Strategy for an Integrated Ocean Observing System in the Mediterranean and Black Seas

Aim: To present a concise and actionable strategy for an **Integrated Mediterranean and Black Seas Ocean Observing System** (an IMBOOS). The strategy synthesises the ideas and discussions from the "Kostas Nittis Scientific and Strategic Workshop on a coordinated European observing systems strategy'' held in Athens in May 2015 to honour this forward thinking ocean scientist. The strategy builds on previous work, existing challenges and a 2030 vision of ocean observation. It constitutes a call to action for the community to take the decisions. Here we define the guiding principals, 4 key components and initial steps for a strategy to bring the vision of an **IMBOOS** into operation.

At the cusp of a paradigm change in ocean observation:

The last 20 years of ocean research have allowed a description of the state of the global ocean circulation directly related to the development of two successful international initiatives that lead to new remote and in situ observing systems; the satellite missions (altimetry, SST, Ocean Colour, etc.) and the Argo in situ programme. In other words, we have concentrated on establishing the ocean circulation at large scales and from this, we have tried to downscale towards regional and/or local scales. However, the ocean varies at a wide range of spatial and temporal scales and it is now key to understand this variability in relation to climate change and anthropogenic pressures. We need to reinforce our capacity to understand critical challenges in the changing relationship between man and sea. Increasing evidence points to this interlink of scales as crucial for the diagnosis and prognosis of ecosystem services provided by the sea, as well as its modification by climate change, habitat destruction or biodiversity loss. Our potential to implement knowledge-based management in the face of these environmental challenges will be based on our capacity to monitor the temporal and spatial variability that characterise global to regional ocean variability and coastal to open ocean exchanges, the mesoscale to sub-mesoscale. What is important is to realize that this is now feasible due to the advent of new technologies and the associated crucial paradigm change in multi-platform observation (remote and in situ).

The strategy presented here has been developed following the discussions at the Kostas Nittis Scientific and Strategic Workshop, held in Athens, 27/28th May 2015, and on experience gained within the PERSEUS project (2012-2015). The need for Integrated Ocean Observing Systems (IOOS) in Europe has been around for more than 10 years now, in line with international initiatives such as IMOS in Australia and/or IOOS in USA, among others. Science based observing and forecasting initiatives at regional, national as well as international level have been progressively implemented during this time and constitute a network of research-based ocean observing structures in Europe, operating with a diversity of funding. The Ocean Obs'09 conference proposed a framework for an enhanced global sustained Ocean Observing System (OOS) to better address societal needs, through integrating new physical and biogeochemical observations, taking into account regional variations, sustaining present observations, and considering how to best take advantage of existing structures. The EurOCEAN 2010 conference and the Ostend Declaration called for a coherent European Ocean Observing System and

the concept for a European Ocean Observing System (EOOS) was presented in 2013 by the European Marine Board (EMB) in line with the needs identified also in 2013 by the Marine Research Infrastructures (MRI) EU Experts Group. More recently the EurOCEAN 2014 Rome Declaration, also explicitly addressed the need for a pan-European Ocean Observing Strategy. However, the complexity of the endeavour is high, as was recently shown in the joint EMB-EuroGOOS EOOS workshop hold in Brussels in May 2015.

The Mediterranean area has a particular response to global processes given its semi-enclosed nature. At the same time, the Mediterranean Sea has important contributions to the global climate system, through for example atmospheric teleconnections, such as the proposed connections between the Mediterranean and the monsoon regimes, and also to the North Atlantic deep convection processes and the Atlantic Meridional Overturning Circulation (AMOC) variability through the Gibraltar outflow. The Mediterranean has often been referred as a reduced-scale ocean because within this region there are many oceanographic features relevant to global ocean science, climate change research and to sustainable development of ocean resources. This implies that Mediterranean oceanographers have the opportunity to observe, model and lead the way in many areas of ocean science that are of global importance to climate change research, to sustainable development of ocean resources and to other issues of more immediate societal need.

The following list highlights just a few such areas, where Mediterranean based research paves the way for oceanography of global relevance:

- Water mass formation - impact on thermohaline circulation at basin and sub-basin scale.
- Mesoscale to submesoscale variability - processes, relevance to vertical and lateral mixing, effects on 3D circulation and modelling.
- Coupled physical-biological process - in particular gradients in oligotrophic and ultra-oligotrophic systems.
- Shelf/open ocean interactions – still poorly characterised and modelled globally, yet vital to ecosystems, the health of a high percentage of ocean productivity, and coastal ocean science based management.
- Integrated ocean observing systems – integrated, multi-platform systems, observing the ocean at multiple scales and delivering quality controlled data to science and society.
- Operational oceanography – ocean forecasting, real time ocean measurements and integration with models, including ecosystem modelling.
- New technologies – ocean gliders, bio-Argo profilers, and adaptive sampling systems.

In summary, the Mediterranean and Black Seas are important marginal seas with well-known scientific and societal specificities that demand a strategy for a sustainable IOOS. The density of population around the Mediterranean and Black Seas transfers significant pressures to the marine environment, added to which are the potential environment impact of new oil and gas production in the Eastern Mediterranean and other human induced change, such as the enlargement of the Suez Canal. The regional importance of the SES ocean observation should not be underestimated, and has relevance for policy now and for the future, where climate change may significantly impact the lives of the millions living in and around the Mediterranean region and more broadly the bordering countries GDP (Gross Domestic Product). Climate change will be felt in the ocean and predicting its impact will be

vital for the regions food supply, disaster services, and ultimately perhaps security, across the world sharpest socioeconomic gradient.

We are now at a cusp of an essential paradigm change in ocean observation that make an Integrated Ocean Observing System (IOOS) in the Mediterranean and Black Seas not only vital, but also possible. In these marginal seas the pressure of climate change and the sensitivity of the environment requires knowledge based sustainability for society and human well-being, and makes an IOOS for the Southern European Seas (SES) increasingly essential. Also important and key for the success of such an initiative is the human capital, and over the last 20 years the SES oceanographers have lead international projects and can be considered amongst the world leaders of this new oceanography, based on new multi-platform observing and forecasting systems with real time data access for science and society.

Guiding principles:

A number of well-defined principles for an Integrated Mediterranean and Black Sea Ocean Observing System in the (IMBOOS) were part of the discussions during the Kostas Nittis Scientific and Strategic Workshop, especially surrounding the issues of multiplatform monitoring, technology development, physical and biogeochemical data and coupling, sustainability, data availability, and support for the next generation of ocean scientists. The principles, as outlined below, will guide the development, decision-making, and interaction with partners, users and other collaborating institutions, of an IMBOOS.

- **Science, technology and society driven objectives**
- **Partnership between institutions**, following the demonstrated leadership and well-coordinated and efficient teamwork, as developed under EU funding for more than 20 years. Working together to be greater than the sum of the parts.
- **Integrated, coordinated multiplatform, multidisciplinary and sustained monitoring**, across core key variables and core key questions
- **Free, open and quality controlled data**, available in near real time (nRT) and delayed mode (DM) and in adherence to scientific community standards
- **Support for technology development activities** with emphasis in areas such as biology, where this is critically needed globally
- **Scientific and technological excellence** through peer review and international awareness
- **Support for the next generation of ocean scientists**
- **Importance of sound governance across the region**, in particular through the participation of Eastern Mediterranean and North African countries.

Vision 2030:

A system of observing and forecasting systems in the Mediterranean and Black Seas, providing key ocean variables from days to decades and from the coast to the open sea, in response to science and society needs, contributing to citizens quality of life and welfare, supporting sustainable use of our common ocean resource and contributing to the challenges posed by climate change.

Four Key Components for building an IMBOOS:

Below are four key components of a strategy for building an IMBOOS. These are based on issues discussed at the Workshop and also reflect experience within PERSEUS of multi-platform observing and forecasting systems in the SES.

1. Observing for science and society with state-of-the-art technology.

The IMBOOS should address the specific scientific questions and society issues inherent to the Mediterranean and Black Seas and should promote marine technological development in order to collect observations in the most effective and integrated way.

The key scientific questions of paramount importance in the Mediterranean and Black Seas have been reviewed in previous documents and noted during the Strategic Workshop. They include the processes of dense water formation and their dynamical effect over the entire basin; the mesoscale/submesoscale variability and turbulence mixing, and its consequences on biogeochemical cycles and biological dynamics; the fluxes across transects and hot spots (including Gibraltar and the Bosphorus-Dardanelles System); fluxes across the air-sea interface, especially in extreme forcing conditions and to detect trends at different scales; the interaction between the coastal and open sea dynamics; the impact of global climate change; the link between physical and biological processes; the impact of ocean variability on key resources such as fish stocks or threats such as jellyfish swarms and/or invasive species; and the impact of river discharges.

The IMBOOS must also provide data and science background to support decision making in the following society issue areas, environmental protection and stewardship for future generation: Climatic and human pressures on biodiversity, pollution (contaminants, oil spill, litter, ambient noise), sustainable coastal development and tourism, sustainable food and energy resources, fishing and aquaculture, marine protected areas, shipping routes, maritime emergency and security.

2. Based on existing infrastructure.

As indicated in key background documents and echoed many times during the Kostas Nittis Scientific and Strategic Workshop, the IMBOOS should be based on existing infrastructure. It should be a system of systems. The logical way to do this, as rooted in suggestions made at the Workshop and in the practical experience of the attendees, would be to take the existing ocean observatory and operational oceanography infrastructures (multi-platform and integrated real time observing and forecasting systems) as an initial base for such a system, i.e. MOOSE, PORTUS, RITMARE, SOCIB, SIO RAS OOS, NOMOS, CYCOFOS, IOLR and POSEIDON. This would provide the base from which to upgrade and expand full coverage, including not only new institutions but also new actors. The existing OOs are a vital component, however regional scientific institutes, through local agreements, also need to be considered part of a realistic IMBOOS for the following reasons; scientific guidance on regional adaptation of core strategy, cross-fertilization of expertise, science users for observations, and quality assurance/quality control (QA/QC) of datasets. In addition, environmental actors (Search and Rescue Operators, MSFD implementation agencies, private sector, such as oil companies, etc.) beyond scientific institutions could be incorporated through a co-design process, where the routine monitoring/surveillance programs of these actors can act as platforms for research at no additional

cost. This has the additional benefit that the scientific results would be immediate and relevant to apply through these institutions.

3. Fill gaps and needs.

Based on the clear scientific and societal drivers of the observing strategy (component 1), gaps and needs within the existing base should be progressively addressed under the core strategy and core variables, with regional, science led adaptation. Both immediately, to respond to the pressing needs outlined in the workshop, and into the future. Gaps highlighted in the workshop include, increasing temporal coverage, geographical coverage in the eastern and southern Mediterranean as well as in the Black Sea, biogeochemical and biological/ecosystem observations, air-sea fluxes (including atmospheric deposition), and coastal observations, which currently lack coordination, harmonisation and sustainability.

With a view to addressing these identified gaps and needs the following key coordinated IMBOOS developments are proposed, including new ideas put forward during the workshop:

- **Greater regional coverage:** more OOS will be required to fill gaps in observations, most significantly in the coastal eastern Mediterranean, the Black Sea and North African coast.
- **Key straits, channels and bio-domain boundaries:** should be monitored with different platforms (ships, gliders, moorings, etc.), including transects extending towards the North African coast, immediately for physical variables, with evolution to biogeochemical.
- **Review multi-parametric moorings:** upgrade new sensors, support new variable analysis/QC
- **Recruit and harmonise coastal network:** invest/support HF radar, SL gauges, cabled structures, ferry box, and VMS.
- **Develop biological strategy:** long term core monitoring, strategic process/ecosystem studies, and including funding new technological development in sensors or platforms
- **Air-sea fluxes:** should measured at key locations

4. Provide central coordination and sustainability.

A central coordinating function is required to set and agree the overarching issues that will make this a functioning IMBOOS, capable of delivering consistent data services to science society and technological users. This would include setting the common observing system strategy and core variables, coordinating QC and observational best practice, supporting the sharing of know-how and non-duplication of effort, and the implementation of an open and free data policy. The issue of QC came up many times during the Workshop and is clearly a key area for coordination across observatories and institutions, in a Europe that expects high quality ocean data to be available in nRT. Central funding could also be distributed to support upgrades, technological development and process studies.

A second coordinating role is for external relationships. IMBOOS will pay close attention to aligning its strategies and implementation plans with those from other European entities associated with marine observations and data; entities that are part of the delivery chain from observations to users, such as CMEMS (Copernicus Marine Environmental Monitoring System), key OO groups such as EMODnet and MonGOOS, entities that could form part of the observational infrastructure, such as Euro-Argo, and

those that could supply knowledge, such as JERICO for coastal ocean observing. The final key role for a central coordinating function is to give visibility and voice at EU level to issues of relevance to the Mediterranean and Black Sea community, to provide a united strength against the closure of individual observing facilities and to oversee the evolution of the observing system to meet future and evolving needs.

Recommendations and first steps for implementing an IMBOOS:

In the short term we need to catalyse on the existing infrastructure of observing and forecasting systems in the Mediterranean and Black Seas and improve their coordination based on strong partnership, real multidisciplinary integration that responds to science, technology and societal drivers, with open and interoperable data principles, and involving key international organisations and sound governance. Several OOS are already operational, at least partially, across the SES. Under the proposed IMBOOS strategy, consensus would be developed between these systems and a structure, and funding mechanism, developed for the central coordination and sustainability. The gaps and needs in the system, as outlined in this document, would then be progressively addressed under the IMBOOS strategy. In particular, the under sampling of the north African coast is an issue that requires specific coordinated (political) action and vigorous capacity building, in tandem with continued effort at a regional level through local contacts.

An IMBOOS would form part of the 3 core components/infrastructures that deliver ocean products to European and global ocean data users; the satellite remote sensing infrastructure, the in-situ ocean observing infrastructure and the forecasting/analysis products and services (CMEMS) infrastructure. This implies strategic coordination with other regional in-situ ocean observing systems, as well as with the operational modelling and satellite communities. Deeper connection with the numerical modelling community, through a two-way dialogue, will provide tools for the optimization of the observing strategy which will result in better forecasting products. Similar interaction should also be followed with the satellite remote sensing community in order to improve satellite calibration and products.

Over the long term we should create a system of systems, where each region is responsive to local needs, whilst harnessing the power of a common strategy and vision to improve scientific knowledge and environmental status across the basin, overcoming threats, supporting opportunities, identifying trends and delivering sustainability, at the SES level.

The challenge of achieving an IMBOOS across the Mediterranean and Black Seas region should not be underestimated, however the rewards, in terms of efficiency, consistency and data availability, to support great science and societal needs, are significant. Developing a functioning and consistently delivering IMBOOS is a ‘big science’ project.

The strategy presented here has been developed from the discussions at the Kostas Nittis Scientific and Strategic Workshop and from experience gained within the PERSEUS project. The coordinating authors are: Tintoré, J. Perivoliotis, L. Heslop, E.E., Poulain, P-M., Crise, A. and Mortier, L., and the full list of workshop attendees can be found at http://workshop.hcmr.gr/kostas-nittis/participants