The Impact of New Multi-platform Observing Systems in Science, Technology Development and Response to Society Needs; from Small to Large Scales...

Joaquín Tintoré[1,2], Benjamín Casas[2], Emma Heslop[2], Guillermo Vizoso[2], Ananda Pascual[2], Alejandro Orfila[2], Simón Ruiz[2], Lionel Renault[1], Melanie Juzà[1], Pau Balaguer[1], Lluís Gómez-Pujol[1], Amaya Álvarez-Ellacuria[1], Sonia Gómara[1], Kristian Sebastian[1], Sebastián Lora[1], Joan Pau Beltrán[1], David March[1], Romain Escudier[2], Miguel Martínez-Ledesma[2], Marc Torner[1], Simó Cusí[1], David Roque[1], Irene Lizarán[1], Carlos Castilla[1], Tomeu Cañellas[1], Aránzazu Lana[2], Daniel Conti[2], Juan Manuel Sayol[2], Evan Mason[2], Bàrbara Barceló-Llull[2], Francisco Alemany[3], Diego Álvarez-Berastegui[1], Patricia Reglero[3], Enric Massuti[3], Pedro Vélez-Belchí[4], Javier Ruiz[5], Temel Oguz[1], Marta Gómez[6], Enrique Álvarez[6], Luís Ansorena[7], and Mario Manriquez[7]

[1] SOCIB,
Palma de Mallorca, Spain
http://www.socib.es
[2] IMEDEA (CSIC-UIB),
Esporles, Spain
http://www.imedea.uib.es
[3] COB-IEO, Centro Oceanográfico de Baleares, Instituto Español de Oceanografía, Palma de Mallorca, Spain
[4] COC-IEO, Centro Oceanográfico de Canarias, Instituto Español de Oceanografía, Santa Cruz de Tenerife, Spain
[5] ICMAN, Instituto de Ciencias Marinas de Andalucía. CSIC, Cádiz, Spain
[6] Puertos del Estado, Madrid, Spain
[7] UTM, Unidad de Tecnologías Marinas, CSIC, Spain

Abstract. New monitoring technologies are key components of ocean observatories, also called marine research infrastructures being implemented in the worlds oceans. As a result, new capabilities to characterise, in quasi-real time, the ocean state and its variability at small scales exist

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today. The challenge is the integration of theses multiplatform observing and forecasting systems to (a) monitor the variability at small scales (e.g. mesoscale/weeks) in order to (b) resolve the sub-basin/seasonal and inter-annual variability and by this (c) establish the decadal variability, understand the associated biases and correct them. The challenge is also to change focus and now monitor from small to large scales. SOCIB is leading this new small to large-scale multi-platform approach in ocean observation. Some examples are presented and discussed together with initial ideas on the optimal design of an observational network in the world oceans, responding to science priorities, technology development and response to strategic society needs.

Keywords: new marine technologies, ocean observation, multi-platform systems, gliders.

1 Introduction

New monitoring technologies are being progressively implemented in the world oceans leading to major changes in our understanding of the variability of the oceans. The last decade (2000-2010) has seen the development of the sustained Argo program -http://www.argo.net- that contributed to the understanding of the large-scale open ocean variability and accordingly, much effort has been place on large-scale ocean studies.

Gliders (soon to become fleets of gliders) are an example of theses new technologies being progressively implemented in coastal to open ocean regions allowing repeated high resolution monitoring of specific areas showing the dynamical relevance of new features, such as for example sub-mesoscale eddies that are characterised by strong horizontal gradients and intense vertical motions. These eddies, that could not be routinely monitored before, can interact with the underlying mean flows, blocking the general circulation in key ocean regions; or they can give rise to enhanced upper ocean biogeochemical exchanges modifying the ecosystem response at a scale that was not previously observable on a routine basis. These are just two examples of the contribution of new technologies to address and better understand state of the art oceanic questions of worldwide relevance in a climate change context.

When different types of these new monitoring technologies are implemented and used together with more traditional platforms, we are then confronted with the new multi-platform integrated observing systems –also called ocean observatories or marine research infrastructures- that are being established in the world oceans, and in particular in key regions of the interface between the open-ocean and the coastal areas [5].

Theses new observing systems respond to a twofold change of paradigm in ocean observation [4]. The first one is that the observation of the oceans has evolved from being centred on a single platform, the oceanographic ships, to an observation today based on multi-platform and integrated systems that also rely on buoys, gliders, AUV's, HF radars, drifters, Argo profilers, satellites, etc.

In other words, we have evolved from a single-platform/ship-based observation to multi-platform integrated observing systems. The second paradigm change is related to the amount of data and data availability. Historically, just the teams directly involved in data collection had access to the cruises data and were involved in the analysis. Today, much data is quality controlled and available in quasi real time, and all scientists and society can directly have access to the data. This greatly enlarges the community and also offers the possibility to better respond to strategic society needs, developing tools for reliable and independent decision support and a new way of science based and sustainable oceans and coastal management.

These observing systems can in turn be integrated with powerful modelling and forecasting systems available today, giving rise to the new multiplatform observing and forecasting systems that can allow us to describe the three-dimensional oceanic structures and understand the underlying processes of multiple interacting spatial and temporal scales that characterise the variability of our oceans. Theses systems are already providing answers to state of the art scientific questions, enhancing technology development and increasing our capability for knowledge-based response to society needs.

2 Technical Description

SOCIB, the Balearic Islands Coastal Ocean Observing and Forecasting System, is one such ocean observatories, a new multiplatform observing and forecasting system, a facility of facilities extending from the nearshore to the open sea. SOCIB, as a part of the Large Scale Infrastructures Programme from the Spanish Ministry of Economy and Competitiveness, provides streams of oceanographic data and modelling services to support operational oceanography in a European and international framework, therefore also contributing to the needs of marine and coastal research in a global change context. In line with EuroGOOS, operational oceanography is here understood in a wide sense, including both the systematic long-term measurements of the seas and their interpretation and dissemination, and also the sustained supply of multidisciplinary data to cover the needs of a wide range of scientific research and societal priorities. This will allow a quantitative increase in our understanding of key questions on oceans and climate change, coastal ocean processes, ecosystem variability, sea level rise, etc. and will also drive us towards a more science based coastal and ocean management.

SOCIB benefits from the strategic position of the Balearic Islands, an Atlantic/Mediterranean transition area, one of the 'hot spots' of biodiversity in the world's oceans and also a region where mesoscale and submesoscale dynamics are of particular relevance (Internal Rossby Radius - Ri=10km). Thus physical mechanisms can be more easily monitored in this 'ocean basin', contributing to the advancement of knowledge of physical interactions and biogeochemical coupling at nearshore, local, sub-basin and global scales. The early studies established the relevance of mesoscale frontal instabilities and associated vertical motions [17,18] and the importance of synoptic sampling, using AXBT's or repeated synoptic samplings using ships, to fully understand eddy-mean flows interactions, as well as the impact on shelf/slope exchanges, among other related contributions (only a quick outline -obviously incomplete- of more than 100 peer reviewed publications is here provided for completeness to show the scientific evolution followed). [11] used satellite altimetry and showed the relation between mesoscale activity and the basin and sub-basin scale circulation. The implementation of new technologies such as gliders started in 2006. A first experiment combining one glider with satellite altimetry was carried out in Alborn Sea in 2008 [14,15] showing the benefits of multi-platform studies that were also further established by [12] and [1,2] . In this context, coastal ocean research and technology development in the Balearic Islands have significantly contributed to our understanding of different oceanographic and coastal erosion problems of worldwide interest over the last 20 years (see for example the IMEDEA/TMOOS 2010-2013 Strategic Plan at www.imedea.uib.es/tmoos).

SOCIB (in line with Nature ed., Vol. 450, Issue 7171, 6 Dec. 2007) was therefore the next logical step to 25 years of work in physical oceanography and the first proposal was submitted to the Spanish Large Scale Infrastructures Programme in 2006, later approved in 2008. SOCIB [19,20] is unique among the new observing and forecasting systems in that its mission and objectives are science, technology and society driven. Together with NANOOS -www.nanoos.org- it is one of the few examples that run from the coastline to the open ocean.

The SOCIB Design Phase spanned from 2009 to 2010 and was followed by the Construction Phase that formally ended in December 2012. Simultaneously, the Operational Phase commenced in 2012 when the different facilities have started to provide operational data and modelling services through the SOCIB THREDDS catalogue at www.socib.es.

Seven major Observing Facilities are now operational at SOCIB, from the open ocean waters to the Balearic beaches: a 12 MHz long range HF radar system in the Ibiza channel, coastal and open ocean gliders, coastal moorings and fixed stations, Argo profilers and surface drifters, a nearshore monitoring system of selected beaches and a new coastal catamaran (24 m LOA).

The Glider Facility is operational at SOCIB and run in conjunction and in kind support from IMEDEA (CSIC-UIB), following the research activities and associated glider developments at IMEDEA (CSIC-UIB) since 2005 [14,15] . SOCIB has improved the glider infrastructure providing new glider units, new electronics, ballasting and operations labs, as well as new deployment capabilities (Hurricane Zodiac 9.2 m RIB). The present SOCIB glider fleet consists of 5 Slocum gliders (3 in kind from IMEDEA) and 2 iRobot Seagliders. More than 25 glider missions have been performed, collecting ˜17.000 hydrographic and biogeochemical profiles. Gliders have specifically contributed to better understanding of mesoscale and sub-mesoscale process (1-20 km) in the upper ocean [12,16], including the coupling between the physical and bio-geochemical process of the marine ecosystem. In combination with remote sensing, high-resolution glider data have also improved coastal altimetry results [1,2] and path planning tools [7] and thermal lag correction tools have been also developed [8]. Since January 2011, glider operations have focused on the routine and sustained operational monitoring in the Ibiza Channel. [6] reported a new view of the temporal and spatial variability of the Atlantic and Mediterranean N/S exchanges through the channel. This Ibiza channel glider track will be maintained on a routine basis. Additional permanent glider sections will be progressively considered in the Balearic, Algerian and Sardinian sub-basins in strong collaboration with international partners. As an example, a first mission to Sardinia was carried out in early 2013 in the frame of the Trans National Agreement call from EC funded JERICO project (`http://www.jerico-fp7.eu/`).

The Modelling Facility is presently running an operational model for ocean currents (WMOP, nested to MONGOOS/MFS system), a wave operational system (established together with Puertos del Estado -`www.puertos.es`-) for the Southern coast of Mallorca and the Palma harbour entrance, as well as a pre-operational meteo-tsunami system [13] to support Balearic harbours authority (Ports de les Illes Balears) when strong sea level oscillations occur (for example at Ciutadella harbour in Menorca).

The Data Centre Facility is the core of SOCIB and is developing and implementing a general data management system to guarantee international standards of quality assurance and inter-operability. It is also performing specific developments and tools for the different facilities when required. Its main functions and capabilities range from data reception to its distribution and visualization (via web services and THREDDS/OPeNDAP protocols), passing through processing, quality control, documentation, standardization and archiving (NetCDF format and CF conventions), and data discovery (based on OGC protocols).

3 Key Scientific Challenges

The strategy for this implies selecting key control sections [6] in coastal/open ocean regions, major straits or channels (e.g. Denmark and Fram Straits, Drake passage [10] , Rapid Array and Rapid Watch -`http://www.noc.soton.ac.uk/rapidmoc/`- in the Atlantic at 26 °N [9, etc.] for routine monitoring of these control or choke points to establish ocean state and variability, evaluating for example the relevance of mesoscale activity, shelf/slope exchanges, etc.

The optimal design of an observational network in the world oceans is also a challenge that will need to combine the sound and relatively well established key ocean areas (the hot spots of ocean dynamics and ecosystem response), with existing and or relocatable systems. The new capabilities of Observing Systems Simulation Experiments (OSSE) will be most helpful in (1) establishing how well the different platforms contribute to characterize coastal ocean state and variability, (2) examining the interactions and impacts between coastal and open ocean and (3) studying the processes and factors that control the accuracy of the reconstruction of the oceanic state. The strategy would imply using OSSE to subsample the oceanic fields in order to quantify the errors in the reconstruction of the ocean state and the ocean variability.

4 Responding to Society Needs

It is also important to mention the impact of theses new multi-platform systems or marine infrastructures on society driven objectives. An excellent review of the science and society challenges in the US in 2030 can be found in Committee on an Ocean Infrastructure Strategy for U.S. Ocean Research in 2030 (2011) [3] and in Europe, in the recent report from the Marine Infrastructures Working Group [5] . An example of this society driver is the monitoring needed by the implementation of the Marine Strategy Framework Directive (MSFD), the marine pillar of the Integrated Maritime Policy in Europe. One of the aims of IMP is to offer a more coherent approach to maritime and marine affairs and an improved coordination between relevant actors and sectors, by this contributing to establish the potential of the seas and oceans for growth and jobs. More specifically, the implementation of the MSFD requires (1) an Initial Assessment of the present status (carried out in 2012) to guarantee the achievement of (2) Good Environmental Status by means of specific actions that include (3) Monitoring Programs (to be implemented in 2014) and detailed (4) Programs of management measures (2014). Multi-platform systems, by integrating different types of monitoring platforms at different scales, and by this, providing data and tools, contribute to MSFD pressures and states indicators.

Finally, the development of tools for routine analysis of the results from these new multiplatform observing and forecasting systems is also a real challenge. The impact of these new systems cannot be overlooked and it is important we face and prepare the forthcoming generations and ourselves.

These types of new marine infrastructures are presently establishing new ways of international cooperation that will lead to major science breakthroughs, innovations in oceanographic instrumentation and new ways of science based coastal and ocean management.

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