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IEOOS: the Spanish Institute of Oceanography Observing System

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Abstract

Since its foundation, 100 years ago, the Spanish Institute of Oceanography (IEO) has been observing and measuring the ocean characteristics. Here is a summary of the initiatives of the IEO in the field of the operational oceanography (OO). Some systems like the tide gauges network has been working for more than 70 years. The IEO standard sections began at different moments depending on the local projects, and nowadays there are more than 180 coastal stations and deep-sea ones that are systematically sampled, obtaining physical and biochemical measurements. At this moment, the IEO Observing System (IEOOS) includes 6 permanent moorings equipped with currentmeters, an open-sea ocean-meteorological buoy offshore Santander and an SST satellital image reception station. It also supports the Spanish contribution to the ARGO international program with 47 deployed profilers, and continuous monitoring thermosalinometers, meteorological stations and ADCP onboard the IEO research vessels. The system is completed with the IEO contribution to the RAlA and Gibraltar observatories, and the development of regional prediction models. All these systematic measurements allow the IEO to give responses to ocean research activities, official agencies requirements and industrial and main society demands as navigation, resource management, risks management, recreation, etc, as well as for management development pollution-related economic activities or marine ecosystems. All these networks are linked to international initiatives, framed largely in supranational programs Earth observation sponsored by the United Nations or the European Union. The synchronic observation system permits following spatio-temporal description of some events, as new deep water formation in the Mediterranean Sea and the injection of heat to intermediate waters in the Bay of Biscay after some colder northern storms in winter 2005.

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1 Introduction

The Operational Oceanography (OO) means the activity of systematic and longterm routine measurements of the seas and oceans, their interpretation and dissemination (Parrilla, 2001) in order to fulfill upcoming needs from many different sectors: industry, service, policy making, etc., besides the scientific one. The IEO aims scientific knowledge of the oceans and the marine environment and developed based on observation and research. For more than two decades ago has been investing resources, time and funds in the field of OO, to promote these results in the social development and benefit. Institutional strengthening is desirable to form the network core sampling has managed to develop. This service is given to the interested national and international community and the IEO's Spanish representative in the European forums (ESA, ICES ...) for appropriate action. Some data collected across this Observing System are linked to international initiatives. As example, the IEO participates in FixO3 european project with data from AGL buoy; and nutrients and dissolved oxygen information from water samples at different deep levels, that are collected along the hydrographic sections, are included in the EMODNet (European Marine Observation and Data Network, DG-Mare/2012) initiative in order to improve the knowledge and perform distribution maps of the variables along the European coasts.

Although all the datasets are quality controlled locally, by the same researchers that are responsible of the different programs, the IEO performs a double validation when the data arrive to its datacenter for their permanent archive. Following the internationally agreed protocols, data are checked for spikes and position/date errors, and validated against climatological values in the different areas. To preserve the data for the future, all detected problems are flagged by a numerical code, that gives added value to the original data and facilitate further uses of them. Reformatted to internationally accepted standard formats, and metadated following the SeaDataNet protocols, both, data and metadata, are incorporated to the IEO data archive structure, linked to SeaDataNet network, and made them accessible across its web portal. This paper aims to

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give a general overview of the different programs that the IEO supports to achieve its scientific objectives as well as to serve the different demands that are imposed by the society.

2 Tide gauge network

5 The Spanish tide gauge network (RONIMAR) is being operating since 1943. It has 12 stations, 4 of them on the islands, meets the international requirements and contributes with the data to the Permanent Service for Mean Sea Level (PSMSL). Some stations are integrated in the Global Sea Level Observing System (GLOSS) and the long period of data registered by RONIMAR has allowed to integrate these sea level
10 time series to global and regional datasets for studies of long term trends, as well as for decadal and interannual variability (Tel and Garcia, 2002; Tel, 2007). Nowadays the hourly and higher frequency data are being relevant for the estimation of extreme sea levels (Garcia et al., 2012). Along the time, tide gauges network has been upgraded in line with technological advances, both in the system measurement, from the mechanical tide gauge with graphical recorder to a radar technology, and for data transmission,
15 from postal mailing to automatic transmission. These tide gauge data are daily made available from <http://indamar.ieo.es>.

3 Hydrographic monitoring sections

20 The IEO has been monitoring the Spanish shelf waters for the last 25 years. This is the oldest field program for multidisciplinary marine research addressing long term variability issues at ecosystem level. Core observations include ship-based hydrographic, biogeochemical and plankton observations at monthly frequency in several oceanographic sections along the Iberian shelf. First series initiated in the northwestern shelf, and other programs extended the observations to the Mediterranean and, in 2009, to

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Gulf of Cadiz. In 2003, an initiative to monitored off-shelf waters using the same approach had been stabled.

With the data collected, the IEO was able to detect the deep changes that were produced in the Bay of Biscay and Mediterranean Sea. As an example, the extremely cold and dry Winter of 2005 in the south-western Europe was detected on the different characteristic of the water masses. In the southern Bay of Biscay, information of the IEO Shelf and Slope Sections shows that in the Bay of Biscay the episode caused a profound transformation of the upper ocean hydrographical structure, making it completely different that what it was in the previous decade (Somavilla et al., 2009). The strong local cooling and the precipitation deficit resulted in the highest density flux estimated, which triggered the mixed layer to reach unprecedented depths, affecting directly East North Atlantic Central Water (ENACW) that are usually unconnected to air sea interaction. In the Western Mediterranean the anomalous low precipitation and persistency of northerlies over the NW Mediterranean caused a large extension both in time and space of deep convection processes and a New Western Mediterranean Deep Water (N-WMDW) was produced, slightly denser, warmer and saltier than the usual WMDW (Salat et al., 2007). Also near the continental slope, a cascading of colder and even denser water was found.

3.1 Shelf and slope sections

Since 1990, 181 stations are sampled over a regular grid to get information on the shelf-slope gradient (Radiales program). They conform the longest multi-disciplinary oceanographic dataset in Spain (Bode et al., 2014) and attempt to characterize the ocean variability at different scales, seasonal, inter-seasonal and decadal ones, including biogeochemistry and plankton behaviour, as well as the ecosystem responses. It covers Galicia (9 stations along 2 sections) and Bay of Biscay (13 stations along 3 sections). These observations are complemented with buoy and satellite observations and all these data are used to validate hydrographic and ecological models of plankton at local and regional scales. The success of Radiales extends beyond pure scientific

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shelf break in the summer and widely distributed in winter (Prieto et al., 2013). The complete deep sections in the Cantabrian Sea have been discontinued recently while some deep stations have been included for the monthly sampling. The aim is establishing the scales of variability in the range decadal/subdecadal. Its information contributes to the knowledge of the oceanographic climatic variability and global change monitoring (Prieto et al., 2015).

The Canary Islands are immersed in the eastern margin of the North Atlantic subtropical gyre, in the coastal transition zone of the Canary Current Upwelling System. In 2006 the IEO began the deep hydrographic section around the Canary Islands (RaProCan program), in order to establish the scales of variability in the range decadal/subdecadal in the subtropical gyre, specifically in its eastern margin. It consists 50 hydrographic stations around the Canary Islands (Velez-Belchi et al., 2014) sampled each 6 months. In each one of the stations velocity, temperature, salinity, pressure, oxygen, turbidity and fluorescence are continuously measured (CTD) and bottle samples are taken for calibration and for determination of alkalinity, carbon and chlorophyll content in collaboration with the University of Las Palmas de Gran Canaria (ULPGC). The warming of the upper 600 m continues at a rate of $0.14\text{ }^{\circ}\text{C decade}^{-1}$ in the oceanic waters and $0.32\text{ }^{\circ}\text{C decade}^{-1}$ in the waters between Lanzarote and Africa under influence of upwelling off the African coast. At intermediate levels the warming continues at rate of $0.04\text{ }^{\circ}\text{C decade}^{-1}$ in the oceanic waters and $0.08\text{ }^{\circ}\text{C decade}^{-1}$ in the waters between Lanzarote and Africa. At deeper levels, since 1997 there is not statistical significant trend. Regarding the oceanic circulation, the Canary Current presents a seasonal cycle, with the minimum transport occurring during fall, concentrated between Tenerife and Lanzarote Islands. (Vélez-Belchí et al., 2010)

4 Permanent moorings

In the Atlantic Ocean, the IEOOS comprise two deep moorings in the RadProf monitoring of N/NW Iberia since 2004 Finisterre and Santander. The second one is not working

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nowadays. Mooring lines with current-meters and hydrographic sampling at the cores of main water masses have been operative with some interruptions from 2003 at the western Iberian margin and in southern Biscay, and complete the hydrographic sections samples. The goal is to maintain permanently at least one mooring line at each region. In the Canary Basin a permanent mooring has been placed in the eastern Boundary Current EBC4 to quantify the water masses variability of these current as well as the Canary Current (Velez-Belchi et al., 2015).

In the Gibraltar Strait, the IEO is involved in the Gibraltar monitoring system with a mooring, the INGRES mooring in coloboration with the University of Malaga. This mooring is included in the HydroChanges program. In the Mediterranean Sea, this program comprises an international set of deep moorings for the long-term monitoring of the hydrological variability (Schroeder et al., 2013). The IEOOS contributes to this program with a mooring in the continental slope at the north of the Ibiza channel. Additionally, a second mooring will be installed in the next months at the NE of the Menorca island. The mooring maintenance is planned to be every 6 to 12 months within the RadMed monitoring program (Balbin et al., 2014).

5 Ocean-meteorological buoy

Deployed in 2007, at 43°50' N 3°47' W, the Augusto Gonzalez de Linares (AGL) buoy is located 22 nmi (nautical miles) north of Cape Mayor, off Santander (southern Bay of Biscay). Water depth at the buoy site is 2850 m. The obtained information is of great importance for the scientific, meteorological, environmental, fishery, maritime and tourist activities which have a real-time marine information source. Integration of different scales has been matter of study from hourly to monthly, and some products are freely available, together AGL buoy real time data, at www.boya_agl.st.ieo.es. Also, comparisons between AGL data and monthly Santander Hydrographic Section. The Biscay AGL buoy is the IEOOS contribution to the EU FixO3 project.

6 IEO Research vessels underway monitoring

Nowadays the IEO maintains continuously working 5 thermosalinometers, 4 meteorological stations, 4 marine data management systems and 2 vessel mounted ADCP on board the IEO R/V fleet. Collected data are routinely sent to the IEO datacenter for QC (mainly date, position, and range for near realtime data), dissemination and archive. These systematic measures had allowed some climatological products based on repeated shiptracks. So, from thermosalinometer data, the monthly repeated track from Santander to Gijon, has enabled the subsurface temperature and salinity maps in Cantabrian Sea (Viloria et al., 2012; Viloria, 2012) and let us a better description of coastal conditions and their seasonal variability. In Galician Rias where the inter-seasonal variations have consequences as algae blooms that strongly affect to local fisheries, the weekly repeated surveys of R/V *Navaz* since 2008, allows us getting better descriptions of their variability patterns (Tel et al., 2014).

7 IEO contribution to ARGO international program

Spain participates in the international Argo program since its beginning (Roemmich et al., 2009; Freeland et al., 2010). This participation began in 2002 through the first European project where a total of 80 Argo profilers were deployed in the North Atlantic. Later, the IEO has led different special governmental actions through which Argo–Spain program is being financed. At this moment a total of 47 profilers has been deployed. Additionally, 10 profilers were acquired for three Spanish research groups as part of their observational strategy. Nowadays, the continuation of the Spanish participation in the Argo program is pending of official approval, once the interest of such participation was demonstrated in various European research infrastructures.

The Spanish participation has always been subject to scientific objectives, whether to support independent objectives approved under the R+D National Plan or as a means to achieve their own goals of Argo–Spain program. These objectives are the study

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of the mass transport variability and the changes in temperature and salinity in the North Atlantic (24.5° N) (Vélez-Belchí et al., 2010) or the the Meridional Overturning Circulation in the North Atlantic (Hernandez-Guerra et al., 2010).

8 Satellite SST images reception station

In July 1998 a satellite reception station was mounted at the IEO Santander Centre to receive SST images. This information is important in order to develop studies of ocean primary production, water quality and turbidity, identification of thermal fronts, eddies and upwelling events, seasonal behaviour of water masses, etc. Because of technical problems the station stopped working in 2007, but a new reception station has been mounted in 2010, and 10 daily SST images are now available. These data are digitally processed and converted in SST images.

The main scientific objectives are related to the identification of mesoscale features, as coastal marine ecosystems and continental margins represent the transition zone between the continents and ocean basins, and they play a crucial role in regulating the materials and energy exchanges between mainland and the deep ocean (Otero et al., 2009), being areas of intense biological productivity. In particular, these data has also been used in studies of the oceanographic conditions in the Prestige oil spill accident (Ruiz-Villarreal et al., 2006). Furthermore, assimilation of satellite data is an important tool for the validation of the hydrographical circulation models of the area and an important support tool (Garcia-Soto, 2004) in the designing and developing of the Spanish oceanographic surveys and research.

9 Hydrodynamical forecasting models

The IEO runs high resolution models in the N–NW Iberian Peninsula to give response to the oceanographic water conditions, upwelling system variability (Otero

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et al., 2008) and harmful algal bloom prediction, among others. The main task consists of providing insight on the coastal and ocean dynamics in support to the intense IEO ecosystem and fisheries research in the area. The Regional Ocean Model System (ROMS) outputs for temperature, salinity and currents layers are freely available through a THREDDS server <http://centolo.co.ieo.es:8080/thredds/catalog/ROMS-IEO/catalog.html> and a data viewer http://www.indicedeafloramiento.ieo.es/index1_en.php. Using ROMS data the following derived products are generated: thermal, haline and mix layer fronts, eddies, shellfishing areas and beaches temperature.

In the last years, a high resolution (~ 3 km) configuration of the ROMS physical model with atmospheric forcing which has shown to represent the main features of the shelf and slope circulation in the area, was run coupled to a biogeochemical model (N2PZD2). Any biogeochemical model aimed at providing a reliable representation of the dynamics of a certain area should be tuned according to its characteristics. In an upwelling system, the composition of phytoplankton varies from the beginning to the end of the bloom. The spring bloom is reasonably reproduced in the NW and N coasts in time, space and intensity (Garcia-Garcia et al., 2015). Some examples of the use of the IEO models to get some insight on sardine recruitment variability (Bode et al., 2006) and harmful algal bloom prediction. In the last case, the circulation models at Rias, and data from RV *Navaz* thermosalinometer and CTD monthly profiles from Radiales program at Ria de Vigo, enable an HABs alert bulleting <http://www.asimuth.eu/en-ie/HAB-Bulletin/Pages/default.aspx> that is used by fishermen and local aquaculture enterprises in order to manage their activities.

10 Conclusions

The Spanish Institute of Oceanography (IEO) maintains a large and coherent ocean observing system around the Iberian Peninsula, the Canary and the Balearic Islands. The Spanish Institute of Oceanography Observing System (IEOOS) provides quality controlled data and information about Spanish surrounding waters and compre-

hends several subsystems. Furthermore, all the information obtained from the IEOOS is actually providing valuable information to study the biological resources and their dependence on the physic-chemical variables (Alemany et al., 2010, e.g.), and also physical effects like deep and intermediate water masses formation (Somavilla et al., 2013; Vargas-Yáñez et al., 2012, e.g.) modification and transport (Lopez-Jurado et al., 2005, e.g.), and oscillations and trends in environmental variables (Prieto et al., 2015; Vargas-Yáñez et al., 2010) while models information is being successfully used in local fisheries.

The Marine Strategy Framework Directive (MSFD), whose main objective is the achievement of good environmental status of european seas is a planning of the marine environment action policy. The IEO is already conducting many of the required evaluations on the Spanish coasts. In fact, data collected in the framework of IEOOS structure has been the core of the initial assessment and a key for the identification of environmental objectives that follow up.

In the pursuit of giving visibility to the sampling network IEO data, as well as the activities of this group, a single web portal-style is currently being developed. It would help to strengthen their position and status in the national framework and international as well as responding to demands that we are proposing recently under proposals such as H2020 or MSFD.

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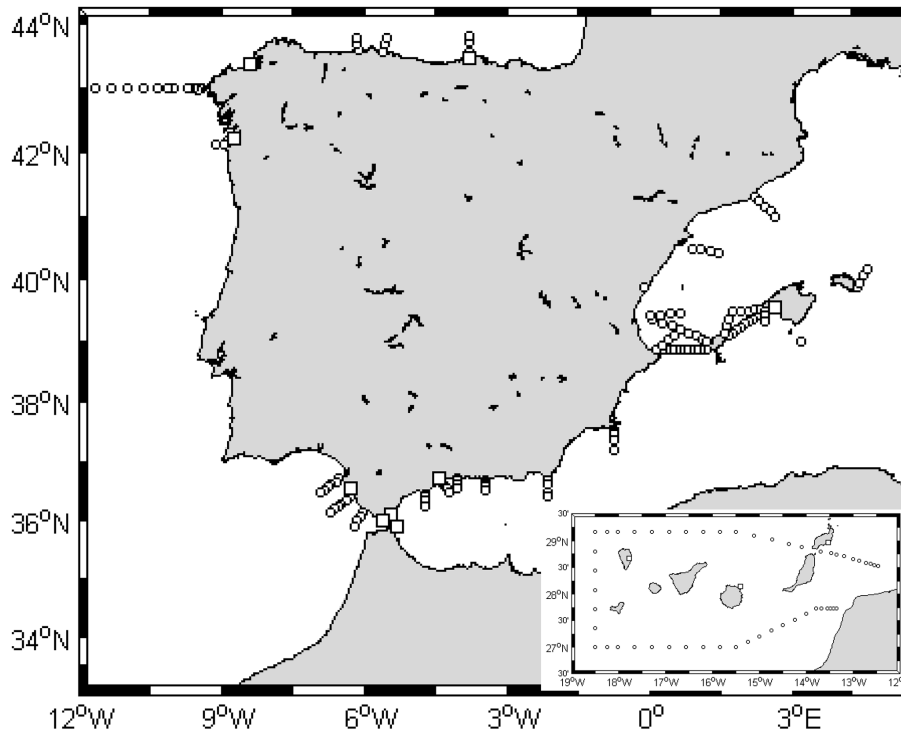


Figure 1. IEO tide-gauge network (squares) and oceanographic stations (dots) from the IEO Hydrographic Monitoring Sections.

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