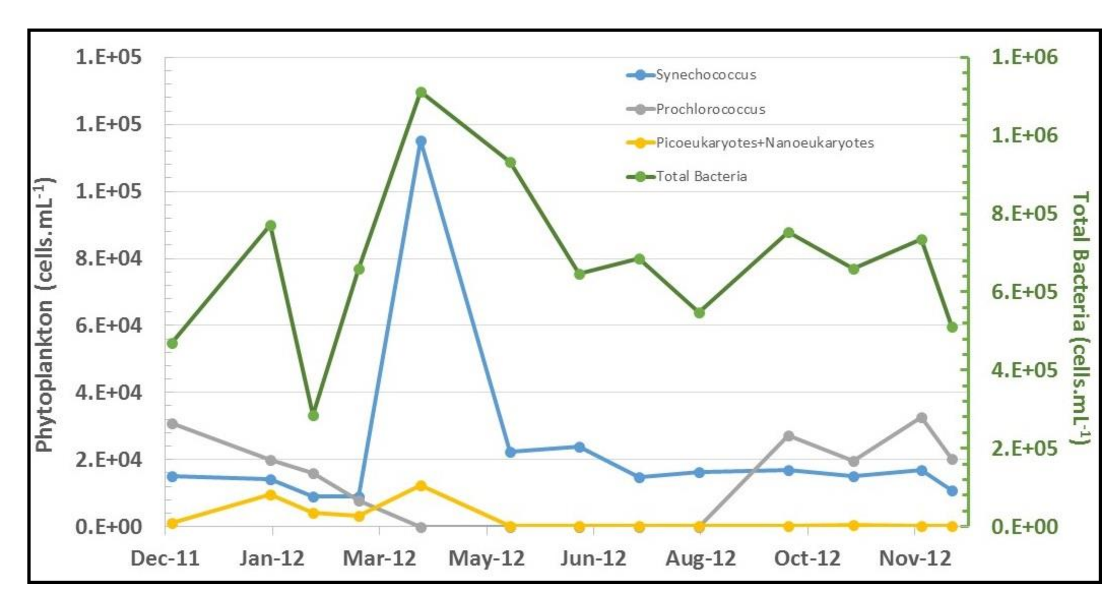


Fig. 5: Total heterotrophic bacteria and phytoplankton concentrations from flow cytometry analyses between December 2011 and December 2012 (values displayed are the mean concentrations measured at 5 m and 10 m).

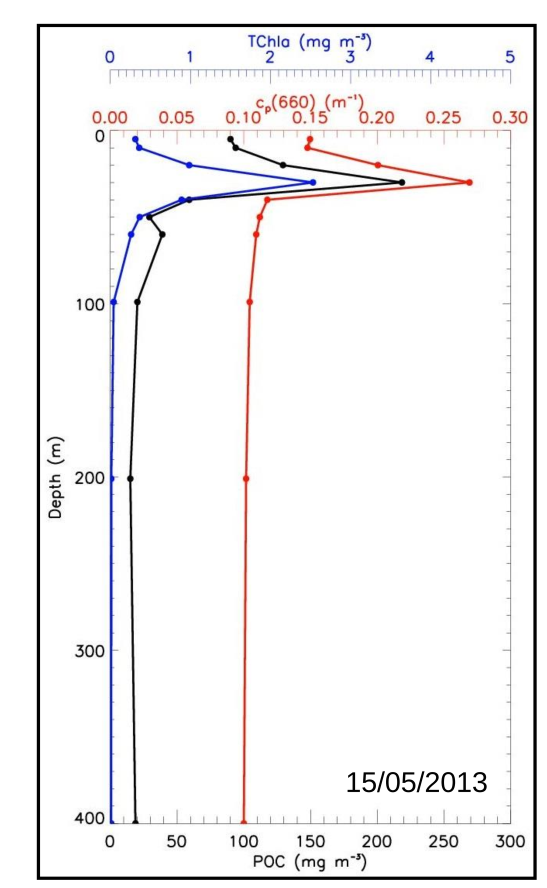


Fig. 6: Vertical profile of total chlorophyll a, POC concentration and attenuation coefficient Cp(660).

3. Conclusion & Perspectives

- **BOUSSOLE**: one of the **most comprehensive time series** of bio-optics and radiometry measurements in the open ocean (IOPs + AOPs).
- **BIOCAREX**: new knowledge on diel variability of optical properties. **3 scientific papers*** and **1 PhD thesis*** were published in 2013 and 2014.
- More details about the studies presented in posters 2015 and 2019 (session 1) and in poster 2085 (session 2).
- **Net Community Production** (NCP) based on diel and day-to-day changes of Dissolved Inorganic Carbon (derived from CARIOCA fCO_2 and O_2) will be compared to those obtained from optical proxies.
- **Hyper-spectral** information's will be exploited to identify and understand ecosystem changes.

References:

Antoine, D. *et al*. 2006 BOUSSOLE: a joint CNRS-INSU, ESA, CNES and NASA Ocean Color Calibration And Validation Activity. *NASA Technical memorandum N° 2006–214147*, NASA/GSFC, Greenbelt, MD, 61pp.
Antoine, D. *et al*. 2008. The « BOUSSOLE » buoy – A new transparent-to-swell taut mooring dedicated to marine optics : design, tests and performance at sea, *Journal of Atmospheric and Oceanic Technology*,25, 968-989.
***Kheireddine, M., 2014. Caractéristiques et origine de la variabilité diurne des propriétés optiques. Thèse de l'Université P. & M. Curie, Paris, 250 p.**
***Kheireddine M. and D. Antoine, 2014. Diel variability of the beam attenuation and backscattering coefficients in the northwestern Mediterranean Sea (BOUSSOLE site). *Journal of Geophysical Research*, 119, 5465-5482, doi:10.1002/2014JC010007.**
***Organelli, E., A. Bricaud, D. Antoine and J. Uitz. 2013. Multivariate approach for the retrieval of phytoplankton size structure from measured light absorption spectra in the Mediterranean Sea (BOUSSOLE site). Applied Optics, 52, 2257-2273.**
***Organelli E., A. Bricaud, D. Antoine and A. Matsuoka, 2014. Seasonal dynamics of light absorption by chromophoric dissolved organic matter (CDOM) in the NW Mediterranean Sea (BOUSSOLE site). *Deep-Sea Research I*, 91, 72-85.**

Acknowledgment: