ID7- SEVEN YEARS OF MARINE ENVIRONMENTAL CHANGES MONITORING AT COASTAL OOCS STATIONS (CATALAN SEA, NW MEDITERRANEAN)

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***Abstract** - Since March 2009 up to the present (more than 7 years now), the Operational Observatory of the Catalan Sea (OOCS; http://www2.ceab.csic.es/oceans/) remains a witness of persistent marine environmental changes. The OOCS has two fixed observation stations at the head of the Blanes Canyon (200 m depth, 41.66°N; 2.91°E) and at the Blanes bay (20 m depth, 41.67°N; 2.80°E) in the Catalan Sea, NW Mediterranean. At the canyon station, a multi-parametric buoy presently installed delivers high frequency (by 30 min) and multi-parametric oceanographic (i.e. salinity, temperature, chlorophyll, turbidity, as well as light intensity in the PAR range for the upper 50 m depth) and atmospheric (air temperature, relative humidity, wind speed and direction and PAR) data. Subsurface photos and videos by an IP high resolution fisheye camera attached to the buoy are also delivered at 4-hour basis. Data and multimedia are transmitted in near real time for public access, via combined GSM/GPRS and 3G connections. At both stations, CTD profiles and water samples (collected for nutrients and picoplankton analyses) are carried out on board a research vessel at fortnightly basis. Numerical simulations along with the time series of in-situ observations show inter-annual seasonality anomalies possibly linked to global environmental changes. The lower-atmosphere and upper-sea environmental time series data collected prove the occurrence of shifting patterns of heat and matter fluxes impacting pelagic and benthic organisms.*

***Keywords** – Operational oceanography, oceanographic buoy, coastal monitoring, numerical modelling, long-term time-series.*

1. INTRODUCTION

Long-term time series of marine environmental variables allow detecting anomalous trends and patterns impacting human activities and health and overall living organisms. Global warming, including the warming of the oceans [1], is perhaps the most widely known event.

One of the typical signals of global warming is the increasing occurrence of extreme seasons with a higher occurrence of warmer summers and less extreme cool weather [2]. A consequence of these changes has made temperature records to become nearly a rule. For example, the seven highest monthly global sea surface temperatures ever recorded has taken place within seven consecutive months from September 2015 to March 2016 [3, 4]. Though global warming was detected in the last decades, the recent records and reports suggest the Earth is facing an overall fast increasing temperature period irregularly evolving at diverse locations.

In-situ monitoring stations contribute to record environmental variability allowing the assessment of local anomalies potentially connected to global environmental changes. These stations, when integrated into marine observing networks, contribute to validate operational numerical ocean models and help improving marine weather forecasting. The Mediterranean Operational Oceanography Network for the Global Observing System (MONGOOS) contributes to that challenge.

Recent records show that Mediterranean Sea surface temperature [4, 5] and salinity [5] are increasing, though may not be increasing as fast as in areas of the Indian Ocean, Pacific, western and southern Atlantic, and the Arctic Seas [3]. Other areas have shown recent cooler-than-average records of temperatures such as the North Atlantic and the Southern Ocean near Antarctica [3]. Marine monitoring stations recording changes from daily to monthly time scales contribute to improve accuracy of reports and studies dealing with environmental changes. Warming of seawater is producing behavioural changes in a number of organisms, e.g. earlier spawning of fishes [6] or species assemblages moving from warmer to cooler areas [7]. Smaller organisms with shorter life times may be also altered particularly because of potential changes taking place at daily or hourly scales.

The Operational Observatory of the Catalan Sea (OOCS, http://www2.ceab.csic.es/oceans/) started operations in March 2009 [8] with a fixed observation station at the edge of the continental shelf, at 41.66°N, 2.91°E at the head of the submarine Blanes canyon, in the Catalan Sea, NW Mediterranean.

Inter-annual, seasonal and daily environmental trends are measured, recorded and processed by the OOCS team. Two main time-scale data types are provided for public use in order to assess the effect of environmental conditions on living organisms with relatively short (e.g. hours, days) and long live (e.g. monthly, seasonal, inter-annual) cycles. Firstly, fortnightly sampling is performed collecting information of the biogeochemical and hydrological conditions at the observation stations. These data allow seasonal and inter-annual variability monitoring and are available to the public within days after collection. Secondly, 30-m time resolution information is provided of the lower atmosphere (i.e. 2 m above the sea level) and upper sea conditions (from surface to 50 m depth) by an oceanographic buoy. The data collected are available to the public in near-real time. The oceanographic buoy operates about six months per year, though full year coverage was achieved between June 2015 and May 2016.

The fixed observation stations maintained by the OOCS are expected to continue operating indefinitely to become a reference of long-term marine environmental time series acquisition and processing. In the present work, operational characteristic and milestones achieved by the OOCS are provided, for the seven years of continuous data recording of relevant environmental changes beyond sea surface temperature, including biogeochemical parameters [8] with potential impact on marine living organisms.

II. RELEVANT OBSERVATORY ACTIVITIES

A. Consolidation of long-term time series observations

As expected from its foundation, during seven years of operations, the OOCS has faced the basic challenge of consolidating long-term coastal monitoring [9]. This has implied, among other factors, getting over the budget cuts imposed by the economic crisis affecting Spain since 2007 up to the present. This was possible because of the persistent support from the CEAB to the relatively low-cost infrastructure, consisting of a small research boat (R/V “Dolores”) with its instrumentation and instrumentation on the oceanographic buoy. Though initially expected to take to port once per year for maintenance, the oceanographic buoy has been taken to port and deployed twice the times expected i.e. 12 deployments have been made (see in Fig. 1). A number of situations dealing with quality of materials, galvanic corrosion and entanglements with longlines operating nearby, have caused the buoy to nearly stop operations, after rescuing it from mooring line detachments or after electronic failures or structure damages.

Coastal oceanography within the framework of the OOCS is possible with relatively low resources or with an efficient use of available resources. For example, the deployment of the 250 meters-long mooring line with a heavy weight required the use of an expensive research vessel only at the beginning of operations, in 2009. Subsequent operations were carried out with the in-house R/V “Dolores” trawling the line with the use of floating balloons. The CEAB facilities and the closeness of the Blanes port have also contributed to keep the observatory uninterruptedly running.

B. Two monitoring observation stations

Apart from the fixed original monitoring station set at the Blanes canyon head, visited twice per month on board the R/V “Dolores” and providing data on 30-minute basis from the probes and sensors on the buoy, a new observation station was added since March 2010 at the Blanes bay [see Fig. 1]. This station was added as a collaborative action with the Microbial Observatory group at Institute of marine Science (ICM-CSIC, http://www.icm.csic.es/bio/projects/icmicrobis/) in Barcelona. The station is moored at 20 m depth, contrasting with the 200 m depth mooring in the canyon. The Blanes bay station serves as a reference for comparing nearshore waters with those from the offshore station in the canyon. The two stations are sampled twice per month within the same cruise and have provided us with supporting data for explaining oligotrophic

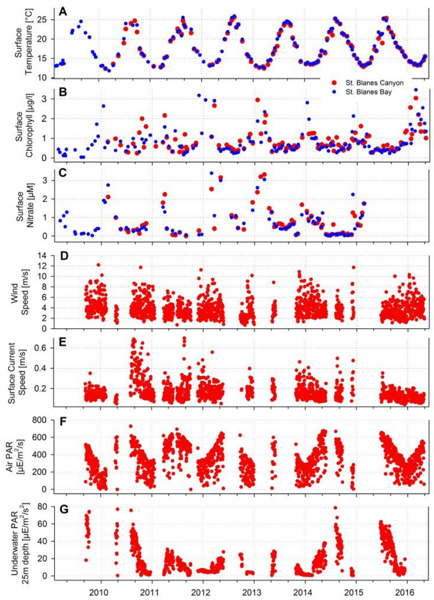

Fig. 1. Examples of available time series of marine environmental data collected at the OOCS fixed stations in the Blanes canyon head and in the Blanes bay. Some time series are created on a fortnightly basis on board R/V "Dolores with a CTD profiler (A, B) and from Niskin bottles samples (C) at both stations. Some other time series are created on a 30-minute basis by the oceanographic buoy at the Blanes canyon head, for segmented deployment periods. Daily averages from meteorological (D, F) and oceanographic (E, G) data collected by the buoy shown for reference.

conditions in the Blanes bay with supporting data showing oligotrophic conditions in the Blanes bay probably due to offshore water arriving from the Blanes canyon head.

C. Near real time data and media transmission

At the time the autonomous buoy was moored in September 2009, we weighted the possibility to add an underwater camera to the system for near-real monitoring of pelagic organisms (Fig. 2). In October 2012, a surveillance IP camera was adapted to operate underwater and attached facedown to the buoy. Images and short videos transmission is made taking advantage of the 3G coverage at the buoy location, 2.7 miles offshore. Therefore, apart from hourly data transmission via GPRS since March 2012, the video camera system provides image at 4-hour basis in summer time only, due to limited power energy resources [9].

D. Numerical modelling

Available climatic hourly data from the whole water column from surface to 200 m depth at the Blanes canyon station, allowed for the first time full validation of the 1DV model [9] operating at 1-hour time-step [10]. Following the IPCC scenarios, the model also tested the potential impact of longer summers on the CO2 flux, suggesting that the Station can twist from yearly sink to source of CO2. Also 3D numerical simulations were partially validated with the OOCS monitoring station data [5], allowing a better understanding of seasonal changes in the formation of gyres and meanders that impact local productivity. The same model was also used to track passive particle dispersion over the canyon area [3] (Fig. 3), showing a potential great impact of meanders on the dispersion of crustacean and fish eggs and larvae known to recruit and live in the area.

E. Outreach

A number of high school students and undergraduate and graduate students, as well as researchers, have made or are making use of data and OOCS facilities or have attended conferences and citizen science activities for learning about oceanography, marine observing systems and marine ecology. The evolution of the environmental conditions at the observation stations is communicated to public through Twitter (@ceab_oocs) and Facebook (www.facebook.com/ObservatorioMarino/) accounts. The social networks have been the way to inform the public on the inferred trends of water warming along the Catalan coast, in line with warming of the Mediterranean Sea in recent months and years. Since 2014, OOCS provides information to global marine networks such as MONGOOS (http://oceanobs.mongoos.eu/) fuelling operational models of the NW Mediterranean (e.g. IBI-ROOS) predictions. The Station is also a component of the EMODNET (http://www.emodnet-physics.eu/portal/) and COPERNICUS (http://marine.copernicus.eu/). These networks are of public access and make available in-situ information for modelling hindcast and forecast providing a social service regarding e.g. the marine weather conditions or the expected circulation pathways in case of environmental emergencies, related to the field of operational oceanography.

Fig. 2. Pictures taken by the fisheye IP camera attached to the oceanographic buoy showing schools of rudderfish (Centrolophus niger, left and right) and pilot fishes (Naucrates doctor, center).

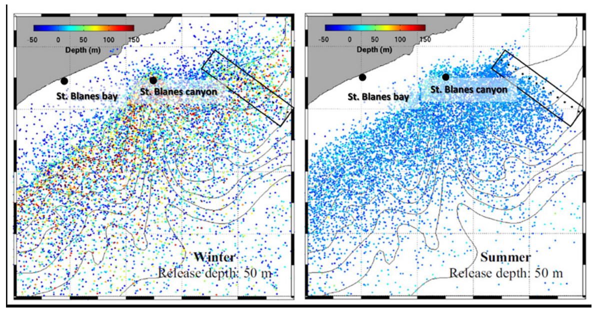

Fig. 3. Location of passive particles after 15-day tracking simulations around the OOCS observation stations (adapted with permission from Ahumada-Sempoal et al., 2015). Rectangles show initial particles release positions.

III. FUTURE DIRECTIONS

Activities dealing with observation, analysis and numerical modelling remain the main target of the OOCS, in line with current international calls to gather information on the on-going changes in ocean physics, chemistry and biology in order to determine trends and variability, and assess their potential causes [6]. Analysis of the time series at the OOCS station may allow validating hypothesis regarding at which extent the local conditions reflect regional or global environmental changes. Finally, numerical modelling efforts at OOCS are currently addressed toward assessing the impact of local and remote circulation on the dispersion of organisms along the Golf of Lions, Catalan and Valencian coasts in order to investigate potential interconnections among pelagic and benthic populations.

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