Review of existing and operable observing systems and sensors

Deliverable D1.4
of the COMMON SENSE project

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Acronym: COMMON SENSE
Title: COST-EFFECTIVE SENSORS, INTEROPERABLE WITH INTERNATIONAL EXISTING OCEAN OBSERVING SYSTEMS, TO MEET EU POLICIES REQUIREMENTS
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Deliverable 1.4

Review of existing and operable observing systems and sensors

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RE Restricted to a group specified by the consortium (including the Commission Services)	
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COMMON SENSE
MARINE SENSORS - MARINE MONITORING

Authors:	Jordi Salat[1], Raquel Casas Muñoz[1], Joaquim Ballabrera Poy[1], Emilio Garcia-Ladona[1], Jordi Sorribas[1], Fabio Antognarelli[2], Andrea Satta[2], Alberto Ribotti[2], Maurizio Avella[2], Roberto Avolio[2], Gennaro Gentile[2], Mireno Borghini[2], Katrin Schroeder[2], John Cleary[3], Marcin Wichorowski[4], John Barton[5], Saskia Heckmann[6], Paolo Magni[2] [1]CSIC, [2]CNR, [3]DCU, [4] IOPAN, [5]UCC, [6]SubCtech
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EXECUTIVE SUMMARY AND STRUCTURE OF THE DELIVERABLE

Deliverable 1.4 is aimed at identification of existing and operable observing systems and sensors which are relevant to COMMON SENSE objectives. Report aggregates information on existing observing initiatives, programmes, systems, platforms and sensors.
The Report includes:

- inventory of previous and current EU funded projects. Some of the them, even if started before 2007, were aimed at activities which are relevant or in line with those stemming from MSFD in 2008. The ‘granulation’ of the contents and objectives of the projects varies from sensors development through observation methodologies to monitoring strategies,
- inventory of research infrastructure in Europe. It starts from an attempt to define of Marine Research Infrastructure, as there is not a single definition of Research Infrastructure (RI) or of Marine Research Infrastructure (MRI), and there are different ways to categorise them. The chapter gives the categorization of the MRI, together with detailed description and examples of MRI – research platforms, marine data systems, research sites and laboratories with respect of four MSFD descriptors relevant to COMMON SENSE project,
- two chapters on Research Programs and Infrastructure Networks; the pan-European initiatives aimed at cooperation and efficient use of infrastructural resources for marine observation and monitoring and data exchange are analysed. The detailed description of observing sensors and system are presented as well as frameworks for cooperation,
- information on platforms (research vessels) available to the Project for testing developed sensors and systems. Platforms are available and operating in all three regions of interest to the project (Mediterranean, North Sea, Baltic),
- annexed detailed description of two world-wide observation networks and systems. These systems are excellent examples of added value offered by integrated systems of ocean observation (from data to knowledge) and how they work in practice.

Report concludes that it is seen a shortage of new classes of sensors to fulfil the emerging monitoring needs. Sensors proposed to be developed by COMMON SENSE project shall answer to the needs stemmed from introduction of MSFD and GES descriptors.

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COMMON SENSE
MARINE SENSORS - MARINE MONITORING

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1 INTRODUCTION

Observation of the marine environment is driven either by curiosity (science and research) or as a result of societal awareness of the need of clean environment (marine monitoring and assessments programs). For a long time those two areas were considered to be separate. However, emerging problems as climate change, growing level of pollution together with growing economic interests in coastal marine areas and resources shifted the public and stakeholders attention towards the marine and maritime issues. In this changing perspective existing monitoring methods and observation systems seems not fully capable to assess and control state of marine environment. Moreover, most of the monitoring system lagged behind the science in terms state of the art and a quality of infrastructure, organization, funding and methodological rigor. To address this problem, introduced EU and national regulations push for convergence of the scientific and monitoring observations as the way to improve monitoring quality and also to guarantee the re-use of data (research vs monitoring) which will leads to efficient use of resources. As a results, the number of current pan-European programs and projects are focused for development of the observation systems, platforms and sensors which will serve equally for both research and monitoring purposes.

The following review aims at giving the overview of the current landscape of marine European programmes, projects (both EU and nationally funded) observing systems, platforms and sensors. The review is performed from the perspective of COMMON SENSE (CS) project objectives, hence the focus on initiatives relevant to four MSFD Descriptors tackled by the Project: Eutrophication, Contaminants and Pollution, Marine Litter and Underwater Noise. Within each of category the special attention is given to sensors and measuring and observational methodologies (already deployed or under development) which might be of interest to CS sensor development plan.

The review consists of following parts:

- inventory of previous and current EU funded projects,
- broad definition and categorization criteria of Marine Research Infrastructure,
- Research Programs and Infrastructure Networks,
- description of research platforms available to the Project.

Annexes to the report give thorough description of two world-wide monitoring and observation systems: ARGO and Global Tropical Moored Buoy Array. Description starts from sensors design/specification up and along the data and information processing chain, Web-based user interface included. Both systems are the model examples of the modern operational systems, fully capable to deliver top-quality data and information about the marine environment which can be later employed for the variety of purposes – for monitoring, basic research, studies of process, numerical modelling.

Gathered information gives overview of state-of-the-art in sensors and systems domain, helping in identification of gaps in existing systems and also providing partial input for D.1.3 in subject of interoperability and integration of sensor's functionality to meet MSFD monitoring requirements.

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2 INVENTORY OF PREVIOUS AND CURRENT EU FUNDED PROJECTS AND INITIATIVES

Recent and current EU Projects relevant to GES descriptors were extracted through EurOcean Knowledge Gate 2.0. [EKG] http://www.kg.eurocean.org/

Past projects results were extracted through their Web Pages.

For a comprehensive overview of research projects many of which are relevant to COMMON SENSE objectives see the EC Report "The Ocean of Tomorrow Projects (2010-2013). Joint Research Forces to Meet Challenges in Ocean management", [OTP].

2.1 *Before 2007 (Pre- FP7)*

2.1.1 *BIOMARE*

http://www.biomareweb.org/
Implementation and networking of large-scale long-term marine biodiversity research in Europe.
FP5 Energy & Environment
Concerted Action
2000-2002

A concerted action (CA) at European scale was proposed to establish the infrastructure and conditions required for marine biodiversity research. The objectives were implemented through 3 work packages, consisting of a series of evaluations, recommendations, regional meetings and joint workshops. The purpose of the CA was to lead to 1) the selection and implementation of a network of Reference Sites as the basis for long-term and large-scale marine biodiversity research in Europe, 2) internationally agreed standardised and normalised measures and indicators for (the degree of) biodiversity and 3) facilities, such as a data-base, a web-site, and workshops, for further dissemination and integration of data by students, researchers, and administrators dealing with socio-economic questions, and improvement of the awareness of the public on marine biodiversity issues.

2.1.2 *MFSTEP*

mfstep.bo.ingv.it
Mediterranean Forecasting System Towards Environmental Prediction
FP6 Environment
Integrated Project
2003-2006

In the period 1998–2003, two Integrated Projects were funded by the EU with the IV & V Framework Programmes, Energy, Environment and Sustainable Development, the MFSPP (Mediterranean Forecasting System Pilot Project; contract n. MAS3-CT98–0171) and MFSTEP (Mediterranean Forecasting System Towards Environmental Prediction; contract n. EVK3-CT-2002-00075). The objectives of both were the development of a sustainable pan-European system including the prediction of biogeochemical and ecosystem parameters for some European regional seas including the Mediterranean.

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In particular the MFSTEP project aimed at the further development of an operational forecasting system for the Mediterranean Sea based upon three main components: a) the Near Real Time (NRT) Observing system; b) the numerical forecasting systems at basin scale and for regional areas; c) the forecast products dissemination/exploitation system. The problems to be solved belonged to three major categories:

1) technology developments, connected to the new instrumentation for NRT monitoring and the provision of NRT protocols for data dissemination, comprehensive of telecommunication technology and quality control procedures;

2) scientific development, connected to the understanding of the sampling scheme for different measuring platforms, the design and implementation of data assimilation schemes for different spatial scales, the ecosystem modelling validation/calibration experiments at the basin and the coastal areas scale and the development of data assimilation techniques for biochemical data;

3) exploitation developments, consisting of software interfaces between forecast products and oil spill modelling, general contaminant dispersion models, relocatable emergency systems, search and rescue models, and fish stock observing systems. In addition, the study of forecast economic value and impact will be carried out.

The MFSTEP project was followed by the EU project MERSEA whose description is below.

2.1.3 *MERSEA*

no website
Marine Environment and Security for the European Area
FP6 SPACE
Integrated Project
2004-2008

The strategic objective of MERSEA was to provide an integrated service of global and regional ocean monitoring and forecasting to intermediate users and policy makers in support of safe and efficient offshore activities, environmental management, security, and sustainable use of marine resources. The developed system is a key component of the Ocean and Marine services element of GMES (Global Monitoring for Environment and Security). GMES is a joint initiative of the European Commission and the European Space Agency, designed to establish a European capacity for the provision and use of operational information for Global Monitoring of Environment and Security. In order to support the development of the Ocean and Marine Applications component of GMES, the EC is funding the MERSEA integrated project. The system is based on the assimilation of remote sensing (altimetry, sea surface temperature, sea ice) and in situ observations (ARGO and XBT profiles) into high resolution ocean models. The project included research and development activities on data products, ocean modelling, assimilation, nesting and downscaling, ecosystems, and seasonal forecasting. The project federated the European contribution to the GODAE. It intended to contribute to the development of integrated core ocean services in Europe. The system design includes a global, as well as four regional components (Nordic, Baltic / North Sea, North East Atlantic, and Mediterranean seas) which provide ocean analyses and forecasts in real time through assimilation of in situ and satellite data. The essential variables are the temperature, salinity and velocity fields, but research efforts are underway to include bio-geochemical and ecosystem variables. The input data and forcing fields are provided by dedicated Centres. The whole system is linked through an Information Management System. The overarching objective was to provide an integrated service of global and regional ocean monitoring and forecasting to intermediate users and

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policy makers in support of safe and efficient offshore activities, environmental management, security, and sustainable use of marine resources. Some forty agencies, laboratories and institutions participated in the research and development effort of this project. The project was oriented towards applications, and the delivery of products and services in support of marine safety and offshore industry, marine meteorology, wave forecasts and ship routing, oil drift fate prediction, seasonal forecasting, research, and reporting to public bodies. The system was also intended to deliver boundary conditions and data to coastal operational systems.

2.1.4 *ECOOP*

www.ecoop.eu
European COastal-shelf sea OPerational observing and forecasting system
FP6 SUST-DEV, Priority - 6.3 - Global Change and Ecosystems (contract 036355-2).
Integrated Project
2007-2010

The overall goal of ECOOP was to: consolidate, integrate and further develop existing European coastal and regional seas operational observing and forecasting systems into an integrated pan-European system targeted at detecting environmental and climate changes, predicting their evolution, producing timely and quality assured forecasts, providing marine information services (including data, information products, knowledge and scientific advices) and facilitate decision support needs.
This has been attained through the following activities:

- Integrating existing coastal and regional sea observing (remote sensing, in situ) networks into a pan-European observing system;
- Integrating existing coastal and regional sea forecasting systems into a pan-European forecasting system and assimilate pan-European observation database into the system; Assessing the quality of the pan-European observing and forecasting system;
- Advancing key technologies for the current and next generation pan-European observing and forecasting system;
- Developing and generating value-added products for detecting environment and climate change signals;
- Integrating and implementing a pan-European Marine Information System of Systems (EuroMISS) for general end user needs;
- Developing methodology and demonstrating an European Decision Support System for coastal and regional seas (EuroDeSS) that responds to the needs from targeted end users, as emphasized in the GEOSS and GMES initiatives;
- Carrying out technology transfer both in Europe and at intercontinental level, establish education and training capacities to meet the need for ocean forecasters.

ECOOP has achieved its goals by implementing an integration of observations and modelling into a pan-European marine information system of systems (EuroMISS) and design of a European decision support system (EuroDESS) for coastal and regional seas.

The work continued in the following years through the EU funded projects MyOcean and MyOcean2 (see below).

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2.2 2007-2014 (FP7 Completed)

2.2.1 PROTOOL

http://www.protool-project.eu
Productivity tools: Automated tools to measure primary productivity in European seas.
FP7 ENVIRONMENT – Environment (including Climate change)
FP7 - Small or Medium-Scale Focused Research Project
2009 – 2012

PROTOOL stands for PROductivity TOOLs: Automated Tools to Measure Primary Productivity in European Seas. The project will develop and adapt sensor technologies to measure primary production of phytoplankton with automated optical techniques, so that they can be placed on ships of opportunity (SOOP, ferries, container ships). The complete PROTOOL Measuring Device will consist of (1) a fluorometer measuring the rate of photosynthesis (using the variable fluorescence approach), (2) an algal absorption meter and (3) a hyperspectral reflectance unit. PROTOOL partners will further promote the inclusion of primary production within the list of important biological properties to be considered for ecological status assessment in the future in the context of the Water Framework Directive (WFD) and the Marine Strategy Framework Directorate (MSFD).

PROTOOL results: Three new types of sensors were developed, tested and are ready to be commercialized:

- FFL-40 automated fluorometer to measure photosynthetic activity.

Tool for assessing phytoplankton physiological status and measurements of primary production. Impact: the PRotool approach is implemented in being evaluated as a tool for primary production monitoring in the Scheldt estuary monitoring program of the Ministry of Infrastructure and Environment (RWS). NIOZ will introduce the PROTOOL approach in a trial on the North Sea for RWS. A grant proposal has been submitted to install the PROTOOL modules on two ships: one crossing the North Sea (Hoek van Holland, NL to Harwich, UK) and St Petersburg to Bilbao (in cooperation with the Finnish Environment Institute). Algorithms to predict the electron requirement for C-fixation (= calibration of C-fixation of the PROTOOL fluorometer) were also developed.

- OSCAR - in-line absorption meter to measure absorption of water constituents.

Tool to measure a number of water quality parameters (CDOM, chlorophyll, SPM, inherent optical absorption coefficients useful for modelling of ocean colour and thus for remote sensing applications). This is the first operational instrument that measures light absorption directly, not being affected by scattering errors.

- Reflectance module - Hardware and software to measure reflectance.

Tool for continuous registration of chlorophyll, light attenuation. Can be used to validate earth observation

…ceived funding from the European Union's Seventh Framework
…013-2) under the grant agreement no 614155.

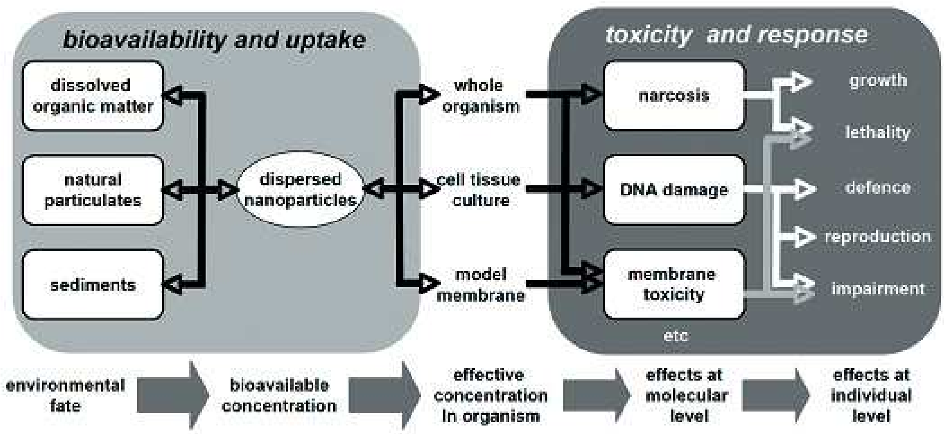
algorithms. Knowledge Output Impact: the Finnish Environment Institute (SYKE) has implemented the Reflectance module on a ship of opportunity. Trials organized by NIOZ in cooperation with RWS to see if it is a useful tool in the standard monitoring which takes place in the framework of the MFSD.

2.2.2 *ENNSATOX*

http://www.ennsatox.eu
Engineered nanoparticle impact on aquatic environments: Structure, activity and toxicology
FP7 NMP – Nano-sciences, nano-technologies, Materials and new Production Technologies
FP7 - Small or Medium-Scale Focused Research Project
2009 – 2012

ENNSATOX performed comprehensive investigations relating the structure and functionality of well characterized engineered nanoparticles to their biological activity in environmental aquatic systems. Through an integrated approach, the activity of the particles in a series of biological models of increasing complexity were assessed. Parallel environmental studies were performed on the behaviour of the nanoparticles in natural waters and how they modify the particles' chemical reactivity, physical form and biological activity.

The results:



An integrated theoretical model was developed describing the environmental system as a series of biological compartments where particles transport between a) compartments by advection-diffusion and b) between phases by a transfer function. Following optimization of the transfer functions a generic predictive model is derived for the environmental impact of each class of nanoparticle in aqueous systems. The results are described in detail in a series of publications, see project Web Page.

2.2.3 *ALARMTOX*

http://alarmtox.net/
Assays and biosensors for the detection of biotoxins from aquatic media
Interreg IV
South West Europe (SUDOE)
2009 – 2011

The aim of the project was to investigate, develop and validate biosensors for the detection of biotoxins from aquatic media, in order to ensure the quality of inland waters and shellfish producing

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areas. The project also aimed at disseminating the results to organizations and agencies involved in the management of water resources.

The results

Enzymes (protein phosphatases) sensitive to water biotoxins were produced, thereby constituting the first step in the development of assays and biosensors. Afterwards, assays and biosensors were designed and developed using the protein phosphatases previously produced. Finally, water, bivalves and microalgae samples have been collected and analysed with the assays and biosensors. Samples were analysed with spectrometric techniques in order to validate the colorimetric assays and electrochemical biosensors. This project has increased the existing knowledge in the SUDOE area on the presence of aquatic toxins (okadaic acid and derivatives, and microcystins) and helped to improve the protocols of action in situations of toxic microalgae blooms. Results have been disseminated to the scientific community, the shellfish producers and the administration. Network activities with experts on marine toxins and biosensors, including bionanotechnological aspects, have been created and consolidated.

Knowledge output done through scientific publications and technical manuals, [ALA12] [GDE12], [GDM12]

2.2.4 *OPTOCO2FISH*

http://www.optoco2fish.eu/
Development of an Opto-chemical Carbon Dioxide Sensor for Aquaculture and Oceanography Applications
FP7 SME – Research for the benefit of SMEs
FP7 - Research for SMEs
2009 – 2011

The objective of the project OptoCO2Fish was to develop a CO_2 sensor to meet these demands. A novel solid state opto-chemical CO_2 sensor system is based on the principle of Resonance Energy Transfer. This principle offers the opportunity to generate a compact and cost effective sensor system and furthermore is able to meet the essential requirements of fish farming staff, which is high accuracy and stability combined with low maintenance and low re-calibration effort. Secondary objective was to enhance the competitiveness of European companies, strengthen the position of aquaculture in Europe against the worldwide competition and can contribute a reliable sensor system for the research on effects of global warming due to CO_2 emission.

The results:

The Opto-chemical Carbon Dioxide Sensor dedicated to Aquaculture and Oceanography was developed, tested and marketed through project partners. The sensor was presented at a series of conferences dedicated to marine monitoring. For more information contact Ponsel Measure, France, www.ponsel.fr**.**

2.2.5 *RADAR*

http://www.fp7-radar.eu/

The COMMON SENSE project has received funding from the European Union's Seventh Framework Program (Ocean 2013-2) under the grant agreement no 614155.

Rationally Designed Aquatic Receptors integrated in label-free biosensor platforms for remote surveillance of toxins and pollutants
FP7 KBBE – Food, Agriculture and Fisheries, and Biotechnology
FP7 - Small or Medium-Scale Focused Research Project
2011 – 2014

The project has 3 objectives:

1. To increase the sensitivity, specificity and versatility of biosensors using nanostructured surfaces and genetically engineered recombinant bio-receptors derived from aquatic organisms.
2. To provide a robust, label-free, remotely-controlled, and portable biosensor platform for cost-effective spot measurements and on-line monitoring with integrated fully automated sample preparation for non-experts.
3. To validate the RADAR biosensor and demonstrate its application for cost-effective spot measurements and on-line monitoring of toxins and pollutants in food processes and in the aquatic environment.

The results:
The project is on its ending phase, partial results on Self-Referencing Label-Free Waveguide Grating Sensor For Remote Surveillance Of Toxins And Pollutants are published in [AGM13]

2.2.6 *SESAME*

http://www.sesame-ip.eu
Southern European Seas : Assessing and Modelling Ecosystem Changes
FP7 Environment VI FP, Priority - 6.3 - Global Change and Ecosystems (contract n. 036949-2).
Integrated Project
2006–2010

The SESAME project was designed to study the past, present and future environmental changes in the Mediterranean and Black Sea ecosystems, and their abilities to provide goods and services with fundamental societal importance, such as tourism, fisheries, mitigation of climate through carbon sequestration and ecosystem stability through conservation of biodiversity. With the help of historical data, in combination with newly collected data, SESAME aimed to identify the changes these two ecosystems have experienced over the last 50 years. The goal was, based on the past and current status, to predict possible changes within the next 50 years.

The project assessed the changes in the Southern European Seas (SES) ecosystems over the last 50 years, determined the current status and predicted the changes that may happen in the Mediterranean and Black Sea ecosystems in the 21st century. In addition, SESAME assessed and predicted the abilities of these ecosystems to provide goods and services with fundamental societal importance. The project approached the two seas as a coupled climatic/ecosystem entity, with links and feedbacks to the world ocean, something not attempted before at such a large scale for these ecosystems. Overall the project, working in an integrated and multidisciplinary mode, managed to create a large network of scientists who worked together as a team, to increase the capacity building especially in less advanced SES regions, and to ensure that a structured dialogue between researchers and potential users is created and maintained. Strong focus was placed on disseminating this knowledge to all relevant stakeholders. This involved the integration of socioeconomics and natural sciences, while at the same time creating a platform for education and further learning opportunities. SESAME completed its research activities through multidisciplinary collaborations,

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both within as well as outside the EU. One of these examples was the simultaneous multi-national cruises carried out in the Mediterranean and the Black Seas, which not only strengthened collaborations among the scientific teams of different partner institutes, but provided the scientists with the opportunity to produce a "snap-shot" of the ecological state of the Southern European Seas in 2008, which could be used in the years to come as reference for potential changes. The assessment of ecosystem changes was based on the identification of the major regime shifts that occurred during the last 50 years, which was successfully accomplished through the research cruises, the modelling efforts and the socio-economic focus of the project. Integrating the socio-economic evaluation of SES marine ecosystems with solid, state-of-the-art scientific modelling and field observations achieved a dual future projection. Firstly, it provided information in terms of numerical modelling efforts and, thus, the process through which we can now define the potential changes occurring in the SES ecosystem dynamics under unified consensus scenarios of climatic change and direct anthropogenic pressure. Secondly, it allows for the quantification of welfare effects for SES countries (GDP effects), which may be caused by changes in the ability of these ecosystems to provide goods and services (e.g. fisheries catch potential, ecosystem biodiversity, attractiveness etc.). Moreover, SESAME's scientific efforts were effectively and efficiently managed, starting with the analysis of existing and newly collected data at basin and regional scale as well as through model simulations, to attain and create a comprehensive, integrated Database regarding the Mediterranean and the Black Sea, to be maintained beyond the project's life span.

SESAME is followed by the project PERSEUS (*Policy-oriented marine Environmental Research for the Southern European Seas*; www.perseus-net.eu), funded by the EU under FP7 Theme "Oceans of Tomorrow" OCEAN.2011-3. This research project assesses the dual impact of human activity and natural pressures on the Mediterranean and Black Seas. PERSEUS merges natural and socio-economic sciences to predict the long-term effects of these pressures on marine ecosystems. The project aims to design an effective and innovative research governance framework, which will provide the basis for policymakers to turn back the tide on marine life degradation.

2.3 ONGOING Projects (including FP7)

2.3.1 FixO3

http://www.fixo3.eu/
Fixed point Open Ocean Observatory
FP7 Infrastructures
CP-CSA-Infra - Combination of CP and CSA
2013-2017

The network FixO3, is a FP7 project that seeks to integrate European open ocean fixed point observatories and to improve access to these key installations for the broader community. These will provide multidisciplinary observations in all parts of the oceans from the air-sea interface to the deep seafloor. Coordinated by the National Oceanography Centre, UK, FixO3 will build on the significant advances largely achieved through the FP7 programmes EuroSITES, ESONET and CARBOOCEAN. Available facilities: The list of observatories offered for Transnational Access (TNA) in FixO3 was designed to offer the broadest scientific and technological capabilities to future users in the framework of TNA. The list of observatories includes seafloor, mid-water and surface infrastructures, with different scientific specificities mainly due to the characteristics of their location. A shallow water test-site, OBSEA, has also been included and was chosen on the basis of ease of access, standard interfacing and highly specialized local support for accelerated testing of instrumentation

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and communication protocols. This is a unique opportunity for scientists and engineers to avail of high-quality, interlinked instrumented infrastructures operating in open ocean observatories for carrying out research and/or testing activities. Interested users can request access to one or more infrastructures and installations. They will be provided with technical assistance and ancillary data that may be necessary to their work. Visitors and projects will be selected on the basis of the scientific and technical quality and novelty of the proposed activities. Infrastructural, logistical, technological and scientific support will be offered by providers to successful bids accessing the TNA facilities. The nature of the support being offered may change from facility to facility and will be outlined in detail in the text of the open calls. Detailed and periodically updated information will be made available from the project specific knowledge base developed and published on the website.

2.3.2 *RITMARE*

www.ritmare.it
The Italian flagship project **RITMARE** *(The Italian research to Sea)* is funded by the Italian Ministry of University and Research. It is the leading national marine research project for the period 2012-2016; the overall project budget amount to 250 million euro, co-funded by public and private resources. It is coordinated by the National Research Council and involves an integrated effort of most of the scientific community working on marine and maritime issues, as well as some major industrial groups. The project aims to implement what is suggested by the European Commission's Blue Book (COM2007/575 of October 10, 2007), in research and innovation, through a multi-annual national research program of science and technology for the sea that is open to a wider participation of public and private actors.
The project is divided into seven sub-projects:

1. Maritime Technologies;
2. Technologies for a Sustainable Fishery;
3. Planning of the Maritime Area along the Marine Coastline;
4. Planning of the Deep and the Open Sea Marine Environments;
5. Observing System of the Marine Mediterranean Environment;
6. Research Structures, Education and Dissemination;
7. Interoperable Infrastructure for the Observing Network and the marine data.

The RITMARE project:

- will support training of a new generation of researchers, through the funding of innovative projects selected through calls for proposals;
- will strengthen the strategic presence of Italian research in Europe and in the Mediterranean;
- will strengthen national oceanographic fleet, through the creation of a new research vessel with polar capacity;
- will promote the establishment of a permanent forum between researchers, decision makers and stakeholders in both the public and private sector, with the aim of fostering the integration and transfer of research results and thus place the knowledge as a reference starting point for strategies and management decisions.

2.3.3 *MyOcean/MyOcean2*

www.myocean.eu
Prototype Operational Continuity for the GMES Ocean Monitoring and Forecasting Service
FP7 SPACE

Integrated Project
2009-2014

The two European Integrated Projects **MyOcean** and **MyOcean2** intended to develop, implement, validate and operate a robust and sustainable Ocean Monitoring and Forecasting component of the GMES Marine Service delivering ocean physical state and ecosystem information to intermediate and downstream users in the areas of marine safety, marine resources, marine/ coastal environment and climate, seasonal and weather forecasting. The IP-**MyOcean** was the first implementation project of the GMES Marine Core Service with the deployment of the first concerted and integrated pan-European capacity for Ocean Monitoring and Forecasting. It was funded by the EU with the FP7 under SPACE (contract n. 218812) in the period April 2009 – March 2012. MyOcean was followed by the IP-MyOcean2 funded by the EU with the VII Framework Programme SPACE (contract number 283367) in the period April 2012 – October 2014. This second project will be followed by a six-months project named MyOcean Extension and then by a larger, but at the date of this report not defined yet in its definitive architecture, named ECOMF (European Centre for Ocean Monitoring and Forecasting), a GMES Marine service sustained for users.

2.3.4 *E-AIMS*

http://www.euro-argo.eu/EU-Projects-Contribution/E-AIMS
Euro-Argo Improvements for the GMES Marine Service
FP7 SPACE
CP-FP - Small or medium-scale focused research project
2013-1015

The project E-AIMS is part of the European contribution to the international Argo observing system (See Section 4.3 and Appendix A). Its main objective is to prepare the evolution of the Argo floats for the next decade. It provides laboratory and field experiments testing new telecommunication capabilities, biogeochemical observations, deep measurements, under ice operations, and sampling of marginal seas.
Several lines of technological R&D are being tested, involving both the sensors ant the observed variables, the operating environment and the data transmission:

- Biogeochemical Argo experiments in the Atlantic and in the Nordic Sea and Black Sea are being conducted to acquire data about chlorophyll-a (a proxy for phytoplankton biomass), dissolved oxygen (a key parameter to characterize the health of the ocean), nitrate (the primary source of new nitrogen) and particle carbon (related with the quantity of living and dead matter).
- Evaluate new float technology for observations deeper (3500-4000 meter) than the current nominal 2000 meter.
- Development of new specifications and algorithms (sea ice detection and positioning) to extend the array into the seasonal ice zones and marginal seas of European interest (Nordic, Mediterranean and Black seas).
- Assess new telecommunication systems (Argos-3 and Iridium), increased telecommunication bandwidth, and enlarged number of sensors to improve the overall performance of the floats and to enhance the surface layer sampling.
- Perform Calibration/Validation activities to address the evolving requirements brought about by new satellite missions and to contribute to the definition of the future extended Argo missions.

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E-AIMS activities will continue until December 2015.

2.3.5 *EnviGuard*

http://www.enviguard.net/
Development of a biosensor technology for environmental monitoring and disease prevention in aquaculture ensuring food safety
FP7 KBBE – Food, Agriculture and Fisheries, and Biotechnology
FP7 - Collaborative Project
2013 – 2018

The aim of the EnviGuard project is to develop a highly specific and precise (i.e. quantitative and qualitative) in situ measurement device for currently hard to measure man-made chemical contaminants and biohazards (toxic microalgae, viruses & bacteria, biotoxins & PCBs) that can be used as an early warning system in aquaculture and as an environmental monitor to assess the good environmental status of the sea in compliance with the MSFD.
The objectives:

- highly specific, precise and reliable in-situ measurements of biohazards and chemical contaminants in seawater with real-time results
- multi-class, multi-analytic method for the simultaneous determination of harmful microalgae species, Betanodavirus , E. coli , okadaic acid and the co-planar family of PCBs
- automatic sampling in the marine environment
- easy access to data from everywhere through internet database
- a modular system (of up to three sensors) integrated in a single, portable, durable device

EnviGuard will allow an easier, faster and cheaper way to measure harmful substances in-situ. Thus, it will provide a unique, competitive advantage and leadership to the European aquaculture industry.

2.3.6 *NeXOS*

http://www.nexosproject.eu/
Next generation, Cost-effective, Compact, Multifunctional Web Enabled Ocean Sensor Systems Empowering Marine, Maritime and Fisheries Management
FP7 ENVIRONMENT – Environment (including Climate change)
FP7 - Collaborative Project
2013 – 2017

As stated by the marine research decision makers in Europe in the “Ostend Declaration” in 2010, a major challenge is to support the development of a truly integrated and sustainably funded European Ocean Observing System. This will be achieved with more long-term measurements of key parameters but is impaired by the costs and lack of reliability of ocean sensors in general. The NeXOS project aims to improve the temporal and spatial coverage, resolution and quality of marine observations through the development of cost-efficient innovative and interoperable in-situ sensors deployable from multiple platforms, and Web Services for key domains and applications. This will be achieved through the development of new, low-cost, compact and integrated sensors with multiple functionalities including the measurement of key parameters useful to a number of objectives, ranging from more precise monitoring and modelling of the marine environment to an improved assessment of fisheries. Seven new compact, cost-efficient sensors will be developed, based on optical and acoustics technologies, addressing a majority of descriptors identified by the Marine Strategy Framework Directive for Good Environmental Status. Two of the new sensors will

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specifically contribute to the Common Fisheries Policy with variables relevant for an Ecosystem Approach to Fisheries. All new sensors will respond to multiplatform integration, sensor and data interoperability, quality assurance and reliability requirements. These will be specified for each new sensor system. All new sensors will be calibrated, integrated on several types of platforms, scientifically validated and demonstrated. One of the main objectives of NeXOS will finally be to enhance the competitiveness of European SMEs in the ocean sensor market. To this end, sensor requirements and specifications will be assessed at an early phase of the project for market penetration.

2.3.7 *SMS*

http://www.project-sms.eu/
Sensing toxicants in Marine waters makes Sense using biosensors
FP7 KBBE – Food, Agriculture and Fisheries, and Biotechnology
FP7 - Collaborative Project
2013 – 2017

SMS will deliver a novel automated networked system that will enable real-time in situ monitoring of marine water chemical and ecological status in coastal areas by the detection of a series of contaminants regulated by the MSFD. SMS will design a multi-modular apparatus that will host in a single unit—the Main Box (MB)—a Sampling Module and an Analysis Module. The former will contain sample collection and treatment components, whereas the latter will include four biosensor sub-modules that will enable detection and measurement of algal toxins and their associated algal species; several hazardous compounds (tributyltin, diuron and pentaBDPE); sulphonamides and a series of standard water quality parameters. The MB will be equipped with a communication module for real-time data transfer to a control centre, where data processing will take place, enabling alarm functionality to Health Warning Systems, whenever some critical value exceeds a pre-defined threshold. It will be placed on a floating platform or buoy positioned in loco at defined locations. SMS will also develop a Specific Marine Pollution Metric that will combine real-time data of pollutant concentrations and water quality parameters, to produce a quantitative assessment of marine water quality. All work will culminate in showcasing the project's results in three demonstration sites: in La Spezia, Italy, in the Slovenian Adriatic Sea and in the Alonissos marine park in Greece. The consortium brings together skills from industry and academia to address the proposed work program. The track record of the partners is a strong indication that the project will achieve its ambitious objectives and make a lasting impact through its exploitation plan. The technology development and test cases bring together a multi-sectorial team of experts interacting with end-users and marine water stakeholders, demonstrating that ICT, biotechnology and nanotechnology can increase the potential of biosensors for marine applications.

2.3.8 *BRAAVOO*

http://www.braavoo.org/
Biosensors, Reporters and Algal Autonomous Vessels for Ocean Operation
FP7 KBBE – Food, Agriculture and Fisheries, and Biotechnology
FP7 - Collaborative Project
2013 – 2016

BRAAVOO aims to develop innovative solutions for real-time in-situ measurement of high impact and difficult to measure marine pollutants. The concept of BRAAVOO is based on a unique combination of three types of biosensors, which will enable both the detection of a number of specific marine

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priority pollutants as well as of general biological effects that can be used for early warning. First, innovative bimodal evanescent waveguide nanoimmuno-sensors will enable label-free antibody-based detection of organohalogens, antibiotics, or algal toxins. Secondly, bacterial bio-reporters producing autofluorescent proteins in response to chemical exposure will enable direct detection of alkanes or PAHs from oil, heavy metals, or antibiotics, and can further assess the general toxicity of the water sample. Finally, the photosystem activity of marine algae is exploited to monitor changes induced by toxic compounds. BRAAVOO will construct and rigorously test the three biosensor systems for their analytical performance to the targeted pollutants. To enable low-cost real-lime measurements, the three biosensors will be miniaturised, multiplexed and integrated into innovative modules, which allow simultaneous multianalyte detection. The modules will include all optical elements for biosensor signal generation and readout, the microelectronics for data storage, and specific microfluidics to expose the biosensors to aqueous samples from dedicated auto-samplers. The modules can be used either as stand-alone instruments for specific marine applications, or can operate autonomously and in real-time in an integrated form. Hereto, they will be embedded in a marine buoy and an unmanned surveying vessel. Vessels and stand-alone biosensors modules will be tested extensively and in comparative fashion on real marine samples and in mesocosmos. We expect that the flexible BRAAVOO solutions will present useful new systems for marine environmental monitoring.

3 INVENTORY OF RESEARCH INFRASTRUCTURES AND SITES AROUND EUROPE

There is not a single definition of Research Infrastructure (RI) or of Marine Research Infrastructure (MRI), and there are different ways to categorise them. MRIs considered here are infrastructures which directly or indirectly support the collection, management and use of marine data. The MRIs can be physical equipment that collects and produces marine data, databases and information systems that give access to these data, as well as supercomputers and models that process these data. MRIs can collect data in real time or in delayed mode. In real time mode, data is directly acquired by a device equipped with a sensor, then transferred (through submarine cables or satellite or Wi-Fi…) to be used immediately in a data processing system. In delayed mode, typically a device extracts samples (water, sediments), which are then processed in a laboratory before being analysed with analytical apparatus to produce data. Data collection MRIs therefore comprise both devices equipped with sensors that collect directly marine data and sampling devices/laboratory equipment for data acquisition in delayed mode.

MRIs can be owned by public or private organisations (marine industries). Different types of ocean and coastal observatories have been established in Europe and internationally in recent years.

Sensors are at the start of this chain since they make the measurements, which allow data collection. They can be physical (temperature, wave, current, noise…), chemical (oxygen, carbon dioxide, nutrients, pollutants…), biological (chlorophyll, plankton, biotoxins, genetic material like DNA or RNA…) or geological (sediments, seismic activity…). Sensors can operate in situ or remotely (remote imaging from satellites, radars…), depending on the platforms that carry them. Sensors are carried by fixed or mobile platforms. The platforms can be submersible (buoys, moorings, drifting platforms, autonomous underwater vehicles, remotely operated vehicles, cabled seabed observatories…), floating (research vessels, ships, ...), fixed (offshore platforms, coastal platforms, …) or airborne (satellites and planes). Mobile and fixed platforms can carry several sensors and collect a range of data. The kind of parameters that can be measured by a platform therefore depends on the sensors that are adapted on it. Sometimes this is the result of a choice; for example, a cabled seabed observatory can collect physical, chemical, biological or geoseismic data depending on the issues it

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should deal with. But often there are technological limitations (size of sensors, need for electric power…), which prevent scientists from adapting more sensors on a platform. This area is subject to intense research and innovation, and technology evolves quickly in that domain, leading to more sensors being put on platforms and increasing the scope of their measurements. There is a continuous feedback between scientific challenges, technology developments and society needs: technology developments can be driven by science and societal needs but they can also trigger scientific breakthroughs, which in turn become crucial for the sustainable management of ocean and coastal areas.

The following Table has been adapted from [EC13] and provides a detailed description of different categories of marine research infrastructures (mobile platforms, submersible platforms, autonomous and drifting platforms, fixed platforms and systems, in-situ and remote sensors, ICT infrastructures and models, modelling and data management infrastructures), their roles, their ongoing and future challenges, as well as their potential suitability for application in the COMMON SENSE project (i.e. for measurements of eutrophication, underwater noise, marine litter and contaminants).

The European framework of MRIs is complex, with many initiatives organising the governance of MRIs and data flows at different geographical scales (local, national and European) and at different stages of the data chain (data collection, management, integration and dissemination...). With the exception of satellite remote sensing infrastructures (usually managed by European agencies), MRIs of European scale are essentially set up by integrating similar marine research infrastructures distributed in several member states. Some of these European scale MRIs are already operational, while others are only projects aiming at creating European governance for distributed MRIs. There are also initiatives integrating several MRIs of European scale to create large observing systems or programmes.

The nature and number of MRIs managed by marine research centres / observatories will give them a more or less extensive geographical coverage (local / coastal, or regional / open Ocean…). Oceanographic vessels can have a coastal, regional or global range. Fixed platforms (such as moorings, buoys or cabled seabed observatories equipped with a range of sensors) produce frequent measurements in a specific zone, while drifting platforms (like Argo floats or gliders) will cover broad areas. Some of their MRIs contribute to European scale distributed MRIs (Euro-Argo, EMSO, EURO-SITES, EMBRC) or simply to European networks of MRIs. Many of these MRIs are however not integrated at European level. A precise inventory of MRIs existing at European and national levels has been made by the marine research ERA-Net, SEAS-ERA [SEA14].

The European Strategy Forum on Research Infrastructures (ESFRI) is a strategic instrument created in 2002 by the European Commission and the Member States to support a coherent and strategy-led approach to policy-making on research infrastructures in Europe and to facilitate multilateral initiatives leading to a better use and development of research infrastructures. In 2004 the Council gave ESFRI a mandate to develop a strategic roadmap for Europe in the field of Research Infrastructures. A first roadmap was produced in 2006 with a list of European scale research infrastructures of vital importance, which was subsequently updated in 2008 and in 2010.

Among 38 infrastructures identified in the last roadmap, 3 are distributed marine research infrastructures (Euro-Argo, EMSO, EMBRC) while 4 others have a substantial marine component (ICOS, LIFEWATCH, ECCSEL, SIOS). Many marine research infrastructures were developed in the framework of research projects, supported either by the Research Framework Programme. Most of these projects (e.g. Eurofleets, Euro-Sites or Groom) seek to develop European governance for distributed infrastructures (harmonisation of operational conditions, coordinated management and investments…). Although they must be assessed on their individual merits, they may have potentially similar societal or scientific impact as the ESFRI projects.

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Long-term trends can only be distinguished from seasonal changes and decadal-scale natural variation if observations from the past including those collected before the advent of digital storage devices can be compared with those of the present. If these data are lost they are gone forever; the observations cannot be repeated. Accordingly a number of Member States are in the process of setting up catalogues using standards and technology allowing retrieval of data through automated processes. These national systems are the foundations of the distributed processes that are being built up at an EU-level. The development of National Oceanographic Data Centres (NODCs) is particularly important in that respect.

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Infrastructure Category [+ European governance projects]	Description	Role	Ongoing Challenges	Future Challenges and Developments	MRI suitable for CS application
MOBILE PLATFORMS					
Research Vessel [EUROFLEETS]	A research vessel is a ship designed and equipped to carry out research at sea.	Provide access to the sea as carriers for measuring instruments and sampling equipment for scientific cruises, process study campaigns, event-driven responses, surveys and mapping, and routine monitoring.	-Fleet planning at European level as part of a marine infrastructure review process, including platform construction, and on board equipment upgrades, with particular attention to the renewal of regional fleet (building on EUROFLEETS' work). -Continued availability of general purpose ships and some special purpose ships for the deployment of complex and heavy equipments. -Flexibility in fleet scheduling, for efficient use, event response, and surge capacity. Further improve the efficiency of the Ocean Facilities Exchange Group (OFEG) for regional vessels.	-Ability to meet increased demand for rapid launch and recovery for diverse arrays of autonomous platforms. -Electric propulsion and alternative power systems to limit fuel consumption.	Eutrophication X Noise X Litter X Contaminants X
Ships of opportunities / Ferry Boxes [JERICO for FB]	The Ships of Opportunity facility utilises a combination of volunteer merchant and, less frequently, research vessels to collect measurements related to physical, chemical and biological oceanography. FerryBoxes combine a set of sensors and biogeochemical analysers that are installed on ships of opportunities.	Repeated measurements for operational oceanography, biodiversity (plankton…), marine pollution (nutrients, chemicals, micro plastics…)	-Increased use of volunteer observing ships to collect and transmit underway scientific data to national repositories for verification and analysis.	- Develop standardized "container type" sensor packages with small footprint for compatibility and rapid exchange. - Develop methodologies for transect sampling	Eutrophication X Noise X Litter X Contaminants X
SUBMERSIBLE PLATFORMS					
Remotely Operated Vehicles (ROVs)	A crewless submersible vehicle tethered to a vessel by a cable. It carries a variety of devices (sensors, cameras…).	Provide water column and seafloor access for process study campaigns, event-driven responses,	-Broader ranges of biological, chemical and optical sensors. -More sophisticated sonar systems for bathymetry and water column uses.	-Continued development of advanced ROV capabilities (e.g., higher power, greater depth ratings, sampling tools,	Eutrophication X Noise X

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		surveys and mapping as well as routine monitoring, and sampling.	-Advancements in underwater navigation for more precise and geodetic referenced vehicle locations. -Continued development of hybrid ROVs.	sensors), including ROVs to be deployed from coastal or regional vessels not equipped with DP systems.	Litter X Contaminants X
Towed Systems	Systems that have been towed behind ships and boats to perform different types of measurements.	Provide observations and sampling from near surface to just above the seafloor, with use on research vessels or ships of opportunity.	Broader ranges of biological, chemical and imaging sensors.	Reconnaissance sampling using high-speed data uplinks that allow for simultaneous video and sample recovery.	Eutrophication X Noise X Litter X Contaminants X
AUTONOMOUS AND DRIFTING SYSTEMS					
Autonomous Underwater Vehicles (AUVs) and gliders [GROOM for gliders]	Programmable, robotic vehicles that, depending on their design, can drift, drive, or glide through the ocean without real-time control by human operators. Underwater gliders are autonomous vehicles with typical endurance reaching now up to 4-6 months. They move horizontally on wings and profile vertically by controlling buoyancy, from the surface down to more than 1000 m, monitoring physical, biogeochemical or acoustic data in quasi real time.	Gliders can operate in coastal and open ocean areas and are ideal for sustained monitoring of key control points. They provide near real time observations (temperature, salinity, velocity, nutrients, optics, fluorometry, acoustics, multi-beam or side-scan sonar) for process study campaigns, event-driven responses, surveys and mapping.	-Scalable, multiplatform arrays capable of local, regional, and global-scale observations at broader ranges of spatial and temporal resolution. -Improved battery power for increased mission duration, expanded range, and ability to support more sensors. -Expanded ocean depth capability for a variety of platforms. -AUVs with larger payloads, higher endurance, and ability to work in rough conditions (e.g., high currents, sea states, ice coverage) and at all expected working temperatures.	-Equip platforms with broader suites of multidisciplinary in situ sensors (detailed in section below on in situ sensors). -Autonomous refuelling, at-sea energy harvesting, or other methods for replenishing or self-generating power. - Improvement of piloting algorithms to allow deployment of several AUVs at the same time and have better piloting. -Permanent, large-scale subsurface acoustic positional networks (analogous to GPS) for improved undersea navigation. -Full ocean depth capability for a variety of platforms,	Eutrophication X Noise X Litter X Contaminants X

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				including ability to use AUVs in shallow areas with heavy activity, shipwrecks, high turbidity and strong tidal currents.	
Drifters and Floats [Euro-ARGO for floats]	Float designed specifically to drift passively with the flow of water. Drifter and float are used interchangeably; historically, however, drifter has applied to instruments on the surface and float to those in the water column.	Provide scalable, adaptable arrays with near real time observations (wind, light, passive radiation, atmospheric pressure, temperature, salinity, chlorophyll fluorescence, dissolved oxygen, nitrate) for routine monitoring and assimilation into forecast models.	- Sustain the global array (T & S) for the next decades. -Advancements in underwater navigation for more precise and geodetic referenced vehicle locations. - Evolution of Argo core mission to answer new requirements: • increased float life time and reliability, reduced costs • Extension to biogeochemical parameters with miniaturized, low cost and reliable sensors • Telecommunication (two way) and increased bandwidth • Extension to deeper depths (below 2000 meters)	-Increased deployment options for autonomous platforms such as volunteer ships or aerial vehicles. -Autonomous refuelling, at-sea energy harvesting, or other methods for selfgenerating power.	Eutrophication X Noise X Litter X Contaminants X
FIXED PLATFORMS AND SYSTEMS					
Moorings [JERICO, FixO3, former EUROSITES]	A collection of devices connected to a wire, held up in the water column with various forms of buoyancy and anchored on the sea floor.	Provide surface and water column observations with high vertical and temporal resolution, including persistence at key locations and groundtruth for remote sensing. Provide full integration with mobile autonomous systems	-Continued, sustained support of centers for deep ocean mooring design, construction and deployment. -Ability for docking mobile autonomous systems (e.g., AUVs, benthic crawlers).		Eutrophication X Noise X Litter X Contaminants X
Cabled Seafloor Observatories	Seafloor observatories can have a range of sensors (physical, biochemical, geological, optical,	Provide continuous real-time power and communication to	-Ability for docking mobile autonomous systems (e.g., AUVs, benthic crawlers).	Multiple data extraction modes (e.g., long range acoustic communication).	Eutrophication X Noise

[EMSO]	acoustic…) to collect data in a fixed point in the seabed and transfer them through a submarine cable linked directly to a shore station.	coastal, deep ocean, and seafloor instruments and networks. Routine interactions with mobile autonomous systems.		Autonomous or manual release of automatically collected data capsules and samples.	X Litter X Contaminants X
IN SITU SENSORS					
Physical	Devices which respond to physical parameters such as temperature, salinity, oxygen, density, currents… and provide a signal that allow measuring them.	Provide measurements essential to physical process studies and baseline dynamical contexts for biogeochemical sensors.	-Measurements of the exchange of mass (e.g., gases, aerosols, sea spray, water vapor), momentum, and energy (including heat) across the air-sea interface in a broad variety of conditions (e.g., high wind conditions, severe storms). -Techniques to infer gas exchange under high wind conditions with chemically active (e.g., DMS) and inert (e.g., CO_2, Ar) atmospheric gases. -Fully networked and widely accessible data on river outflows, precipitation, and from tide gauges.	- Optical imagery for spatial and temporal observations of ocean surface, estuarine, and riverine processes. - Development of computerized image recognition technology for analysis of large image datasets in relation to pollution (marine litter) and biological assessments (e.g. habitats). - Development of higher resolution Marine acoustics technology for	Eutrophication Noise X Litter X Contaminants X
Chemical	Devices which respond to chemical parameters such as pH, nutrients, CO_2… and provide a signal that allow measuring them.	Provide routine time-series measurements for major and trace elements, carbon species, nutrients, and pollutants in a broad range of environments.	-Observations of the carbon dioxide system(including pH), major and micronutrients and elemental speciation of key micronutrients (such as iron). -High-resolution analytical tools that enable detailed analysis of oceanic carbon components. -More portable micronutrient analytical systems and speciation analysis for assessing micronutrient speciation and determining its influence on biological activity. -Sensors for identification of chemical pollutants.	Sensor methods for surface micro-layer chemistry. Cheap, easily available sampling systems for testing for chemical pollutants.	Eutrophication X Noise Litter Contaminants X
Biological	Devices which respond to	Provide routine	-Development of methods to obtain	-Cheap, species survey	Eutrophication

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	biological parameters such as plankton, chlorophyll … and provide a signal that allow measuring them.	measurements with small, inexpensive sensors that replicate current complicated laboratory techniques.	organism specific growth rates and advective, turbulent, and sinking fluxes. -Sensors for identification of plankton biomass and community structure – genetic, imaging, and acoustic. -Sensors for identification of higher trophic levels (e.g., fish, marine mammals) - genetic, imaging, and acoustic. -Sensors for toxin identification (including harmful algal blooms and pathogens).	sampling systems for broad distribution throughout coastal regions. -High throughput genomic, protionomic, metabolamic techniques. -Cheap, small toxin sampling systems for broad distribution throughout coastal regions. -Wide-area benthic sensors for seafloor mapping to provide estimates of benthic community state and function.	X Noise Litter Contaminants
MRI REMOTE SENSING					
Satellite	Satellite remote sensing uses devices embarked in satellites to detect at distance natural radiation (infrared or other) emitted or reflected by the ocean surface (or close to the surface). This is then used to determine related parameters such as temperature, colour…	Provide global to regional scale remote observations for sea surface height, temperature, salinity, ocean colour, winds, precipitation, ice and radiation.	Sustained gravity missions that inform crustal, ocean circulation, and geoid observations.	Geostationary ocean colour and LIDAR remote sensing capability.	Eutrophication X Noise Litter Contaminants
Airborne	Airborne remote sensing uses devices embarked in airplanes for the passive characterization of ocean surface (imaging), or active collection using energy emission to detect reflected or backscattered radiation (e.g. Light Detection and Ranging - LIDAR)	Provide low-cost, regional to local-scale remote observations with adaptive and event-driven capabilities. LIDAR is also an effective technology to map coastal areas and seabed in shallow coastal areas.	-Increased use of unmanned aerial vehicles for campaigns and monitoring. -Ability to remotely measure ocean surface and ice properties beneath cloud cover	Use of commercial aircraft to collect and transmit ocean surface observations.	Eutrophication X Noise Litter Contaminants
High Frequency Radar	High Frequency Radar measures speed and direction of ocean surface current near the coast (up	They are part of observational systems for both fundamental research	-Increased use for monitoring and long time-series data. -Completion of the land-based HF radar	-Extension of broad area surface current arrays to offshore activities -	Eutrophication Noise

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	to 70 kms).	and applied needs	Network.	Increased use of tethered aerial platforms. -Increased data gathering capabilities through expanded use of commercial ocean activities.	Litter Contaminants
ANALYTICAL DEVICES FOR DELAYED MODE ANALYSIS					
Laboratory equipment for analysis of marine samples	This comprises all laboratory analytical equipment to perform physical, chemical, biological, geological measurements on extracted samples. It also covers analytical devices for gene sequencing of marine organisms.	Laboratory equipment analysis provides more precise and sensitive measurements than real-time analysis with sensors. In some cases (e.g. gene sequencing), it produces data that cannot (yet) be acquired with in-situ sensors in real time.			Eutrophication **X** Noise Litter **X** Contaminants **X**

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4 PROGRAMS

4.1 SOOP

http://www.jcommops.org/soopip/

The primary goal of the Ship-of-Opportunity Programme (SOOP) is to fulfil upper ocean data requirements which have been established by GOOS and GCOS, and which can be met at present by measurements from ships of opportunity (SOO). SOOPIP is establishing itself as an operational programme and is therefore participating in the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) and particularly in its Ship Observations Team (SOT). Data management is taken care of through the Global Temperature Salinity Profile Programme (GTSPP).

The SOOP is primarily directed towards the continued operational maintenance and co-ordination of the XBT ship of opportunity network but other types of measurements are being made (e.g. TSG, XCTD, CTD, ADCP, pCO2, phytoplankton concentration). This network in itself supports many other operational needs (such as for fisheries, shipping, defence, etc.) through the provision of upper ocean data for data assimilation in models and for various other ocean analysis schemes. One of the continuing challenges is to optimally combine upper ocean thermal data collected by XBTs from the SOO with data collected from other sources such as the TAO array, Argo, and satellites (eg. AVHRR, altimeter, etc.). However, it is considered most important to have the SOOP focused on supporting climate prediction in order to ensure the continued operation of the present network.

XBT (Expandable BathyThermograph) is an expandable temperature and depth profiling system. The Ship Of Opportunity Programme operates a global network of XBT systems onboard merchant ships which data are transmitted in real-time and made available to the oceanographic and meteorological communities for operational (assimilation in ocean models) and scientific purposes. XCTD is an Expandable Conductivity, Temperature and Depth profiling system, a variant of XBT.

TSG (ThermoSalinoGraph) is an automated Sea Surface Temperature and Salinity measurement system making measurement onboard the ship using a water intake.

ADCP (Acoustic Doppler Current Profiler) is a kind of current meter that measures currents through the emission of sound of known frequency then reflected by small particles moving with the water.

Approximately 100 dedicated SOO, operated by 7 Members, report upper ocean temperature along specified routes at sampling intervals developed under the Tropical Ocean and Global Atmosphere (TOGA) and WOCE programmes of WCRP. These sampling requirements have been designed for climate monitoring and prediction applications, and which have been endorsed by the WCRP Ocean Observing System Development Panel (OOSDP). Each vessel is equipped with a data acquisition system provided by the operating agency. These systems vary depending upon the agency, but generally meet agreed standards. Observations (such as the deployment of expendable bathythermographs - XBTs) are made normally by ships officers on a voluntary basis, though there is increasing automation in some underway systems such as used for measuring sea surface temperature (SST) and sea surface salinity (SSS). Observations are also utilised from other "opportunistic" vessels (navy, fishing, research, etc.) not formally participating in the programme. Interface between oceanographic agencies and met services and the ships is through designated Ship Greeters from the contributing national agencies and occasionally the international network of Port Meteorological Officers (PMO). Ship Greeters and PMOs maintain, calibrate and often supply/replace instrumentation. They also provide relevant literature, stationery and computer software, train ships'

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officers, and generally help to provide the feedback required to maintain the volunteer observer support and motivation.

The data management activities of the programme are integrated with the data collection activities and handled with procedures and resources most of which are currently in place and used to support the Global Temperature and Salinity Programme (GTSPP), including regional upper ocean science centres established by WOCE. The Marine Environmental Data Service (MEDS) in Canada is the GTSPP centre responsible for collecting temperature and salinity data from the GTS in real-time on a daily basis. The data are passed through well documented quality control procedures as well as procedures to detect and remove duplicates. The GTSPP regularly monitors the volumes, timeliness and quality of data received in real-time.

The assembly and incorporation of delayed mode data into the GTSPP data stream in a timely manner is an essential activity. Experience has shown that significant amounts of real time data are not being replaced with high resolution versions, and that large quantities of additional data are only available in delayed mode. While these data are not available for operational use, they are critical for climate products and research. The responsibility for tracking and submission of delayed mode data is entrusted to SOOPIP, which works closely with IODE and the research community, e.g. WOCE IPO, to ensure that these data are submitted within one year of observation, as required by IODE.

Because the data management aspect of the SOOP makes use of existing linkages between data archives and oceanographic and meteorological research centres, the products currently available through the GTSPP continue in support of the project.

4.2 CLIVAR

www.clivar.org

CLIVAR (*Variability and predictability of the ocean-atmosphere system*) is one of the four core projects of the World Climate Research Programme (WCRP). CLIVAR's mission is to facilitate observation analysis and prediction of changes in the Earth's climate system, with a focus on ocean-atmosphere interactions, enabling better understanding of climate variability, predictability, and change, to the benefit of society and the environment in which we live. In order to describe and understand the ocean-atmosphere processes responsible for climate variability and predictability on seasonal, interannual, decadal, and centennial time-scales, through the collection and analysis of observations and the development and application of models of the coupled climate system, in cooperation with other relevant climate-research and observing activities.

CLIVAR Panels and working groups made up of senior and early career scientists from around the world meet regularly and interact to coordinate and facilitate research activities in their respective domains world-wide. The CLIVAR *Scientific Steering Group (SSG)* establishes these groups and their terms of reference to ensure that the key objectives of the programme are met. The SSG determines overall priorities for the project in concert with the goals and plans of the WCRP, and oversees and provides guidance to the scientific work undertaken by CLIVAR panels and groups. The International CLIVAR Project Office (ICPO) provides secretariat support to the SSG and the various panels and groups and is responsible for the project's outreach activities. It also serves as the point of contact for the project with the WCRP as a whole and with other relevant activities. The structure of CLIVAR is in place to promote international collaboration and cooperation, increasing the global scientific capacity beyond regional and institutional capabilities. Intra group/panel collaboration is promoted alongside liaison with the WCRP sister programs, GEWEX, CLiC and SPARC. Some panels and groups are organized jointly with other WCRP components and partner organizations, such as, International Geosphere-Biosphere Program (IGBP), the Global Climate and Global Ocean Observing Systems

(GOOS), WMO Commission for Climatology, Joint WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM). Each group/panel meets regularly to address research priorities in the scientific knowledge, develop best practices, guidelines and recommendations for the community as a whole and promote scientific capacity development.

4.3 ARGO

http://www.argo.ucsd.edu/

The international ARGO programme (for more details, see Appendix 1) was initiated in 1999 as a pilot project endorsed by the Climate Research Programme of the World Meteorological Organisation, GOOS, and the Intergovernmental Oceanographic Commission (IOC). The Argo network is a global array of autonomous instruments, deployed over the world ocean, reporting subsurface ocean properties to a wide range of users via satellite transmission links to data centres. In 2007, Argo reached its initial target of 3000 profiling floats. Argo is the first-ever global, in-situ ocean observing network in the history of oceanography, providing an essential complement to satellite systems. It is now the major, and only systematic, source of information and data over the ocean's interior. It is an indispensable component of the Global Ocean Observing System. That's why maintaining the array's size and global coverage in the coming decades is the next challenge for Argo, and Euro-Argo will contribute for the European component to this global network.

4.4 EuroGOOS

eurogoos.eu

EuroGOOS is an International Non-Profit Organization of national governmental agencies and research organizations, committed to European-scale operational oceanography within the context of the intergovernmental Global Ocean Observing System (GOOS). Founded in 1994, EuroGOOS has today 36 members from 18 European countries providing operational oceanographic services and carrying out marine research. Six regional sea areas where operational systems are being developed have been defined: the Arctic (Arctic ROOS), the Baltic (BOOS), the North West Shelf (NOOS), the Ireland-Biscay-Iberian area (IBI-ROOS) and the Mediterranean (MONGOOS). Additionally the Organization cooperates through an MoU with Black Sea GOOS which acts as a ROOS in the Black Sea. Strong cooperation within these regions, enabling the involvement of many more regional partners and countries, forms the basis of EuroGOOS work, and is combined with high-level representation at European and Global forums. Through its Working Groups, EuroGOOS develops strategies, priorities and standards in order to establish a concerted European approach to the development of Operational Oceanography. These strategies are actively promoted towards the European and National operational and funding agencies aiming to maximize their impact. The work is done in close collaboration with the international community of operational oceanography especially through JCOMM and global programs (GODAE, ARGO, OceanSITES, SOOP etc.). EuroGOOS is one of the 12 GOOS Regional Alliances (GRA) and works with them for a coordinated approach in the development of regional and coastal operational oceanography. EuroGOOS aims to work in the collective interest of its members to improve the quality and cost effectiveness in the production of operational oceanographic services at national, regional and global levels. More specifically the purpose of the Organization is to:

1. Identify European priorities for operational oceanography;
2. Promote operational oceanography and the development of underpinning science and technology at regional and global scales;

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3. Foster cooperation within operational oceanography at regional and global scales, including the establishment, support and coordination of Regional Operational Oceanographic Systems (ROOS);
4. Promote and coordinate the development of commonly available, operational, observation and model-based, products and services;
5. Ensure coordination of the European contribution to sustained marine observational systems necessary to meet the requirements for all marine-related purposes, including research, operational oceanography, and regular assessments of the state of our seas and oceans.

4.5 MedGOOS/MOON (MONGOOS)

www.mongoos.eu

The Mediterranean Operational Network for the Global Ocean Observing System (**MONGOOS**) was established in 2012 to further develop operational oceanography in the Mediterranean Sea. MONGOOS comprises the previous activities of MOON and MedGOOS.

The Mediterranean Global Ocean Observing System (**MedGOOS**) was a regional alliance of leading marine institutions founded under the auspices of the UNESCO/Intergovernmental Oceanographic Commission (IOC) to provide a concerted approach and common framework for the planning and implementation of the Global Ocean Observing System (GOOS) in the Mediterranean to the benefit of all coastal states in the region. The MedGOOS was born in Malta in November 1997 at the IOC Workshop on GOOS Capacity Building in the Mediterranean Region. The MedGOOS Association was then formally established on the 12th of March 1999 in Rome at a special session during the 2nd EuroGOOS Conference following the signing of the MedGOOS Memorandum of Understanding by the founding members. It embraced a partnership of 19 members from 16 riparian countries including non-EU countries namely Morocco, Algeria, Tunisia, Egypt, Lebanon, Albania, Serbia & Montenegro, and Bosnia & Herzegovina.

The Mediterranean Operational Oceanography Network (**MOON**) was established in 2002 by INGV (IT) and MERCATOR (FR) in order to elaborate a unique plan for operational oceanography in the Mediterranean Sea and develop an overall science and strategy plan for the expansion of operational oceanography toward environmental predictions and sustainable development of marine and water resources. MOON was participated by representatives from over 20 laboratories in Europe and EU entering/accessing countries around the Mediterranean. MOON specific objectives were to consolidate and expand the Mediterranean Sea concerted monitoring and forecasting systems, and ensure full integration to the overall operational oceanography global ocean European capacity; then to co-ordinate, improve and harmonize observation and information systems and increase the quality of, and harmonize user-oriented operational products, identify new customers and further develop the market for operational oceanographic products co-operate with UNEP-MAP and other relevant bodies acting at regional level; to improve and further establish services to meet the requirements of environmental and maritime user groups and encourage Mediterranean scientific research on monitoring/forecasting activities and their link with operational oceanographic services; finally to facilitate the availability and dissemination of long term high quality data required to advance the scientific understanding of the Mediterranean Sea and promote the transfer of operational oceanography expertise through training and education. MOON is the coordinating body of the EuroGOOS Mediterranean Task Team and it has developed a MoU between several European operational and research agencies.

Then MONGOOS is now promoting partnerships and capacity building for GOOS in the Mediterranean Sea. MONGOOS shall engage in activities related to the production and use of operational oceanography services in furtherance of four principal objectives:

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1. Improved Fitness for Purpose. Continuously advance the scientific understanding and technological development upon which the Services are based;
2. Greater Awareness. Promote the visibility and recognition of the Services with governmental agencies and private companies, encourage their integration at national, regional, European and global levels;
3. Increased Down-streaming. Enhance the usability of the Services and their usefulness for policy implementation, societal needs and science;
4. Improved Capacity. Support the planning and implementation of international initiatives involving operational oceanography and promote the participation of non-EU Mediterranean countries in producing the Services.

MONGOOS will elaborate a continuous working framework with EuroGOOS and GOOS Africa in order to define common roles and activities in the Mediterranean Sea, and foster collaboration with Black Sea GOOS and global ocean GOOS initiatives.

4.6 Algaline

http://www.itameriportaali.fi/en/tietoa/algaline_seuranta/algaline/en_GB/menetelma/

Algaline is a program which use FerryBox systems to measure chlorophyll-a, salinity, temperature and nutrient concentrations in the surface water using automated flow-through systems installed onboard co-operating merchant ships. In addition, onboard one of the ships a CTD system probes the water column from, and samples are collected for oxygen analyses.

The system runs in the Baltic Sea, operated and maintained by Finnish Environment Institute SYKE. It operates on two FerryBoxes: the ferry Finnmaid travelling twice a week across the Baltic Proper from Helsinki to Travemünde, and the ferry Silja Serenade, travelling nightly between Helsinki and Stockholm. Both ferries operate similarFerryBox systems that measure chlorophyll-a and phycocyanin fluorescence turbidity, temperature and salinity with geo-referenced logging every 20 sec. The depth of the inlet is about 5 m below the surface and the water flow is approximately 2 L/min. At an average speed of 20 knots the spatial resolution of the data is 200 m. The FerryBox systems further include a sequence water sampler storing 24 litres water according to a predetermined sampling scheme (usually every 50 miles). Inorganic nutrients, phytoplankton species composition and chlorophyll-a are determined from the water samples. The flow through measurement data from Finnmaid is transferred every hour through a satellite connection and every morning from Silja Serenade through GSM/GPRS modem to the FTP box. All data is stored in MySQL relational database. Phytoplankton species composition analysis (microscopy) reveals the dominant and potentially toxic/harmful species. Chloropyll-a, nutrients, temperature, and Harmful Algal Bloom (HAB) alert are available through the Baltic Sea Portal (http://www.balticseaportal.fi). Data access also is provided through FTP access.

The system is up and running, operational since May 2002.

4.7 SMOS-BEC

http://www.smos-bec.icm.csic.es/

SMOS (Soil Moisture and Ocean Salinity), launched on November 2, 2009, is the first satellite mission addressing sea surface salinity measurements from space. Its unique payload is MIRAS (Microwave Imaging Radiometer using Aperture Synthesis), a new two-dimensional interferometer designed by the European Space Agency (ESA) and operating at the microwave L-band (1.4 GHz). The radiometric multi-angular measurements along an orbit (1000 km swath), with average spatial resolution of 40 km, are inverted to retrieve sea surface salinity using auxiliary information on sea surface state

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provided by operational weather forecasts. The resulting along-orbit (level 2) salinity products are distributed by ESA (https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/smos).
The SMOS Barcelona Expert Centre generates and distributes global gridded salinity maps (level 3) at different spatial and temporal resolutions, as well as objectively analysed and fused (singularity exponents technique) salinity products (http://www.cp34-smos.icm.csic.es/).
The activities of the SMOS-BEC are mostly funded through the Space Area of the Spanish National R+D plan. The facilities are open to postgraduate students and visiting scientists to develop research on different aspects of SMOS data processing and applications
Some examples of SMOS_BEC products can be found in https://www.youtube.com/user/SMOSBEC

4.8 OceanoScentific Program / Boogaloo

http://www.oceanoscientific.org/en/
The OceanoScientific Program is the set of activities designed to enable the international scientific community to enrich their knowledge about the causes and consequences of climate change, through the repeated collection of quality data (oceanographic and atmospheric) at the ocean - atmosphere interface, especially on sea routes subject to little or no scientific exploration. The main idea was to bring science, sport (commercial sailing), industry and public interest together.
One of these activities is to use ocean-going yachts racing around the world via the three capes (Good Hope in South Africa, Cape Leeuwin in Australia, Cape Horn in South America) to collect information below the southern hemisphere forty-fifth parallel for the benefit of scientists. The yachts sail in areas where few other military, commercial, fishing or even research vessels ever venture.
Particularly in these areas, the knowledge of oceanographic and meteorological data is very poor. Races round the world produces a large data base with good spatial and time resolution.
In addition, sailing yachts have a very good carbon footprint and allow sustainable research. These circumstances make sailing yachts very important ships of opportunity for climate in-situ research.
The first ship equipped was the Boogaloo (owned by SailingOne).
This open sea capable, 54” (15meter) racing yacht made out of carbon fibre has only minimal internal and external equipment to make the ship as light as possible. The flotation depth is only a couple of centimetres and the top speed can exceed 27 kn. Normally, the ship will be in an upright position but roll angles of up to 25 degree are possible. The minimal power supply (only very small generator is available), extreme mechanical conditions and air inside the water intake are the greatest challenges. Installing measurement equipment at the outside directly in the water, due to these high speeds, is not possible. Equipment on this kind of boat must be installed on the inside as flow through system, which are light and with a very small footprint, since nearly no space is available. In addition, the equipment must run nearly completely automatically, because only one person will be on board during such races and has no time to take care. The amount of vibration and shock the equipment is exposed to during the trip and especially during bad weather conditions (which are not unlikely on the southern hemisphere) is enormous and all equipment must be very robust. All these conditions are a big challenge for measurement equipment producers and make only few equipment available suitable to equip this ship.
After checking the market and enquire all major companies only SubCtech was able to construct the required measuring system.
A system collecting oceanographic data for salinity, water temperature, pCO_2, pH and chlorophyll and meteorological data for wind direction and speed, air temperature and humidity was developed by SubCtech in cooperation with SailingOne and already installed and successful tested during several cruises.

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The OceanoScientific® Programme is realized by a consortium of the company SailingOne the research institutes IFREMER and Meteo-France (all France) and the company SubCtech (Germany). It is co-founded by the MARTEC-II program and supported by several organisations such as UNESCO (JCOMMops).
The "Boogaloo" as the first prototype shall attempt ocean races at some point. In addition, in the frame of the OceanoScientific Programme it is planned to equip more yachts and other vessels (http://www.oceanoscientific.org/en/)

4.9 NEMO-FOAM

www.nemo-ocean.eu
NEMO (Nucleus for European Modelling of the Ocean) is a state-of-the-art modelling framework for oceanographic research, operational oceanography seasonal forecast and climate studies. NEMO allows several ocean related components of the earth system to work together or separately. It also allows a two-way nesting via the AGRIF software. It is interfaced with the remaining component of the earth system (atmosphere, land surfaces, etc.) via the OASIS coupler.
The latest release of NEMO is the version 3.2 (December 2009). It includes four engines (or components):

- OPA - the ocean engine;
- LIM2 - the previous version of the Louvain-la-Neuve sea-ice model;
- LIM3 - the latest version of the Louvain-la-Neuve sea-ice model including a new thermodynamics and a C-grid Elasto-Visco-Plastic rheology;
- TOP2 - the passive tracer package including a transport component (TRP), and source/sink associated to CFC and LOBSTER and PISCES biogeochemical models.

These engines can be run in standalone mode, except for sea-ice (work in progress). For ocean and passive tracers, AGRIF package is implemented to use embedded sub-grids.
The NEMO system evolves through the improvement of the existing "engines", the addition of "engines" coming from other models or the creation of new "engines", and the improvement and generalisation of the "environment". NEMO is available as a source code. As improvements are validated, they are implemented in the shared reference. In order to ensure the reliability of the system, to allow projects to find the appropriate version and to keep track of the evolutions, NEMO is under SVN (Subversion control System). NEMO also uses Trac (tracking system for software development projects) to share information on the developments and eventual bugs.
The full description of NEMO (as it has been done for its first version based on OPA version 9.0) is:

- Source codes: an ocean general circulation model (OPA_SRC), its tangent linear and adjoin model (TAM_SRC), on/off-line ocean tracer and biochemistry models (TOP_SRC) and a sea-ice model (LIM_SRC);
- a built-in interface to the OASIS coupler and IOIPSL library;
- scripts to compile, create executables and run the experiment on target platforms;
- pre- and post-processing tools built on IDL (SAXO) to configure input files and analyse output files;
- standard configurations, including a tri-3 polar global ocean (ORCA2). These are provided for illustrative purposes enabling one to verify that the code flow is correct;
- a configuration control system based on SVN;
- on-line and off-line documentation of the model formulation and code.

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5 INFRASTRUCTURES/NETWORKS

5.1 JERICO: Towards a joint European research infrastructure network for coastal observatories

http://www.jerico-fp7.eu/

Around European coastal seas, the number of marine observing systems is quickly increasing under the pressure of both monitoring requirements and oceanographic research. Present demands for such systems include reliable, high-quality and comprehensive observations, automated platforms and sensors systems, as well as autonomy over long time periods. In-situ data collected, combined with remote sensing and models output, contribute to detect, understand and forecast the most crucial coastal processes over extensive areas within the various national and regional marine environments.

Coastal observations are an important part of the marine research puzzle of activities and applications. However significant heterogeneity exists in Europe concerning technological design of observing systems, measured parameters, practices for maintenance and quality control, as well as quality standards for sensors and data exchange. Up to now, the expansion of "coastal observatories" has been driven by domestic interests and mainly undertaken through short-term research projects. Therefore the main challenge for the research community is to increase the coherence and the sustainability of these dispersed infrastructures by addressing their future within a shared pan-European framework.

This was the main objective of JERICO (which will end in 2015), which proposed a Pan European approach for a European coastal marine observatory network, integrating infrastructure and technologies such as moorings, drifters, ferrybox and gliders. Networking activities lead to the definitions of best practices for design, implementation, maintenance and distribution of data of coastal observing systems, as well as the definition of a quality standard. Harmonisation and strengthening coastal observation systems within EuroGOOS regions have been sought. Unique twin Trans National Access experiments has been carried out that revealed the potential of datasets used in synergy. Central coastal infrastructure in Europe were opened for international research. This benefits GMES and the European contribution to climate change research. New joint research has been conducted that identified new and strategic technologies to be implemented in the next generation European coastal observatories. Focus was given on emerging technologies and the biochemical compartment.

JERICO is intended to contribute to the international and global effort on climate change research (GEOSS), to provide coastal data inputs for operational ocean observing and forecasting, and also to answer to some of the needs of the environmental research and societal communities.

5.2 EUROFLEETS 1 and 2: Towards an Alliance of European Research Fleets

http://www.eurofleets.eu/np4/home.html

Marine research needs to come together and work in a holistic fashion with a long-term approach. The EU-funded EUROFLEETS1 project has worked to do just this by creating an alliance of marine research centres across Europe, that is able to work together and share resources, improving the quality of marine research in Europe. The infrastructures required for marine research require a variety of specialised expensive facilities. This includes research vessels, satellites, observation networks, data centres and computing and experimental facilities. Together these tools can make up around 50% of the total running costs of a marine exploration project. Of particular importance are the research vessels which are used to maintain observation systems, monitor oceanographic parameters, implement sophisticated equipment and collect rare and sensitive biological samples.

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However, these vessels are expensive to maintain and operate. Thus EUROFLEETS built a coherent pan-European approach to infrastructure policy. Through enhanced partnership, development and use, solutions were created to meet the many needs of European marine research.

By bringing together marine exploration fleet owners, EUROFLEETS enhanced coordination between fleets and promoted the cost-effective use of their facilities with the scope of supporting the efficient provision of necessary research services for monitoring and sustainable management of regional seas and oceans. This gives also access to all European scientists to these vessels and, in turn, gives support to environmental and biodiversity protection and climate change research.

EUROFLEETS' networking activities aims at creating a common strategic vision for European research fleets and their associated heavy equipment, such as submersible vehicles. This ensures that the best quality research is carried out and should work to avoid duplication of experiments. Moreover, the project provides coordinated infrastructure access to researchers across Europe which allows them to take full advantage of marine research fleet services and facilities. EUROFLEETS also created a set of standards and experimental protocols to be used by all members of the alliance. The implementation of such standards serves to ensure the optimal use of marine research fleets and promote interoperability of equipment. In addition, EUROFLEETS focuses on transnational access and the alliance provides researchers across Europe with access to ocean research vessels and their associated equipment which can be used for a wide variety of different experiments. This also allows researchers to more easily share data and results, providing an overall boost to European research in this field (EUROFLEETS1 has provided scientists 66 fully funded days of ship time on 5 global/ocean class research vessels and 110 days of ship time on 13 regional class ships including the use of large equipment such as ROVs and submersibles). A detailed description of the research vessels participating in the project, their technical capabilities, available scientific instrumentation and equipment, completed by a brief description of the obtainable ship time and area of operation can be found at www.eurofleets.eu.

The objectives of EUROFLEETS2 are:

- Promoting a larger integration of European Global/Ocean and Regional RVs as these two types should be addressed separately for most of the strategic and programming issues. In fact in EUROFLEETS2 a higher participation of RVs is expected: 8 Ocean/Global with 4 new ones; 14 regional RVs with 6 new ones and 6 mobile equipments normally not made accessible on their usual national support vessel;
- Integrating a common polar vision in the strategic vision of the European marine research fleets;
- Promoting exchanges of movable equipment on board European RVs and in doing so fostering high operational interoperability within Europe;
- Integrating the European RVs by coordinating multi-vessels experiments (super-integration) for larger and ambitious marine research missions;
- Initiating operational experimental tests demonstrating the higher interoperability of European fleets;
- Enhancing the impact of research infrastructures on innovation by fostering the involvement of industry with specific activities, both as a user (e.g. development and testing of new equipment or deep-sea exploration for new energy or mineral resources) and as a supplier of such facilities.
- The Club of Interest structured in EUROFLEEST1 will be reinforced and multi-activities will be promoted;
- Making an important step towards a long term sustainable European Marine RVs Infrastructures network and prepare a possible insertion into the ESFRI roadmap.

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5.3 EURO-ARGO: European Contribution to Argo Program

http://www.euro-argo.eu/

Started January 2008 as a FP7 project, Euro-Argo aims at developing a European "infrastructure" for Argo to the level where the European partners have the capacity to procure and deploy about 250 floats per year, to monitor these floats and ensure all the data can be processed and delivered to users (both in real-time and delayed-mode). With a mean float lifetime of 3/4 years, such a European contribution would support approximately 1/4 of the global array and provide an additional 50 floats per year for enhanced coverage in the European and marginal seas. This infrastructure is beneficial to all partners and enables Europe to build and sustain its "fair" contribution to the global array whilst providing enhanced coverage in sea areas of particular European interests (e.g. the Nordic Seas, Mediterranean and Black Seas).

To reach its objectives, Euro-Argo transferred the existing cooperative arrangements of the first Preparatory Phase (January 2008- June 2011) into a body with legal personality separate from its Members. The new European Research Infrastructure Consortium (ERIC) will allow active coordination and strengthening of the European contribution to the international Argo programme. Its aims are:

- to provide, deploy and operate an array of around 800 floats contributing to the global array (a European contribution of ¼ of the global array)
- to provide enhanced coverage in the European regional seas
- to provide quality controlled data and access to the data sets and data products to the research (climate and oceanography) and operational oceanography (e.g. GMES Marine Core Service) communities.

Since 2008 and after a 3-year successful preparatory phase, Euro-Argo ERIC is now able to take up this challenge by responding also to specific European interests for marginal seas and biogeochemical measurements.

The Euro-Argo Research Infrastructure is made up of a Central RI (C-RI) and distributed national facilities. The statutes of Euro-Argo European Research Infrastructure Consortium (Euro-Argo ERIC) apply to the Central Infrastructure. The ***Central RI*** is responsible for the overall coordination of EA-RI. It also participates in the procurement and deployment of floats; it has expertise in all aspects of the programme; it acts as a resource centre for all participants and users. The ***distributed RI*** is the network of participating Agencies, operating with direct national resources. As part of the EA-RI, they agree to a multi-annual commitment of resources (in particular in terms of floats to be deployed and for the data system), and to coordinate their activities through the C-RI.

5.4 EMODNET

http://www.emodnet.eu/

The European Marine Observation and Data Network (EMODnet) is a consortium of organisations within Europe that assembles marine data, data products and metadata from diverse sources in a uniform way. The main purpose of EMODnet is to unlock fragmented and hidden marine data resources and to make these available to individuals and organisations (public and private), and to facilitate investment in sustainable coastal and offshore activities through improved access to quality-assured, standardised and harmonised marine data. EMODnet is an initiative from the European Commission Directorate-General for Maritime Affairs and Fisheries (DG MARE) as part of its Marine Knowledge 2020 strategy.

EMODnet is a long term marine data initiative developed through a step-wise approach. Currently, available data is being used to create medium-resolution maps of all Europe's seas and oceans,

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spanning all seven disciplinary themes - these are expected to be complete in 2014. The next phase of EMODnet will involve the development of multi-resolution sea basin maps, commencing in 2015. Presently, there are six sub-portals in operation that provide access to marine data from the following themes: bathymetry, geology, physics, chemistry, biology, and seabed habitats .

5.5 EMBOS (also research infrastructures and sites)

http://www.embos.eu/

Development and implementation of a pan-European Marine Biodiversity Observatory System (EMBOS) is ESSEM COST Action ES1003. COST is an intergovernmental framework for European Cooperation in Science and Technology, allowing the coordination of nationally-funded research on a European level. General background: Most of the recent large scale FP research actions focus(ed) on the integration of existing data sets and the analysis of the gathered information and not on integrated sampling and monitoring strategies. Often these actions are hampered by the lack of standardized approaches. Therefore, this Action EMBOS will step in-between and fill in this gap by developing tools to gather marine biodiversity information in a standardized way that will better serve large scale and long term biodiversity monitoring and research and in the same way will provide relevant information for policy making and sustainable management and use of marine resources. The requested funding by the Action will support the coordination, implementation and test-phase of the observatory network and related activities. Funding for further measuring and monitoring biodiversity will be obtained from outside sources, mainly through the committed partners and will be embedded in their routine research (and mainly nationally funded, e.g. to support existing legal obligations). The scientific workplan includes four main activities: (i) Re-evaluation of Marine Observatories; (ii) Selection of Biodiversity Indicators.; (iii) Pilot studies Integration; and (iv) Installation of EMBOS.

5.6 SeaDataNet 2

http://www.seadatanet.org/

Pan-European infrastructure for ocean and marine data management
FP7 Infrastructures
CP-CSA-Infra - Combination of CP and CSA
2011-2015

Professional data centres, active in data collection, constitute a Pan-European network providing on-line integrated databases of standardized quality.
The on-line access to in-situ data, meta-data and products is provided through a unique portal interconnecting the interoperable node platforms constituted by the SeaDataNet data centres.
The development and adoption of common communication standards and adapted technology ensure the platforms interoperability. The quality, compatibility and coherence of the data issuing from so many sources, is assured by the adoption of standardized methodologies for data checking, by dedicating part of the activities to training and preparation of synthesized regional and global statistical products from the most comprehensive in-situ data sets made available by the SeaDataNet partners.
Data, value added products and dictionaries serve wide uses: e.g. research, model initialisation, industrial projects, teaching, marine environmental assessment.
The overall objective of the SeaDataNet II project is to upgrade the present SeaDataNet infrastructure into an operationally robust and state-of-the-art Pan-European infrastructure for providing up-to-date and high quality access to ocean and marine metadata, data and data products originating from data acquisition activities by all engaged coastal states, by setting, adopting and

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promoting common data management standards and by realising technical and semantic interoperability with other relevant data management systems and initiatives on behalf of science, environmental management, policy making, and economy.
SeaDataNet is undertaken by the National Oceanographic Data Centres (NODCs), and marine information services of major research institutes, from 31 coastal states bordering the European seas, and also includes Satellite Data Centres, expert modelling centres and the international organisations IOC, ICES and EU-JRC in its network. Its 40 data centres are highly skilled and have been actively engaged in data management for many years and have the essential capabilities and facilities for data quality control, long term stewardship, retrieval and distribution.
SeaDataNet II will undertake activities to achieve data access and data products services that meet requirements of end-users and intermediate user communities, such as GMES Marine Core Services (e.g. MyOcean), establishing SeaDataNet as the core data management component of the EMODNet infrastructure and contributing on behalf of Europe to global portal initiatives, such as the IOC/IODE – Ocean Data Portal (ODP), and GEOSS. Moreover it aims to achieve INSPIRE compliance and to contribute to the INSPIRE process for developing implementing rules for oceanography.

5.7 EurOCEAN conferences

http://www.euroceanconferences.eu/
EurOCEAN conferences are major European marine science policy conferences. They provide a forum for the marine and maritime research community and wider stakeholders to interface with European and Member State policymakers and strategic planners, to consider, discuss and respond to new marine science and technology developments, challenges and opportunities. The distinctive feature that characterizes EurOCEAN conferences is the focus on bringing the stakeholders together to speak with one voice towards policy.
Since 2000, EurOCEAN conferences have been organized by the European Marine Board and the European Commission (DG Research & Innovation) in partnership with the national agencies hosting the event. They are normally organized in association with a country holding the Presidency of the European Union. Since EurOCEAN 2004, conference delegates have delivered joint policy statements, EurOCEAN Declarations, to raise decision makers' awareness of the marine research priorities and propose concrete actions. These statements have been critical drivers of research and policy developments in Europe since.
EurOCEAN 2014 will take place from 7 to 9 October 2014 in Rome, Italy, as an official event of the Italian Presidency of the Council of the European Union. EurOCEAN 2014 is the 8th conference of the successful EurOCEAN series initiated in the 1990s. Previous conferences were held in Brussels (1993), Sorrento (1995), Lisbon (1998), Hamburg (2000), Galway (2004), Aberdeen (2007) and, most recently, Ostend (2010).

5.8 MARS

http://www.marsnetwork.org/
The MARS network (The European Network of Marine Research Institutes and Stations) is a foundation created by, and open to, Europe's marine research institutes and stations. Members are world leaders in fundamental marine research and have important research facilities available that allow direct access to the sea. The network serves furthermore as a forum and as an interest group and communicates with international organisations and the managers of European research, including the Commission of the European Community in Brussels. Members are located all over Europe, along the shores of the Atlantic Ocean, the North, Irish, Baltic and Adriatic Seas, and the Black and Mediterranean Seas. The network aims to provide a platform which helps to delineate

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overarching marine research themes, to promote cooperation, and to share relevant expertise and facilities in the marine realm. The MARS marine research stations are able to fulfil these roles, because they do offer:

• Easy access to (sample, monitor, observe) marine ecosystems and marine (model) organisms, with a large geographic coverage all over the coastline provided by the many members in 25 European countries.
• Facilities to study organisms in their natural habitat.
• Support bases for research vessels, boats, OOS, buoys, cabled arrays, submersibles, ROV's, diving
• Laboratories and experimental facilities.
• Valuable (historical) long term data series, often stretching back more than 100 years
• Home to experts in taxonomy, ecology, oceanography, biology etc., yielding expertise and a broad view on the status of European coastal ecosystems.
• Facilities for hosting, catering and accommodation for individual researchers, research groups, students, university courses etc, often in all seasons (classes, field trips, tours, internships).

MARS ended in 2002 and has been incorporated into EMBOS.

5.9 EuroMarine Network

http://www.euromarinenetwork.eu/

EuroMarine (which the EuroMarine project defined from 2011 to 2013) is a European Marine Science network which replaces three former Networks of Excellence (EUR-OCEANS - impacts of global change on pelagic ecosystems -, MarBEF - marine biodiversity - and Marine Genomics Europe - high throughput approaches for marine biology), as well as their follow-up structures (the EUR-OCEANS Consortium and the MarBEF+ Association). Implemented as a new consortium, it was launched in April 2014. It is backed up by a legal, non-profit entity in charge of daily management. The nature and purpose of the EuroMarine Network are: (i) Long lasting integrative marine sciences network; (ii) Operational platform to ensure that bottom-up approaches and initiatives in the marine field are well balanced and complementary to top-down existing structures and initiatives; (iii) Research targets: research, access to research infrastructures and mobility, transfer of knowledge, policy advice and information; (iv) Key activities will deliver: products and services for the benefit of the European marine and research communities in relation to science-policy interfaces, infrastructures, training, education and expertise.

5.10 LifeWatch

http://www.lifewatch.eu/it

LifeWatch is the European e-Science infrastructure for biodiversity and ecosystem research meant to provide advanced capabilities for research on the complex biodiversity system. The term 'research infrastructure' refers to strategic installations at European/international level supplying facilities, resources and related services to the scientific and other user's communities to conduct top-level activities in their respective field of science. On the top of that, e-Science infrastructures capitalise existing resources and data from physical infrastructures, distributed centres and single research groups. The capabilities offered by the LifeWatch, as an e-Science infrastructure, allow users to tackle the big basic questions in biodiversity, as well as addressing the urgent societal challenges concerning biodiversity, ecosystems and other crosscutting issues.

5.11 GEO BON (International)

https://www.earthobservations.org/geobon.shtml

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The Group on Earth Observations Biodiversity Observation Network – GEO BON – coordinates activities relating to the Societal Benefit Area (SBA) on Biodiversity of the Global Earth Observation System of Systems (GEOSS). Some 100 governmental, inter-governmental and non-governmental organizations are collaborating through GEO BON to organize and improve terrestrial, freshwater and marine biodiversity observations globally and make their biodiversity data, information and forecasts more readily accessible to policymakers, managers, experts and other users. Moreover, GEO BON has been recognized by the Parties to the Convention on Biological Diversity. The Biodiversity Observation Network is both a Community of Practice and a Task in the GEO Work Plan. It is a voluntary partnership that is guided by a steering committee comprising the key stakeholders, including DIVERSITAS, GBIF, IUCN, NASA, UNEP-WCMC and others. GEO BON draws on GEO's work on data-sharing principles to promote full and open exchange of data, and on the GEOSS Common Infrastructure to enable interoperability through adoption of consistent standards. The main objectives of GEO BON are to be an operational international framework in order to: (i) provide a global, scientifically robust framework for observations on the detection of biodiversity change; (ii) coordinate the data gathering and coordinate the delivery of information (GBIF); (iii) help to ensure long term continuity of data supply (operational observations); (iv) to provide a set of innovative and relevant – global products. Users of GEO BON include: international treaty processes (CBD, CCD, CITES, Ramsar, CMS), biodiversity and conservation organisations (e.g. UNEP-WCMC, IUCN, CI, WCS, TNC, etc.), conservation agencies and biodiversity custodians (governments), and researchers. Marine products include: Global (CPR plankton) ocean Ecological Status Report; Assessment of population time-series datasets and monitoring stations; Gaps maps: where there is and is not ground-truth data for marine biodiversity over time; by country and/or sea or region; by ecology; Global bacterial richness assessment map and link to ecosystem function and services; Compendium of global environmental data layers (models) including future scenarios on a website; Website providing free access to digital marine maps and resources (VLIZ); Descriptions of ocean environmental and species data (and hotspots) that inform EBSA; Plan for how to monitor ocean biodiversity at global level; Future marine benthic biodiversity (spatial extent, biomass); Global map of marine ecosystems underpinned by environmental data using GEO Ecosystems approach. Major activities include the identification of Ecosystem Essential Ocean Variables (EOVs) and Essential Climate Variables (ECVs). The latter include Atmosphere surface: Air temperature, Precipitation, Air pressure, sea level pressure (SLP), Surface radiation budget, Wind speed and direction, Water vapour, Ocean surface: Sea surface temperature (SST), Sea surface salinity (SSS), Sea level, Sea state, Sea ice, Current, Ocean colour (for biological activity), Carbon dioxide partial pressure (pCO2), Ocean subsurface: Temperature, Salinity, Current, Nutrients, Carbon, Ocean tracers, Phytoplankton.

5.12 SEAS-ERA

http://www.seas-era.eu/np4/homepage.html
Towards Integrated Marine Research Strategy and Programmes
FP7 ERA-NET
Coordination and support action
2010-2014

The main objectives to be attained by Seas-Era were the definition of a European Marine and Maritime research agenda, aiming at improving co-operation and co-ordination and promoting harmonisation of national/regional research programmes; foster synergies at national and regional level, mobilising competitive and non-competitive funds for research in a more coordinated way, through joint calls and common programs; propose a plan for a better and sustainable use and sharing of the existing Marine Research Infrastructures, and a road map for new investments; reduce

imbalances among regions through human capacity building, setting-up a pan-European training and mobility strategy for human resources; and enhance public awareness towards marine and maritime scientific and policy issues in Europe to translate the RTD activities into social, economic and cultural benefits. These general objectives were to be first implemented at the basin scale as a step forward in building-up the overarched pan-European strategy and making progress in establishing a stable and durable structure for empowering and strengthening marine re-search all across Europe.
Since the launch of the initiative, in 2010, Seas-Era has contributed to:

- Consolidate and expand the network of Marine Research Funding Organisations (RFOs) built on previous FP6 ERA-Net partnerships: AMPERA, MarinERA and MariFISH;
- Delineate a Vision for each of the three Sea Basins studied (the Atlantic, the Mediterranean and the Black Sea), to be developed through mutually agreed Sea Basin Research Strategies / Agendas;
- Set-up an Inventory of European Marine Research Infrastructures, further developed by EurOcean into an on-line database: http://rid.eurocean.org/;
- Identify potential topics for Common Programming in the North Atlantic and Mediterranean Sea, and confirm the ability of the Seas-Era partnership to undertake joint funding (€4.4 million) of collaborative research projects;
- Make recommendations for strengthening Human Capacity Building, in particular by facilitating the completion of PhD fellowships within collaborative projects;
- Enhance public awareness towards marine and maritime scientific and policy issues in Europe, to translate the RTD activities into social, economic and cultural benefits.

6 VESSELS

This section will describe in detail the vessels available to the COMMON SENSE consortium, which were briefly described in D2.2

6.1 RV URANIA (CNR)

The Research Vessel URANIA is managed by the National Research Council of Italy (CNR). It is self-sufficient for about 45 days and can accommodate a maximum of 36 people between scientific staff and crew. The range of speed for the continuous detection varies between 1.5 and 11 knots. The propulsion system consists of two variable pitch propellers driven by two motors 1000 KW and 220 KW from the forward propeller. The ship is equipped with a dynamic positioning system Simrad precision maneuvers. The ship has laboratories for analysis, geological sampling, chemical and radiological laboratories and enables the processing of navigation data, geophysical and those acquired with the R.O.V. (Remote Operated Vehicle) and with the multiparametric probe (CTD). The geophysical instruments include a Chirp Datasonic profiler, one Sparker, a 3.5 KHz SubBottom Profiler, a Uniboom, a 100-500 kHz Side Scan Sonar and a magnetometer. Regarding sampling systems (up to the maximum operating depth of the Mediterranean) are available in gravity and piston samplers, box corer, buckets (Shipek and Van Veen) and dredges. It is also possible to use multisamplers, CTDs and devices for biological analysis.
Its main characteristics are:

- IMO: 9013220
- Name: URANIA
- MMSI: 247498000
- Type: RESEARCH/SURVEY VESSEL
- Total length 61.30 m
- Width 11.10 m

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- Draft min/max 3.10 - 3.60 m
- GRT: 1115 t
- Summer DWT: 470 t
- Build: 1992
- Flag: ITALY
- Home port: NAPOLI

6.2 Sarmiento de Gamboa (CSIC)

Designed for the study of global oceanic circulation, biodiversity, fishing resources, climate change and the exploration of oceanic seabeds and their resources, the Spanish Oceanographic Research Vessel Sarmiento de Gamboa was launched on 30th January 2006 in the presence of Her Majesty Doña Sofía. It is considered a Large-Scale Scientific Facility and incorporates state-of-the-art navigation system technologies (e.g. dynamic positioning) and scientific equipment, and is also the first Spanish oceanographic research vessel that will be able to work with unmanned and submersible ROVs (Remote Operated Vehicles) at depths of up to 6km, and with AUVs (Autonomous Underwater Vehicles).

Also, It is a multidisciplinary research vessel, equipped for, oceanography, geology, geophysics, hydrography, and fisheries research, it has a wide variety of scientific and technical equipment for Geophysics, Oceanography, Marine Biology and Geochemistry, as well as several science laboratories on board (250 m2) including a wet lab and a CTD Hangar (55 m2), different freezing storage (50 m2) is a "quiet" vessel in terms of radiated noise to water.

The Sarmiento de Gamboa is a multipurpose Oceanographic Research Vessel operating worldwide, apart from the Polar regions. With a total length of 70.5m, a beam of 15.5m and maximum speed of 15 knots, it has autonomy for up to 40 days with 31 persons onboard (6 officials, 10 crew and a maximum of 25 scientific personnel).

<u>Onboard scientific equipment:</u>
The ship is equipped with an acoustic "gondola" with Multibeam (shallow and deep waters), single beam (hydrographical) and parametric echosounder transducers installed on the lower surface, which provides very high resolution seafloor mapping and penetration into sub bottom surface respectively. This "gondola" is an "airplane-like" structure mounted on the hull. This structure is separated from the hull avoiding the bubbles produced by the bow of the ship that could affect the acoustic transducers installed on the lower surface. The ship also has two drop keels installed in the middle part of the ship. They can be lowered 3 meters below the keel to separate the transducers installed from the hull, avoiding the acoustic noise produced by water flux and from hull itself. The complete list of equipment is as follows:
Simrad EA600 (12 / 200 kHz). Hydrography single beam echosounder Installed on gondola
Simrad EK-60 (18 / 38 / 120/ 200 kHz.) Biologic echosounder. Installed on drop keel
Atlas DS (15 kHz). Deep water Multibeam echosounder Installed on gondola.
Atlas MD (50 kHz). Medium / shallow water multibeam echosounder. Installed on gondola.
Atlas P35 (18 kHz). Parametric Subbottom Profiler. Installed on gondola.
RDI 75/150 kHz. ADCP Installed on gondola.
IXSEA Posidonia. Acoustic Underwater Ultra Short Baseline (USBL) positioning. Installed on gondola.
Scanmar net sensors (Trawl eye / Depth / Catch / Tension / Speed / Distance-Depth) with shipborne transducers installed on drop keel.

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CTD, LHPR, SeaSoar from near the surface to depths down to 500 meters while moving at speeds up to 12 knots.

Deck equipment: Cranes and Winches CTD 8000 m. Coax Ø 11 mm Plankton sampling 6000 m / Ø 6 mm Coring 8000 m / Ø 16 mm Elect. Nets 7000 m / Coax Ø 14 mm 2 x mobile 20 ton trawling Multipurpose Cranes Aft A- frame Main crane (12Tons) Starboard A-Frame 2 x Aux. Cranes CTD Telescopic Crane

IMO: 9335238
Name: Sarmiento de Gamboa
MMSI: 224713000
Call ID: EAKF
Type: Research/Survey vessel
Total length: 70.50 m
Width: 15.50 m
Draft: 4.90 m
GRT: 2754 t
Summer DWT: 850 t
Power: 3x1400 kw Diesel
Propeller: 2x1200 kw DC
Service speed: 15 kn
Range of operation: 11500 nm @ 12 knots /40 days
Build: 2007
Flag: Spain
Home port: VIGO
Crew: 21
Scientist berths: 25

6.3 Aldebaran (Germany)

The multi-purpose sailing vessel, “Aldebaran“ was in 1992 Europe’s only floating radio studio and laboratory and is nowadays a multimedia platform. It is 46 foot long and due to its design it is not only suitable for all kinds of open ocean research (Marine Biology, Geology, Palaeontology and Landscape Ecology), but also provides a perfect platform for shallow coastal, reef and river based research. In addition, it can go aground in tidal waters, without tilting to one side. The relative small size allows a use of the ship all around the world, since it can be easily shipped in transportation ships. This ship has space for 2 crew members and a scientific/editorial team of 4 to 6 members.

For this purpose the ship is equipped with a variety of equipment regarding scientific and multimedia applications.

Inside the ship there is a complete professional television editing area, wet and dry laboratories with a variety of materials (collection jars and flasks), Leica binocular microscope with an attached 3-CCD microscope camera and a flow-through system (with stainless steel pipe into the sea water) available. Different oceanographic and meteorological data are collected by default (e.g. pH, temperature, wind speed and direction).

Diver and equipment like underwater cameras can easily access the water at the rear side of the ship. Landing nets, collection networks and a manual operating crane as well as diving equipment is available. The equipment can be adjusted regarding the need of the scientist.

Using a sailing ship for research is especially interesting for noise and behavioural research of animals, since no engine sound will disturb the environment even when the ship is moving. In

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addition, the ship has a very low CO_2 footprint which fulfills the requirements for sustainable research.
The "Aldebaran" is operated by the non-profit organization ALDEBARAN, based in Hamburg Germany. Due to this fact the schedule of the ship has great flexibility and offers the possibility to plan and attend trips on short notice.
The ship is used by scientists (e.g. from the Max-Planck Institute in Hannover) and camera crews/journalist (e.g. ZDF and Deutsche Welle) all around the world for research and shots equally. In addition, the ALDEBARAN organization is not only active in terms of environmental projects but also supports youth work in different projects. One of these projects is the "Meereswettbewerb", which allows pupil to perform their own research on board of the "Aldebaran" for one week.
The company SubCtech located in Kiel / Germany has already tested the "Aldebaran" as a platform for research equipment. Small flow-through measuring systems were successful tested during several "Meereswettbewerb" events. With support of scientific institutes (GEOMAR Germany, IFREMER France, UniMaine USA) oceanographic parameter such as pCO2, turbidity, salinity, algae-fluorescence can be acquired on board. Young and inexperienced students were able to operate the equipment even during stormy conditions in the Wadden Sea, North Sea and Baltic Sea.

6.4 RV OCEANIA (IOPAN)

The Research Vessel OCEANIA is owned by Institute of Oceanology, Polish Academy of Sciences, Poland. Oceania was built in 1985 and massively reconstructed in 2010 (sails, propulsion, bridge).
She is a 3-mast vessel, 32m tall, with 280 m^2 sails enabled with electric setting.
General specification of the vessel:

- Harbour: Gdańsk - Nowy Port,
- Call sign: SQOC,
- Dimensions: 48.9 m / 9.0 m / 3.9 m,
- Displacement: 370 T,
- Main engine: Diesel, 600 kW MTU,
- Bow thruster: 51 kW,
- Generator: 110 kW,
- Cruising speed: 9 knots,
- Max. speed: 12 knots with endurance of 1 month and unlimited range (except polar area in winter).

The vessel has 13 persons regular crew and can accommodate 14 scientists.

Deck equipment consists of rotating stern frame 6 m height with 2.5T load capacity, 2 side frames, 3 booms for measurement purposes, 2 yards for measuring equipment, 2 deep lifts RAPP- HYDEMA 5000 m and 2000 m ø6, 2 shallow lifts 300 m ø6 and ø10 x 6 wires, 2 net lifts 500 m ø3, 300 m ø5, elevator trawl 2000 m ø10, hydraulic crane with 1T load capacity, 2 RIBs 4.8 m equipped with 40 KM YAMAHA engines.

Research equipment onboard: CTD SEA-BIRD 911 plus, CTD SEA-BIRD SBE 49, CTD 606+ VALEPORT, Current Meter 308 VALEPORT, Current Meter 808 VALEPORT, ADCP Current Profiler RD Instruments, Batfish system, Set of pyranometers KIPP&ZONEN and EPPLEY LABORATORY, Absorption and Attenuation Meter AC9 WET LABS, Marine Spectroradiometer MER-2040 BIOSPHERICAL INSTRUMENTS INC., Ocean Colour Profiling System OCP-100 SATLANTIC, Laboratory UV-VIS Spectroradiometer 4-100 UNICAM, Submerged Fluorometer Pump-Probe ECOMONITOR, Aerosol Particle Counter PARTICLE MEASURING SYSTEMS, Aerosol Lidar FLS-12, Scientific Echosounder DT-X

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BioSonics, Scientific Echosounder EK 500 Simrad, Sidescan Sonar DF 1000 digital EdgeTech, System for non-linear bubble detection, Carousel Water Sampler SEA-BIRD SBE32, Nemo Sampler, Box Corer, Van Veen Bottom Sampler, Oil Pollution Lidar FL-UV, Bongo Macroplankton Net, WP2 Mesozooplankton, Multi Plankton Sampler Midi HYDROBIOS, Epibenthic Sledge.

7 CONCLUSION

The issue of Marine Research Infrastructure was brought to the public discourse as a result of introduction of MSFD, which has obliged Member Countries and, consequently, relevant national agencies to fulfil the agreed goals and targets. In this top-down process the pan-European initiatives were deployed as a vehicle for infrastructure development. The "Infrastructure" in a broad sense – from sensors through the instruments, platforms, data transmission, to data processing and storage systems but also observation sites and laboratories. The basic units in this processing chain are the sensors. Their quality, power-efficiency, miniaturization, ability of integration and interoperability with variety of existing systems and instrumentation to great extent facilitate reaching the targets described as GES. It is expected that goals set by MSFD and [over]ambitious levels of GES descriptors will boost innovation and will help to fill the gaps in ocean observations by developing promising technologies (e.g. marine contaminants detectors, new methods of acoustic observations). This development can make a major breakthroughs also in relation to ocean resources or in research on pressures on environment.

However, the majority of the identified initiatives are focused on broadening the cooperation by establishing systems of joint use and access to research infrastructures, data exchange and sharing, exchange of expertise or integration of existing systems. Very few of them are actually devoted for sensors development. In that respect the COMMON SENSE project offers valuable input to the core of above-mentioned process by offering cost-effective, integrated, miniaturized sensors which currently are not present on the market.

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9 ACRONYMS

ADCP	Acoustic Doppler Current Profiler
AIC	Argo Information Centre
ATLAS	Autonomous Temperature Line Acquisition System
AUVs	Autonomous Underwater Vehicles
AVHRR	Advanced Very High Resolution Radiometer
CA	Concerted Action
CDOM	Colored Dissolved Organic Matter
CTD	Conductivity-Temperature-Depth
DG MARE	European Commission Directorate-General for Maritime Affairs and Fisheries
ESFRI	European Strategy Forum on Research Infrastructures
ECVs	Essential Climate Variables
EOVs	Essential Ocean Variables
EuroDeSS	European Decision Support System
EuroMISS	European Marine Information System of Systems
ERIC	European Research Infrastructure Consortium
GBIF	Global Biodiversity Information Facility
GCOS	Global Climate Observing System
GDACs	Global Data Assembly Centers
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GEWEX	Global Energy and Water Cycle Experiment
GMES	Global Monitoring for Environment and Security
GODAE	Global Ocean Data Assimilation Experiment
GOOS	Global Ocean Observing System
GTMBA	Global Tropical Moored Buoy Array
GTS	Global Telecommunications System
GTSPP	Global Temperature Salinity Profile Programme
IGBP	International Geosphere-Biosphere Program
IndOOS	Indian Ocean Observing System
INSPIRE	Infrastructure for Spatial Information in the European Community
IOC	Intergovernmental Oceanographic Commission
IODE	International Oceanographic Data and Information Exchange
IUCN	International Union for Conservation of Nature
JAMSTEC	Japan Agency for Marine-Earth Science and Technology

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JCOMM	Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology
LIDAR	Light Detection and Ranging
MEDS	Marine Environmental Data Service
MIRAS	Microwave Imaging Radiometer using Aperture Synthesis
MRI	Marine Research Infrastructure
MSFD	Marine Strategy Framework Directorate
NDBC	National Data Buoy Center
NODCs	National Oceanographic Data Centres
NEMO	Nucleus for European Modelling of the Ocean
NOAA	National Oceanic and Atmospheric Administration
NODCs	National Oceanographic Data Centres
NRT	Near Real Time
ODP	Ocean Data Portal
OOSDP	Ocean Observing System Development Panel
OFEG	Ocean Facilities Exchange Group
OceanSITES	Ocean Sustained Interdisciplinary Time Series Environment Observation System
PAHs	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated Biphenyl
pCO2	Carbon dioxide partial pressure
PIRATA	Prediction and Research Moored Array in the Tropical Atlantic
PMEL	Pacific Marine Environmental Laboratory
PMO	Port Meteorological Officers
QC	Quality Control
RAMA	Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction
RI	Research Infrastructure
RFOs	Research Funding Organisations
ROVs	Remotely Operated Vehicles
SES	Southern European Seas
SMOS	Soil Moisture and Ocean Salinity
SOOP	Ships of Opportunity Programme
SOOPIP	Ship Of Opportunity Programme Implementation Panel
SOT	Ship Observations Team
SPM	Suspended Particulate Matter
SSG	Scientific Steering Group
SSS	Sea Surface Salinity
SLP	Sea Level Pressure
SST	Sea Surface Temperature
SUDOE	Programme of the European Territorial Cooperation Southwest
TAO	Tropical Atmosphere Ocean
TNA	Transnational Access
TOGA	Tropical Ocean and Global Atmosphere
TRITON	Triangle Trans Ocean Buoy Network
TSG	ThermoSalinoGraph
UNEP-WCMC	United Nations Environment Programme's World Conservation Monitoring Centre
WCRP	World Climate Research Programme
WFD	Water Framework Directive
WOCE	World Ocean Circulation Experiment
XBT	Expendable bathythermograph

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XCTD	Expandable Conductivity, Temperature and Depth profiling system

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10 APPENDIX A. ARGO

10.1 Introduction

Argo is a global array of profiling floats for observing temperature, salinity and ocean currents. Argo has been operational since the early 2000s, and provides real-time data for climate and oceanographic research. The array of approximately 3,600 floats provides 100,000 temperature/salinity profiles and velocity measurements per year distributed over the global oceans at an average 3-degree spacing. All data collected by Argo floats are publically available in near real-time via the Global Data Assembly Centers (GDACs) in Brest, France and Monterey, California after an automated quality control (QC), and in scientifically quality controlled form, delayed mode data, via the GDACs within one year of collection.

10.1.1 Organisation

The Argo program is a collaborative partnership of more than 30 nations, with the aim of providing a seamless global array exploring the ocean environment. Argo is a key component of the Global Ocean Observing System (GOOS), and is coordinated by the Argo Steering Team – an international body of scientists and technical experts that meets annually. The Argo data stream is managed the Argo Data Management Team. Overall coordination is provided through the Argo Information Centre, an office belonging to the Intergovernmental Oceanographic Commission which also coordinates GOOS, and the World Meteorological Organization. Argo is also supported by GEO (the Group on Earth Observations), and has been endorsed since its early beginnings by the World Climate Research Programme's CLIVAR Project (Variability and predictability of the ocean-atmosphere system), and by the Global Ocean Data Assimilation Experiment (GODAE OceanView).

10.1.2 Objectives

Objectives

The stated objectives of the Argo program include:

- Providing a quantitative description of the changing state of the upper ocean and the patterns of ocean climate variability from months to decades, including heat and freshwater storage and transport.
- Providing data to enhance the value of the Jason altimeter through measurement of subsurface temperature, salinity, and velocity, with sufficient coverage and resolution to permit interpretation of altimetric sea surface height variability.
- Using Argo data for initializing ocean and coupled ocean-atmosphere forecast models, for data assimilation and for model testing.
- Documenting seasonal to decadal climate variability and aiding the understanding of its predictability.

10.2 ARGO SYSTEM

10.2.1 Argo Float Design

Argo collects high-quality temperature and salinity profiles from the upper 2000m of the ice-free global ocean. The data come from battery-powered autonomous floats that spend most of their life drifting at depth where they are stabilised by being neutrally buoyant at the "parking depth" pressure by having a density equal to the ambient pressure and a compressibility that is less than that of sea water. At present there are several models of profiling float used in Argo. All work in a similar fashion but differ somewhat in their design characteristics. At typically 10-day intervals, the

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floats pump fluid into an external bladder and rise to the surface over about 6 hours while measuring temperature and salinity. Satellites or GPS determine the position of the floats when they surface, and the floats transmit their data to the satellites. The bladder then deflates and the float returns to its original density and sinks to drift until the cycle is repeated. Floats are designed to make about 150 such cycles.

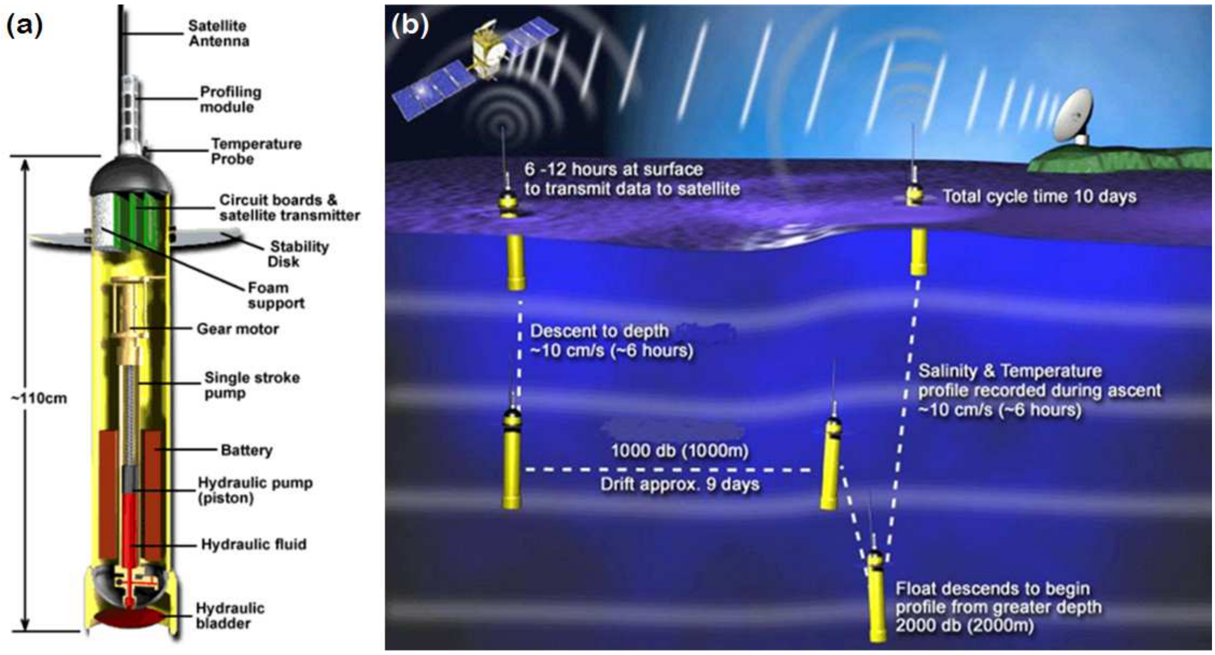

Figure 1 (a) Design of a typical Argo float. Weight: 25 Kg (approx.); Maximum operating depth: 2000m; Crush depth: 2600m. (b) Profile of a standard Argo float mission. Images from: http://www.argo.ucsd.edu/How_Argo_floats.html

Float designs used in the Argo program include:

- PROVOR and ARVOR floats built by NKE-INSTRUMENTATION (France)
- APEX float produced by Teledyne Webb Research Corporation (USA)
- SOLO float designed and built by Scripps Institution of Oceanography (USA)
- SOLO-II float built by MRV Systems (USA)

The Sea Bird Electronics [http://www.seabird.com] temperature and salinity sensor suite is used almost exclusively.

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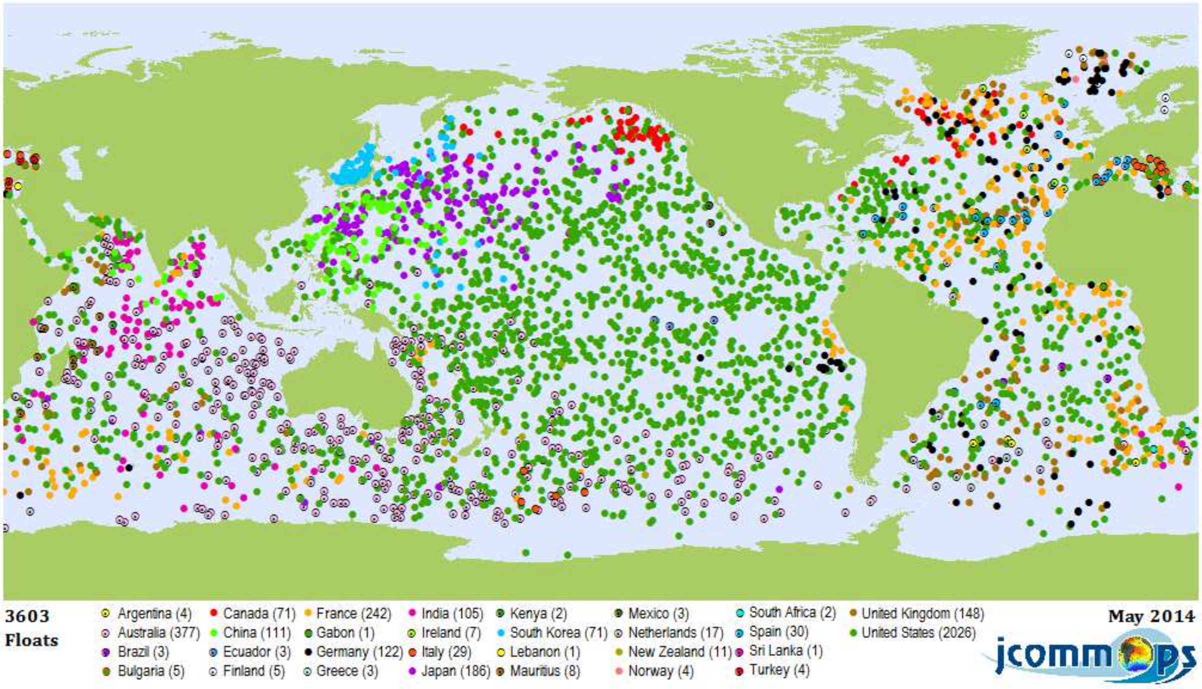

Figure 2. Distribution of active floats in the Argo array, colour coded by country that owns the float, at the end of May 2014. Adapted from http://www.argo.net.

10.2.2 *Data Transmission*

As the float ascends, a series of about 200 pressure, temperature, salinity measurements are made and stored on board the float. These are transmitted to satellites when the float reaches the surface. For floats using high speed communications with more bandwidth capabilities, measurements are taken more frequently, often up to every 2db, resulting in several hundred measurements per profile. For 70% of floats in the Argo array the data are transmitted from the ocean surface via the Système Argos location [http://www.argos-system.org] and data transmission system. The data transmission rates are such that to guarantee error free data reception and location in all weather conditions the float must spend 6 to 12 hrs at the surface. Positions are accurate to approximately 100m depending on the number of satellites within range and the geometry of their distribution.

An alternative system to using positions from the Global Positioning System (GPS) and data communication using the Iridium satellites now comprises 30% of the Argo array. Iridium [http://www.iridium.com] allows more detailed profiles to be transmitted with a shorter period at the surface and also enables two-way communication. In 2013, 60% of floats were being deployed with Iridium antennas and 40% with Argos antennas.

10.2.3 *Data System*

When a float surfaces, the data is transmitted and the float's position is determined either by Système Argos or by GPS. The Système Argos data are monitored by the Argo Information Centre (AIC) in France and then received by national data centres (DACs). The data from floats using other communications systems may go directly to the float's owner or to the AIC before arriving at the DACs. At the DACs, they are subjected to initial scrutiny using an agreed upon set of real time quality control tests where erroneous data are flagged and/or corrected and the data are passed to Argo's two Global Data Assembly Centers (GDACS) in Brest, France and Monterey, California. The GDACs are the first stage at which the freely available data can be obtained via the internet. The GDACs

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synchronize their data holdings to ensure consistent data is available on both sites. The data reach operational ocean and climate forecast/analysis centres via the Global Telecommunications System (GTS). The target is for this "real-time" data to be available within approximately 24 hours of their transmission from the float.
In addition to the real-time data stream, Argo can, after careful data assessment, provide salinity/temperature/pressure profiles that approach ship-based data accuracy.

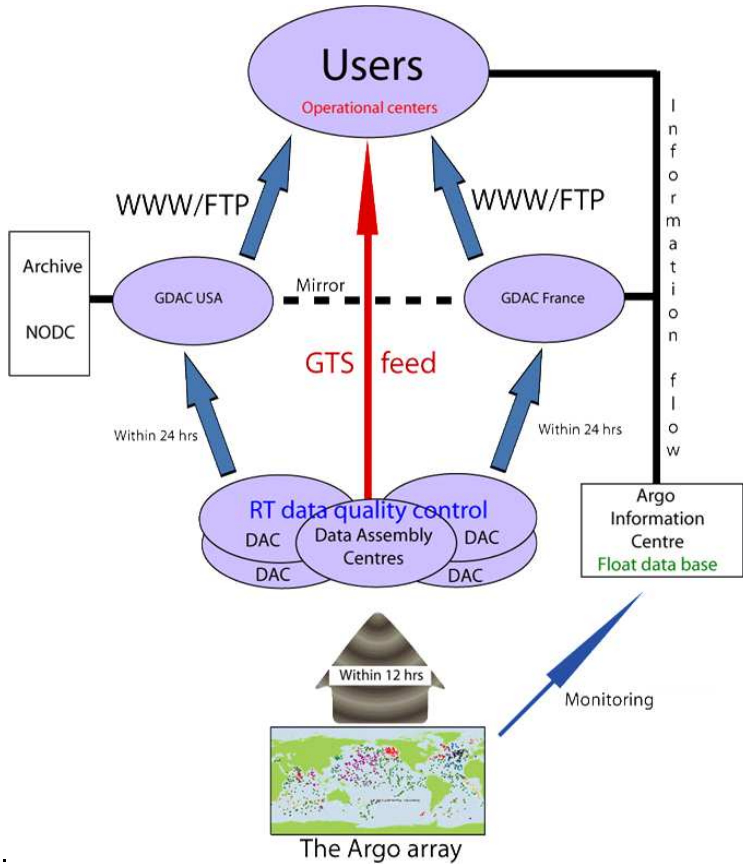

Figure 3. Argo data system

10.2.4 *Argo Real Time Status Viewer*

The Argo Real Time Status Viewer [http://w3.jcommops.org/website/Argo/viewer.htm] provides an online portal on which the real time status of Argo floats can be accessed. The zoomable map-based interface has a number of functions and layers which can be used to identify float characteristics such as model, location, communications mode, deployment date, etc. as well as adding layers such as bathymetry, float trajectories, and planned deployments. A screen capture from the Argo Viewer is shown in Figure 4.

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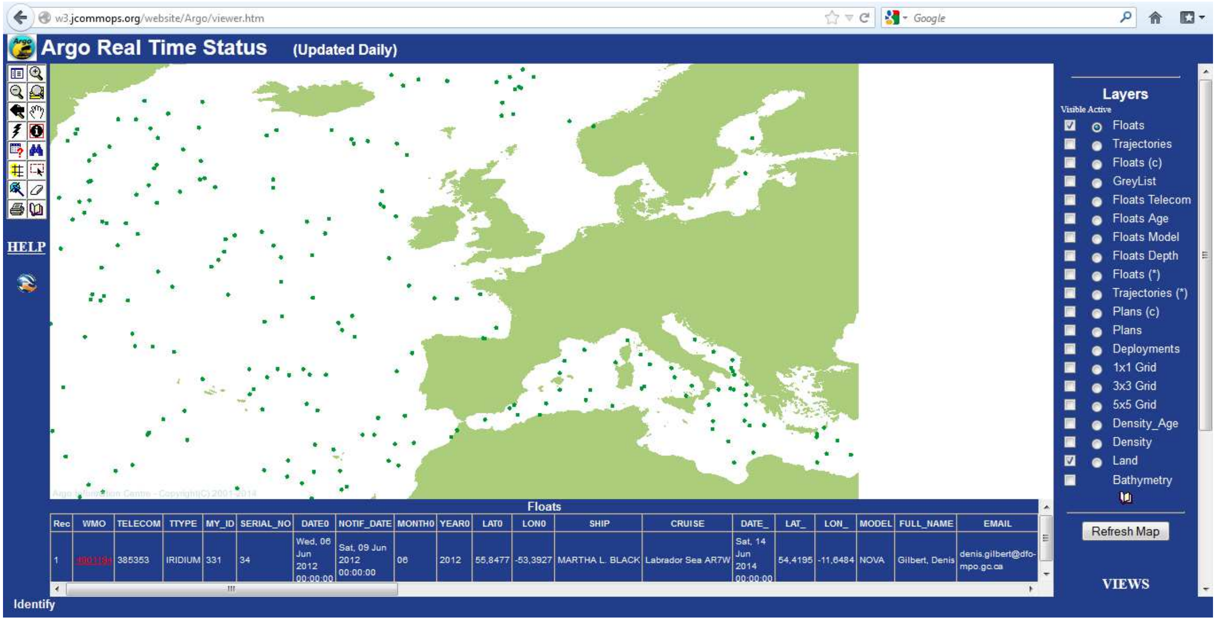

Figure 4. Screen capture of the Argo Real Time Status Viewer.

10.2.5 *Use of Argo Data*

Profiling float data have a large range of applications. As the float array grows and Argo data become more abundant there is an increasing body of scientific literature based wholly or partly on Argo. Applications of Argo data have been highlighted in Argo's Science Workshops held in Tokyo, Japan (2003); Venice, Italy (2006); Hangzhou, China (2009); and Venice, Italy (2012). Argo data use falls into three main categories: educational uses, operational uses and research uses.

<u>Educational Uses</u>

Argo provides a relevant, global ocean data set which can be used for educational purposes at a range of levels. Approaches to the use of Argo data in education include:

- Developing educational material for classroom use.
- Outreach workshops which target the scientific community. Scientists who want to learn more about how to obtain, map, and analyze Argo data are invited to participate.
- Developing user-friendly online resources, such as in Google Earth and Wikipedia, which allow the public, in general, to educate themselves about Argo.

<u>Operational Uses</u>

Centres in Australia, France, Italy, Japan, Norway, the UK and the USA routinely produce global and regional analyses of subsurface properties using the Argo data stream. These are available online [http://www.argo.ucsd.edu/Use_by_Operational.html] and will give early warning of significant temperature and salinity anomalies and changes in ocean circulation.

Examples:

- In the Gulf of Alaska and around Japan, Argo data is being used to aid the monitoring of environmental conditions that affect fish stocks and biological productivity.
- Each summer the UK Met Office issues a forecast of conditions for the following winter based on the subsurface temperatures in the Atlantic Ocean. Argo data now allow these forecasts to be made with greater confidence.

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- At short time scales, Argo data have been used to study the evolution of near-surface temperature and salinity beneath tropical cyclones. The data show clear temperature differences left and right of the cyclone track, but produce conflicting patterns of salinity change.

Research Uses

Over 200 research papers per year are now being published using Argo data covering a broad range of topics including water mass properties and formation, air-sea interaction, ocean circulation, mesoscale eddies, ocean dynamics, seasonal-to-decadal variability, and global change analysis.

A key objective of Argo is to observe ocean signals related to climate change. This includes regional and global changes in ocean temperature and heat content, salinity and freshwater content, the steric height of the sea surface in relation to total sea level and large-scale ocean circulation.

The global Argo dataset is not yet long enough to observe global change signals, as seasonal and interannual variability dominate the present 10-year globally-averaged time series. Analyses of decadal changes presently focus on comparison of Argo to sparse and sometimes inaccurate historical data.

Examples from the different ocean basins (Atlantic, Indian, Pacific and Southern Oceans), showing some applications of data from Argo and from other profiling floats, are provided at: http://www.argo.ucsd.edu/Research_use.html

A bibliography of publications in relation to profiling floats is also provided at:
http://www.argo.ucsd.edu/Bibliography.html

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11 APPENDIX B. The Global Tropical Moored Buoy Array (TAO/TRITON, PIRATA, RAMA)

http://www.pmel.noaa.gov/tao

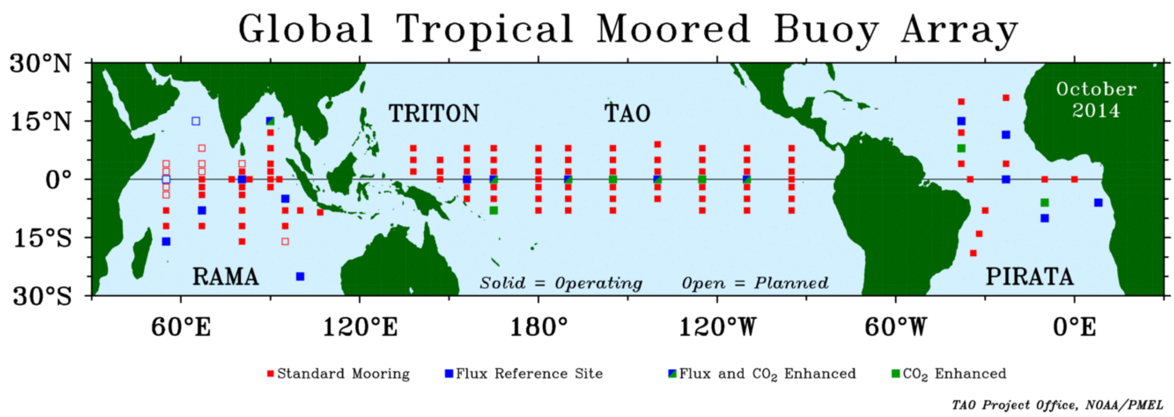

Figure 1. Nominal location of the GTMBA moorings

The *Global Tropical Moored Buoy Array* is a multi-national effort to provide meteorological and subsurface ocean data of the tropics for climate studies. This global tropical array is comprised by the TAO/TRITON array in the Pacific, the PIRATA in the Atlantic, and RAMA in the Indian Ocean. They have been designed and implemented within the context of CLIVAR (Climate variability and Predictability), the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS). [MAB09]

The data collected by the global array are acquired mainly by ATLAS (Autonomous Temperature Line Acquisition System) and TRITON (Triangle Trans Ocean Buoy Network) moorings. These two mooring systems have been designed respectively by the NOAA's Pacific Marine Environmental Laboratory (PMEL) and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). The two mooring systems are equivalent in terms of sensors, sample rates and data quality. The sensors that have been included on the standard ATLAS buoys are listed in Table 1. However, the arrays are presently maintained with the Next Generation ATLAS moorings (Table 2). Some mooring stations (known as *Flux Reference Sites*, and marked in blue in Figure 1) are more heavily instrumented than the rest. The Flux Reference Sites also have higher vertical resolution temperature and salinity to better resolve variations in the mixed layer, barrier layer, and thermocline.

The moorings transmit observation data to shore in real time via the Service Argos. The data are posted daily by the NOAA-PMEL web site (http://www.pmel.noaa.gov/tao/global/global.html). Service Argos inserts the data on the Global Telecommunication System (GTS) for real-time operational weather, ocean and climate forecasting.

The Flux Reference Site moorings and other moorings instrumented with biogeochemical sensors are included in the Ocean Sustained Interdisciplinary Time Series Environment Observation System (OceanSITES, http://www.oceansites.org/).

Ships dedicated to servicing the moored buoy arrays typically repeat at intervals of six months to one year, since the design lifetime of ATLAS and TRITON moorings is one year. These cruises routinely collect standard shipboard data that accumulate as a valuable addition to the climate data base.

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Measurements include Conductivity-Temperature-Depth (CTD) station data and underway Acoustic Doppler Profiler (ADCP), thermosalinograph, CO2, and surface meteorological data. Moreover, cruises servicing mooring arrays also deploy Argo floats and surface drifters to help maintain these observation systems.

Although the moored arrays were primarily designed to address questions regarding physical climate variability, biogeochemical sensors have also been added at several locations to provide time series measurements for studies of biological productivity and oceanic uptake of CO2. In 1999, there were two biogeochemical stations established on TAO moorings in the Pacific. Since 2003, additional multi-disciplinary ocean observatories have been established in the tropical Pacific and Atlantic as a contribution to OceanSITES.

11.1 TAO/TRITON

The TAO/TRITON array was developed under the Tropical Ocean Global Atmosphere (TOGA) program (1985-1994) mainly motivated by the 1982-83 El Niño event (the strongest measured until then). Initiated by the World Climate Research Program (WCRP) and led by the Tropical Atmosphere Ocean (TAO) project of the NOAA/PMEL, the full array of 70 moorings was completed in 1994. The standard TAO-ATLAS mooring measured wind vector, air temperature, relative humidity and subsurface temperature, allowing real-time monitoring of basin-scale thermocline displacements and surface wind. The TAO array successfully monitored the 1991-93 and the 1997-98 El Niño events, and contributed to the improvement of ENSO prediction models. To meet the demands of both operational and research, a new modular design of the ATLAS buoys started in 1994 to take advantage of new sensor accuracy and capabilities (The so called Next Generation ATLAS, Table 2). Since 2001, the TAO array uses exclusively these Next Generation ATLAS moorings. Since year 2006, PMEL began installing sea surface salinity sensors on 55 ATLAS moorings of the TAO array. Additional subsurface salinity measurements were included on all TAO Flux Reference Site moorings.

The TRITON moorings were developed by JAMSTEC between 1992 and 1994. A prototype buoy was built on 1995, and four TRITON buoys were deployed in 1998 along 156^{o}E in the western tropical Pacific Ocean. The existing TAO and the new TRITON buoys were deployed side-by-side for six month to one year check-out periods to ensure that two buoy systems were consistent. On January 2000 the array was renamed TAO/TRITON with the introduction of JAMSTEC TRITON moorings at 12 location west of 165E. At present, the TAO/TRITON array is operated as a partnership between JAMSTEC and NOAA. Each partner provides mooring equipment and ship time under the terms of a Memorandum of Understanding (MOU) between the two agencies.

In 2002, the NOAA Administrator mandated the transfer of the TAO management responsibility from research at PMEL to operations at the National Data Buoy Center (NDBC), which is part of the National Weather Service. Transfer was initiated in 2005.

TRITON buoys are serviced by the Japanese research vessel *Mirai*. Since 1993, the TAO array was being serviced by the NOAA ship *Ka'imimoana*. Due to budget cuts, this ship was retired by NOAA.

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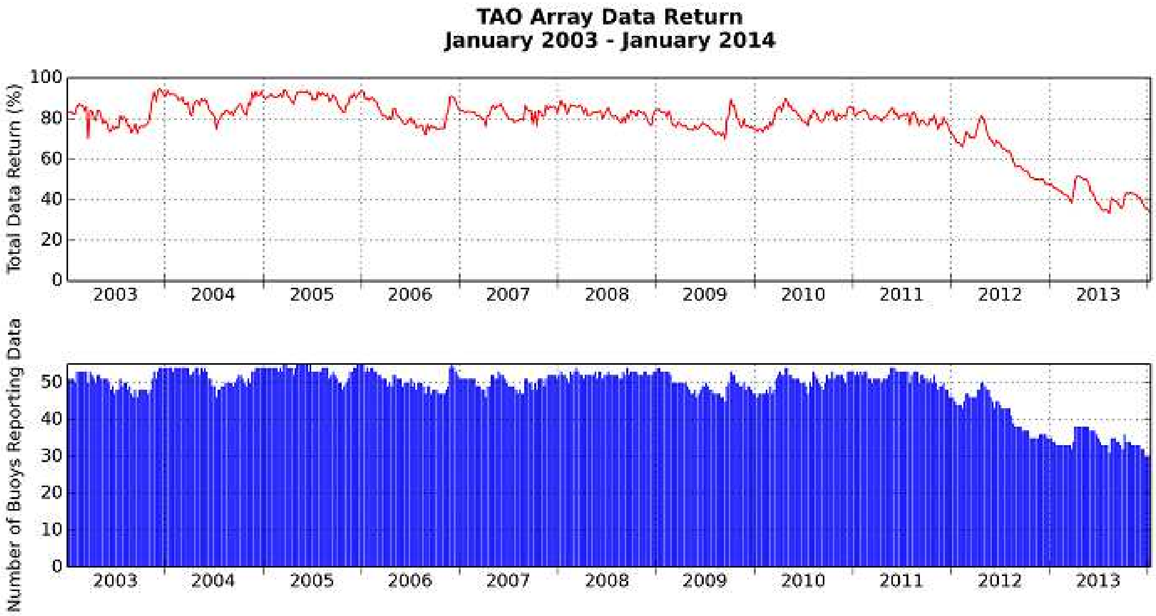

Figure 2. Amount of data returned by TAO. From Tollefson (2014).

In December 2003, TAO wined the 2003 Grace Hoper Government Technology Award.

11.2 PIRATA

The Prediction and Research Moored Array in the Tropical Atlantic (PIRATA) program started with the deployment of two ATLAS moorings in September 1997. The 10 mooring core array was installed by 1999. An ADCP mooring was added at 0°, 23°W in 2001. After the 1997-2001 “pilot phase” and the 2001-2006 “consolidation phase”, in 2006 PIRATA underwent a formal review by the CLIVAR program that endorsed continuation of PIRATA as part of the GOOS and GCOS. As such PIRATA entered a sustained phase, in which extensions were added to the PIRATA backbone. Today, the array has 18 permanent sites with4 Flux Reference Sites (See Figures 1 and 3). [BLM08]

Partners in the US, France and Brazil have committed to support PIRATA through a formal MOU. Under the terms of this MOU, the U.S. provides most of the mooring equipment and ship time for most of the mooring network.

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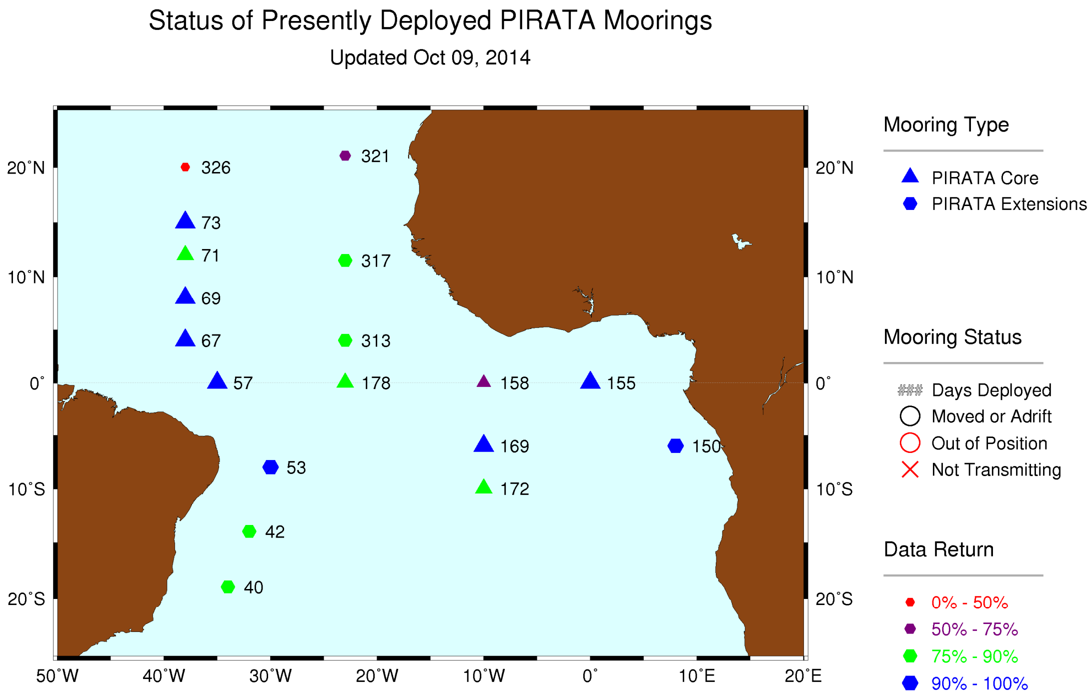

Figure 3. Current status of PIRATA array (http://From www.pmel.noaa.gov/tao/global/status/buoystat-pirata.html)

Despite progress, gaps in PIRATA still remain. In particular, the Southeast Extension Site needs to be reoccupied and sustained.

11.3 RAMA

The Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) was initiated in 2004. It was designed by the CLIVAR/GOOS Indian Ocean Panel as a contribution to the Indian Ocean Observing System (IndOOS). RAMA will consist of 46 mooring spanning the width of the Indian Ocean between 15°N and 26°S. Most of the moorings are either ATLAS or TRITON, eight of which are enhanced Flux Reference Site moorings. Four ADCP moorings are located on the equator and one off the coast of Java. Three deep-ocean moorings collect data down to 2000 m along the equator. At present, 24 of the 46 sites have been occupied (See Figure 4) with support from the U.S., Japan, India, Indonesia, France, China, Kenya, Tanzania, Mozambique, South Africa, Madagascar, Mauritius, Seychelles, Somalia, and Comoros.

Implementation of RAMA has proceeded through several bilateral agreements between agencies in partner nations. In addition to these bilateral agreements, Indian Ocean GOOS has established an “IndOOS Resource Forum” which will provide an international framework to coordinate all resources committed to IndOOS in general and RAMA in particular.

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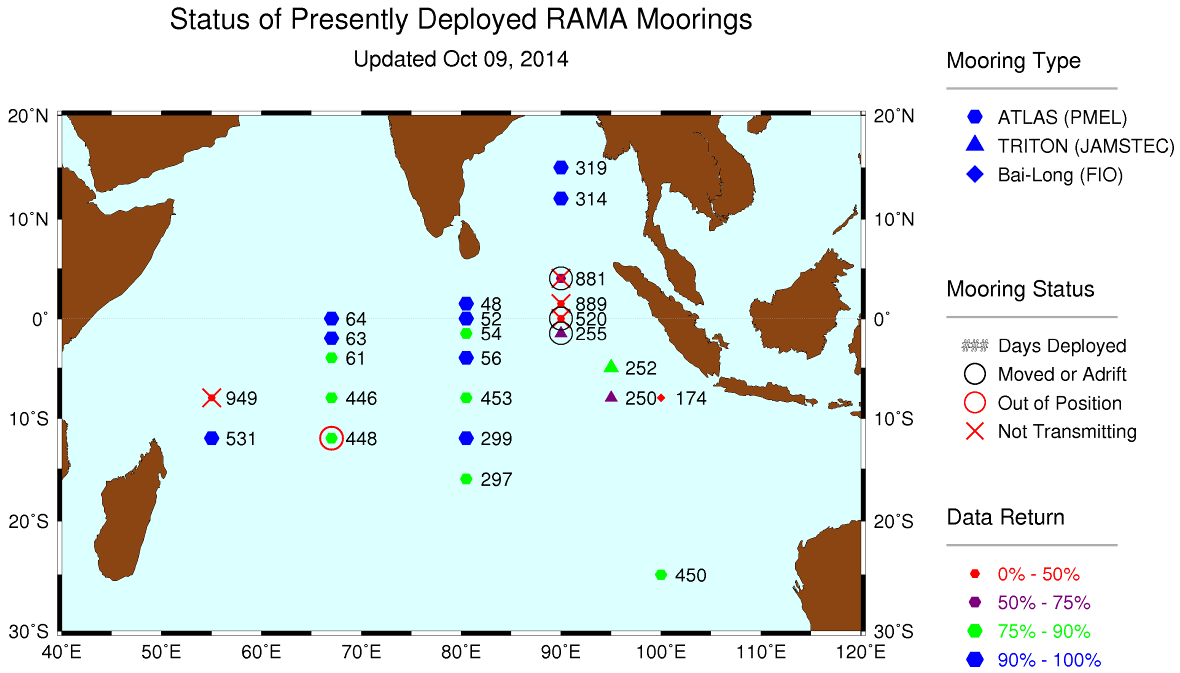

Figure 4. Current status of RAMA array (http://From www.pmel.noaa.gov/tao/global/status/buoystat-rama.html)

So far, NOAA has provided the bulk of the mooring equipment for RAMA (with additional contributions from India, Japan, and China) while nations in the region have provided the bulk of the ship time. Regular servicing ships are *Sagar Kanya* and *Sagar Nidhi* (India), *Mirai* and *Kayo* (Japan), *Baruna Jaya* (Indonesia), and *Algoa* (South Africa). Other countries as France and Norway have also serviced the RAMA array.

11.4 Challenges

Ship time is a critical resource for maintaining the arrays and specialized ships capable of deep-sea mooring operations are required. Such vessels are in high demand and short supply. Ideally, surface moorings should be recovered and redeployed once per year with service visits at six-month intervals for necessary repairs. This ideal is achieved only for the TAO portion of the TAO/TRITON array. Ship time for TAO, moreover, has been trending downward in the past few years due to reduced operating schedules in the NOAA fleet (see below). Similar downward pressure on JAMSTEC ship time for servicing TRITON moorings is also being felt. Servicing of PIRATA moorings in the Atlantic is roughly on a 12-month schedule using French, Brazilian and U.S. vessels. Data return in PIRATA has traditionally been 5–15% lower than in TAO/TRITON in part because of the less frequent servicing. It has been difficult in the start-up phase of RAMA to ensure regular cruises at even 12-month intervals. Partner nations in RAMA recognize that this is a problem and it is being addressed through a more structured planning process that involves coordination through the IndOOS Resource Forum.

Vandalism by fishermen is the greatest source of equipment and data loss in all three ocean basins. Moored buoys act as fish aggregation devices that attract fishermen. While working near the buoys, nets or long lines entangle in the mooring and damaging the line. Sometimes, the damage is intentional (bullet holes, missing sensors, sawed off hardware).

Significant TAO data dropouts have occurred during the development phase of the 2014 El Niño because of damage from fishing boats in the eastern Pacific. This loss of data has been aggravated by

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the retirement of the NOAA ship *Ka'imimoana*. Although NOAA has spent $3 million (roughly half the amount required by the *Ka'imimoana* operations) to charter boats for TAO maintenance, TAO has experimented a significant data dropout as seen in Figure 2. [Tol14]

Table 1. Standard ATLAS and Early Current Meter Mooring Sensors

Measurement	Sensor type	Manufacturer: Model #	Resolution	Range	Accuracy
Wind speed	Propeller	R. M. Young: 05103	0.2 m s^{-1}	1-20 m s^{-1} (0.4 – 36 m s^{-1})	±0.3 m s^{-1} or 3%
Wind direction	Vane		1.4°	0-355°	5°-7.8°
	Fluxgate compass	E.G. and G. 63764 or KVH LP101-5	1.4°	0-359°	5°-7.8°
Air temperature	Pt-100 RTD (Resistance Temperature Detector)	Rotronic Instrument Corp.: MP-100	0.04 °C	14-32 °C (0-40°C)	±0.2 °C
Relative humidity	Capacitance		0.4 %RH *Realtime* 0.02 %RH *Delayed*	55-95 %RH (0-100 %RH)	±2.7 %RH
Downwelling shortwave radiation	Pyranometer	Eppley Laboratory: PSP	1.3 W m^{-2}	700 W m^{-2} (0-1600 W m^{-2})	±2 %
Sea surface temperature	Thermistor	PMEL: Standard ATLAS SST sensor using YSI (Yellow Springs Instruments) thermistor 46006	0.001 °C	14-32 °C	±0.03 °C
	Thermistor	PMEL: Current meter mooring SST sensor using YSI thermistor 46006	0.001 °C	14-32 °C	±0.01 °C
Subsurface temperature	Thermistor	PMEL: Standard ATLAS sensor using YSI thermistor 46006	0.001 °C	6-32 °C	±0.09 °C
	Thermistor	PMEL: Mini Temperature Recorder (MTR) using YSI thermistor 46006	0.001 °C	6-29 °C	±0.01 °C
	Thermistor	EG&G VACM	0.001 °C	1-31 °C	±0.05 °C
	Thermistor	EG&G VMCM	0.006 °C	1-31 °C	±0.05 °C
	Thermistor	Sea Data TR-2, TDR-2	0.01 °C	1-31 °C (-5.35 °C)	±0.05 °C
Sea surface and subsurface temperature	Thermistor	Sea Bird Electronics: SBE16, SBE37	0.001 °C	1-31 °C (-5-35 °C)	±0.003 °C
Salinity	Internal field conductivity cell	Sea Bird Electronics: SBE16 (Seacat)	0.0001 S m^{-1}	3-6 S m^{-1} (0-6 S m^{-1})	±0.02 psu
Water pressure	Transducer	Paine: 211-30-660-01	0.03 psi	400-800 psi (0-1000 psi)	±0.25% full scale (1000 psi)
Ocean current (single point)	Savonius rotor and vane	EG&G VACM	0.005 cm s^{-1} 2.8°	2-300 cm s^{-1}	±3-7 cm s^{-1}, ±5.6°
	Orthogonal propellers	EG&G VMCM	0.01 cm s^{-1} 1.4°	0.9-340 cm s^{-1}	±3-7 cm s^{-1}, ±2.5°
Ocean current (profile)	Acoustic Doppler Current Profiler	RD Instruments: Narrow band, 150 kHz	0.1 cm s^{-1} 0.006	0-256 cm s-1	±5 cm s^{-1}, ±2.5°

Table 2 Next Generation ATLAS Mooring Sensors

Measurement	Sensor type	Manufacturer: Model #	Resolution	Range	Accuracy
Wind speed	Propeller	R. M. Young: 05103	0.2 m s^{-1}	1-20 m s^{-1}	±0.3 m s^{-1} or 3%

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				(0.4 – 36 m s^{-1})	
Wind direction	Vane		1.4°	0-355°	5°-7.8°
	Fluxgate compass	E.G. and G. 63764 or KVH LP101-5	1.4°	0-359°	5°-7.8°
Air temperature	Pt-100 RTD (Resistance Temperature Detector)	Rotronic Instrument Corp.: MP-100	0.01 °C	14-32 °C (0-40°C)	±0.2 °C
Relative humidity	Capacitance		0.4 %RH *Realtime* 0.02 %RH *Delayed*	55-95 %RH (0-100 %RH)	±2.7 %RH
Rainfall	Capacitance	R. M. Young: 50203-34	0.2 mm hr^{-1}	0-50 mm	±0.4 mm hr^{-1} on 10 min filtered data %
Downwelling shortwave radiation	Pyranometer	Eppley Laboratory: PSP-TAO, Delrin case	0.4 W m^{-2}	200-1000 W m^{-2} (0-1600 W m^{-2})	±2 %
Downwelling longwave radiation	Pyranometer	Eppley Laboratory: PSP-TAO, Delrin cae, 3-output	0.1 W m^{-2} 0.03 °C	200 W m^{-2} @ 20 °C (thermopile only)	±1 %
Barometric pressure	Pressure transducer	Paroscientific: MET1-2	0.1 hPa	800-1100 hPa	±0.01 % of reading
Sea surface and subsurface temperature	Thermistor	PMEL electronics using YSI (Yellow Springs Instruments) thermistor 46006	0.001 °C	6-32 °C (0-40 °C)	±0.02 °C
	Thermistor	Sea Bird Electronics: SBE16, SBE37	0.001 °C	1-31 °C (-5-35 °C)	±0.003 °C
Salinity	Internal field conductivity cell	Sea Bird Electronics: SBE16 (Seacat)	0.0001 S m^{-1}	3-6 S m^{-1} (0-6 S m^{-1})	±0.02 psu
		SBE37 (Microcat)	0.0001 S m^{-1}		
		Sea Bird cell with PMEL electronics	0.002 S m^{-1}		
Water pressure	Transducer	Paine: 211-30-660-01	0.03 psi	400-800 psi (0-1000 psi)	±1.4 psi
Ocean current (single point)	Doppler Current Meter	SonTek: Argonaut	0.1 cm s^{-1} 0.1°	0-600 cm s^{-1}	±5 cm s^{-1}, ±5°
Ocean current (profile)	Acoustic Doppler Current Profiler	RD Instruments: Narrow band, 150 kHz	0.1 cm s^{-1} 0.006	0-256 cm s-1	±5 cm s^{-1}, ±2.5°

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12 APPENDIX C. OCEAN SENSOR MONITORING PLATFORMS

Monitoring of waters using buoys, floats and platforms with *in situ* sensors can be expensive due to the costs of deploying of the instruments, and the - as yet unsolved - problem of bio-fouling of the sensors. This requires frequent manual cleaning if a consistent data quality is to be achieved. Depending on the region (water temperature and eutrophic status of the waters) the systems have to be cleaned weekly (eutrophic tropical waters), monthly (temperate eutrophic waters) or half-yearly (cold oligotrophic waters). The rate of fouling also depends on other factors such as daylight length, suitability of local species for colonisation of the instrument and availability of nutrients - for example in the North Sea a buoy system may stay free of fouling for a month some years and only two weeks in others.

Floating platforms

There are several types of floating platform. Some floats are intelligent, can maneuver autonomously and are called Dynamic floats while others can float over the surface of the ocean/ water and transmit data and location to a base station. These are called static floats. All autonomous underwater vehicles (AUV) come under the heading of dynamic floats and are relatively easy to monitor and deploy. As per requirement/ experiments, the location of the AUV floats can be changed. However, static floats always lie within a certain diameter and in some cases would be difficult to re-deploy. Some examples of each are given in the following table.

Dynamic floats	Static floats

• Surface Wave Gliders
• Slocum Sub-surface Gliders
  ○ Thermal
  ○ Electric
• ECO MAPPER
• PISCES
	• Smart Buoys
	• Anchor Moorings
	• Navigation tower/ Lighthouse

12.1 *Dynamic Floats*

- **Surface Wave Gliders:**

The Wave Glider [1] is a Dynamic float that combines a unique propulsion mechanism with energy harvesting. The Wave Glider is composed of two parts, the float (size of a surfboard), and a sub with a wing rack. Connected by 8-meter (26 ft.) umbilical tether, the float is on the surface of the ocean where conditions are the harshest while the sub is below the surface protected from the severe conditions. This two part system enables the Wave Glider to get its' propulsion by harvesting the up and down motion of the waves converting this energy into forward thrust.

The Wave Glider's key innovation is its' ability to harvest energy from ocean waves to provide essentially limitless propulsion, providing a persistent presence at sea. Wave Gliders run totally on renewable energies; using wave and solar energy for propulsion and solar power for communications, navigation and computing. It requires no fuel, no manpower, produces no emissions, and has a zero carbon impact on the environment.

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The Wave Glider is equipped with sophisticated computers for navigation, communication systems (Iridium satellite, Wi-Fi, Cellular), and state of the art ocean sensors to measure the environment around it. It supports a wide variety of scientific and commercial sensors have been integrated to measure weather, sea conditions, water quality and chemistry, bottom topography and currents. Acoustic microphones and arrays enable real time communications from subsea to space and can detect passing ships and capture vocalizations of whales and monitor other mammals.

Critical specifications of wave gliders

- Water Speed: 1kt to 3kts
- Endurance: Up to 1 year
- Operating Water Depth: > 15m
- Station Keeping: 40m radius (CEP90)
- Payload: 7 modular bays
- Tow Capability: Up to 500kg mass
- Average Continuous Power: 5W – 20W
- Max Solar Collection: 156W
- Battery Storage: 0.9kWh – 4.5kWh
- Communications: Satellite, Cell, Wi-Fi

Applications of wave gliders

- Anti Submarine Warfare (ASW)
- Surface Vessel Detection
- Tsunami & Seismic Monitoring
- Oil & Gas deep water rigs.

Payloads of wave glider consist

- Solar Energy harvester platform
- GPS/GPRS/ Satellite communication system
- Acoustic Multi mission sensor
- Chemical sensors for monitoring of atmospheric carbon dioxide (CO_2), pCO_2, pH, oxygen, salinity and temperature levels.

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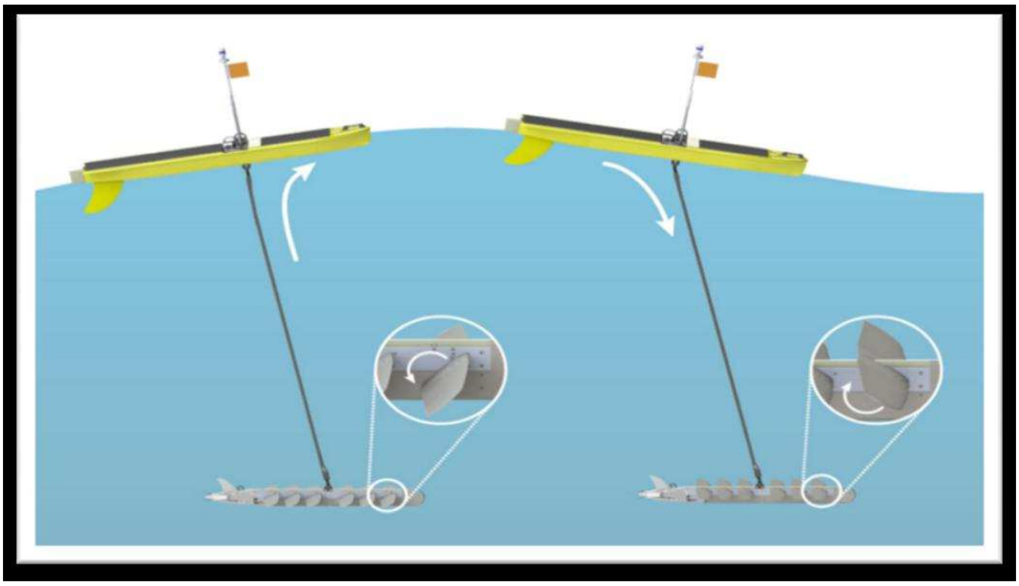

Fig. 1: Wave Glider Propulsion mechanism

- **EGO/GROOM**

Following the technical development of gliders in the US, an increasing glider activity was observed in Europe. In 2006 the European Gliding Observatories (EGO) group was founded. The EGO initiative is a gathering of several teams of oceanographers, interested in developing the use of gliders for ocean observations. The idea was to share expertise and to take advantage of collaborations in the European area. It took formal shape as a COST supported activity (COST action ES0904). The Action started in 2010 with 7 countries. Since then, additional countries have joined the Action which encompasses now 16 partners, 1 being from a non-COST country (http://www.ego-cost.eu).

EGO was first composed of scientific teams from France, Germany, Italy, Norway, Spain, and the United Kingdom and EGO stood for “European Gliding Observatories” for a while but it is now more appropriate to call it “Everyone's Gliding Observatories”[2], while colleagues from Australia, Canada, South Africa and USA are joining this open community. As one of the outcomes, there was the EU project GROOM (Gliders for Research, Ocean Observation and Management) which was accepted for FP7 Infrastructure call 2011-2.1. The objective of the GROOM project was to design a new European Research Infrastructure that uses underwater gliders for collecting oceanographic data for research applications and oceanic surveys. This will ensure better monitoring of European seas and overall marine management [3].

The concept developed by GROOM is based on existing network of EOOSs and so called ‘glider ports’, (Fig. 2.).

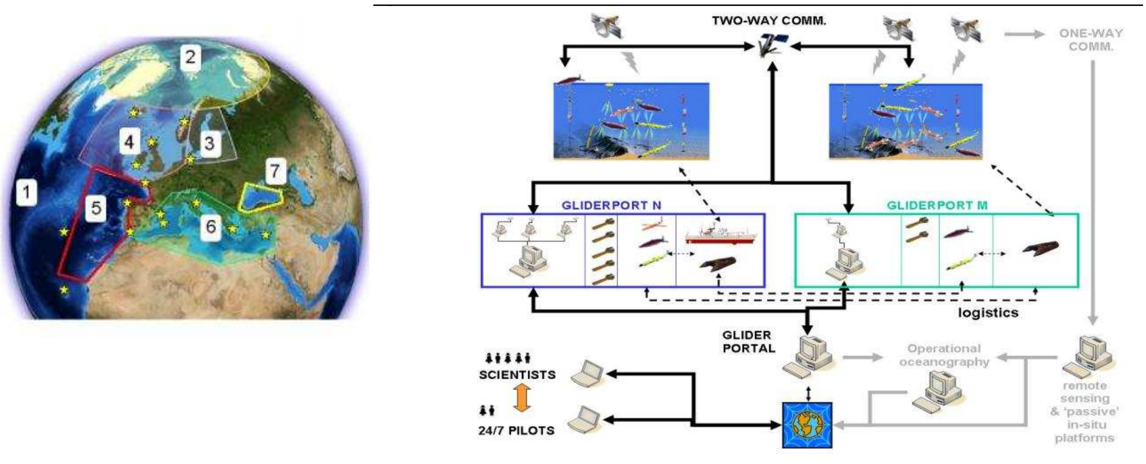

Fig.2: Foreseen principle of gliders observation network Arctic Sea (Arctic ROOS), (3) Baltic Sea (BOOS), (4) Atlantic European North West Shelf Ocean (NOOS), (5) Atlantic Iberian Biscay Irish Ocean (IBI-ROOS), (6) Mediterranean Sea (MOON and Med-GOOS), (7) Black Sea (Black Sea-GOOS) ; European possible "gliderports" are indicated by yellow stars. (COST Action ES0904 Monitoring Progress Report, 2012)

Apart from joint initiatives such as EGO, many institutions have invested into gliders technologies as part of development of their local or regional scale observation systems. Notable example of successful deployment of this still novel technology is Balearic Island Coastal Observing and Forecasting System (SOCIB, www.socib.eu). It became a model example for others interested in deploying gliders. SOCIB generously provides its know-how and controlling software for all interested.

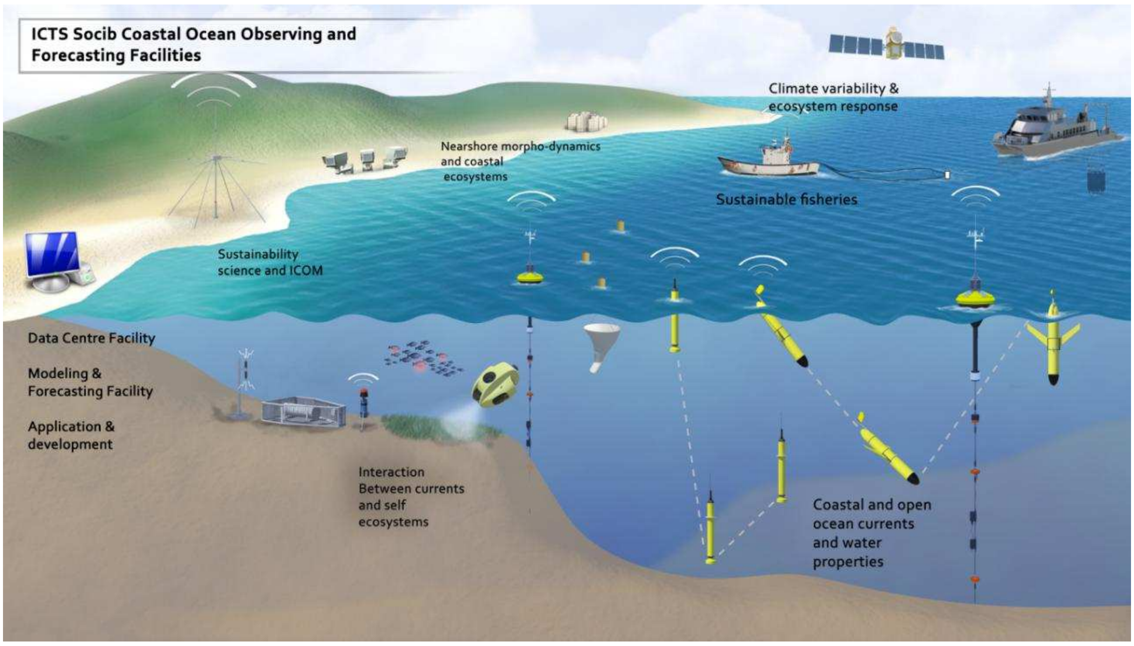

Fig.3: SOCIB facilities.

Gliders have all the capacities suitable for absorbing new generation, low power, miniature, low cost sensors such as are being developed by Common Sense project.

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- **Slocum Sub-surface Gliders: [4]**

The long-range and duration capabilities of Slocum gliders make them ideally suited for subsurface sampling at the regional scale. Carrying a wide variety of sensors, they can be programmed to patrol for weeks at a time, surfacing to transmit their data to shore while downloading new instructions at regular intervals, realizing a substantial cost savings compared to traditional surface ships. There are two types of the Slocum sub-surface gliders, the Slocum electric glider and the thermal glider.

Fig 4: Slocum Sub surface gliders

- <u>Slocum Electric glider</u>: Versatile, maneuverable and powered with alkaline batteries, the electric glider can be deployed for a period of 15 to 30 days at a 600- to 1500-km range. Its flexible payload allows it to carry customized sensors. The coastal glider can be operated to depths of 4–200 meters and the 1-km glider to 1000 meters .

Critical specifications of Slocum Electric Sub-surface Gliders

- Weight: 52 kg
- Hull Diameter: 21.3 cm
- Vehicle Length: 1.5 meters
- Depth Range: 4–200 meter (coastal model) or 1000 meter (1-km model)
- Speed: 0.4 m/sec horizontal average
- Endurance: Typically 30 days, depending on measurements and communication
- Range: 1500 km
- Navigation: GPS, magnetic compass, altimeter, subsurface dead reckoning
- Sensor Package: Conductivity, Temperature, Depth
- Communications: RF modem, Iridium satellite, ARGOS, Telesonar modem
-

Applications of Slocum Electric Sub-surface Gliders

- Improve ocean models with real data
- Ground truth satellite imagery
- Collect water column data
- Improve data quality during greenfield operations

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- Map currents for oil plume migration assessment

Payloads of Slocum Electric Sub-surface Gliders consist

- GPS/GPRS/ Satellite communication system
- Acoustic sensors and Oceanographic survey
- On board Dissolved Oxygen sensors, Optical sensors (Wet labs), Altimeter, Turbidity etc.
- CTD (Conductivity/ Temperature and Depth) Sensor system

o Slocum Thermal glider: Offering long range and endurance using environmental energy via a thermal engine, the thermal glider can be deployed at a maximal depth of 1200 meters for a period of 5 years. It has a 40,000-km range.

Critical specifications of Slocum Thermal Sub-surface Gliders

- Weight: 60 Kg
- Hull Diameter: 21.3 cm
- Vehicle Length: 1.5 meters
- Depth Range: 1200 meters
- Speed: 0.4 m/sec horizontal average
- Energy: Environmental (thermal engine)
- Projected Endurance: 3-5 years
- Projected Range: 40,000 km
- Navigation: GPS, magnetic compass, altimeter, subsurface dead reckoning
- Sensor Package: Conductivity, Temperature, Depth
- Communications: RF modem, Iridium satellite, ARGOS

Applications of Slocum Thermal Sub-surface Gliders

- Low cost, rapid mobilization for oil spill mitigation.
- Pipeline monitoring
- Marine mammal awareness
- Real time current monitoring during equipment installation
- Stay compliant with current laws and environmental regulations
- Map currents for oil plume migration assessment

Payloads of Slocum Thermal Sub-surface Gliders consist

The payload section is capable of accommodating a flexible science payload where a variety of instruments can be easily placed. The front ring is typically ported for the conductivity, temperature, and depth (CTD) sensor assembly, but it can be fitted with a penetrating connector to accommodate a variety of other science sensors [5].

- **Eco Mapper:** It is designed for water quality, water current monitoring and it could be used as a monitoring platform that will generate the highest-resolution data at a low cost and low risk. This autonomous underwater vehicle (AUV) has YSI 6600 V2 bulkhead built in for collection of up to 10 water quality parameters in large water bodies. Other features include side-scan sonar imaging and a Doppler velocity log for accurate navigation below surface [5].

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Critical specifications of Eco Mapper

- Platform: Iver2Body Type: Torpedo
- Size (LxWxH): 0.15m x 0.01m x 0.01m
- Body Size (LxWxH): 0.15m x 0.01m x 0.01m
- Hull Material: Aluminium
- Weight: 20.40kg
- Maximum Depth: 200.00 m
- Dynamic Buoyancy: No
- Self-Righting: Yes
- Obstacle Avoidance: No
- Endurance (nominal load): 8 hours

Applications of Eco Mapper

- Baseline Monitoring
- Source Water Mapping
- Event Response
- Bottom Mapping
- Point Source and Non-point Source Mapping
- Oceanographic Research

Payloads of Eco Mapper

- CTD (conductivity, temperature, depth)
- salinity; blue-green algae, chlorophyll
- Dissolved oxygen levels
- Chemical sensors such as ORP, pH, rhodamine, turbidity

- **PISCES**: The PISCES is a lightweight floating platform which supports water quality, water velocity, and meteorological sensors as well as computer logging systems. The platform holds two topside aluminium chests that house the data acquisition system, cellular modem, and battery. The chests are easily serviceable from the water and accommodate multiple underwater cable connections. The PISCES platform is ideal for coastal, estuary, river, and lake monitoring. It can be deployed by two persons with a truck and a small boat. The platform provides several instrument array options as well as several data acquisitions products [6].

  Critical specifications of PISCES

  - Hull: Polyethylene with optional closed cell filled pontoons
  - Weight Standard Configuration: 100kg
  - Pumped Configuration 181.4kg
  - Shape Catamaran Dimensions Height Length Width 1.8 m 3.2 m 1.3 m
  - Mooring Attachment One or two-point attachment points Frame 6061 marine-grade, powder-coated aluminium
  - Tripod 6061 marine-grade, powder-coated aluminium
  - Hardware 316 stainless steel
  - Antenna 3db. gain omni low profile

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- Sonde Tube Retractable 10.2 cm schedule 40 PVC pope with schedule 80 flange 1 meter instrument deployment depth

Applications of PISCES

- Monitoring around construction, dredging, and more
- Easy to deploy
- Fits in pickup truck
- Tow-able by small vessels
- Stable one- or two-point mooring
- Ideal for high currents up to 12 knots
- High profile for visibility in navigable waterways
- Abundant power reserve and solar accumulation
- Cellular modem, meteorological sensors, and ADP configurations
- Sonde standpipe is retractable for transportation and towing
- Available in flow-through cell configuration with optional multiple-depth sampling

Payloads of PISCES

- Water quality sensors
- Data logger
- Power source (solar panel or lead acid battery)
- Communication systems

12.2 Static Floats

The most prominent and widely known of the static floats would be the system of ARGO floats currently deployed worldwide followed by the Global Tropical Moored Buoy Array. These have been extensively discussed in Appendix A and B. The following section will thus give a brief description of smart buoys and moorings.

- **Coastal and Harbour Smart Buoys:** Several types of buoys are used for coastal, off-shore, near-shore, bay, and canal monitoring and data telemetry. Usually smart buoys have been deployed with several types of sensors such as wet-chemistry nutrient and metal analyzers, current meters, water quality monitors, GPS, atmospheric sensors, wave sensors, hydrocarbon sensors, and more. The stable platform can be easily customized to maximize instrumentation on a single monitoring platform. Adding satellite, radio, or cellular telemetry provides data to a custom visual display, making it easy for researchers and operators alike to receive critical data on a daily basis [7].

Critical specifications of Smart Buoys

- Conductivity 0 to 9 S/m
- Temperature -5 to +35 °C
- Pressure Strain gauge 0 to 7000m
- Memory & Data Storage 64 Mbyte non-volatile FLASH. Power Supply & Consumption 9 alkaline D-cell batteries, 60 hours CTD profiling
- Optional External Power 9 - 28 VDC; consult factory for required current

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- Auxiliary Sensors Power out up to 500 mA at 10.5 - 11 VDC; A/D resolution 14 bits and input range 0-5 VDC.
- Housing, Depth Rating, & Weight Acetal Copolymer Plastic, 600 m, in air 7.3 kg, in water 2.3 kg. 3AL-2.5V Titanium, 7000 m, in air 13.7 kg, in water 8.6 kg. 6AL-4V Titanium, 10,500 m.

Applications of Smart Buoys

- User-programmable mode: profiling at 4 Hz, or moored sampling at user-programmable intervals.
- RS-232 interface, internal memory, and internal alkaline batteries (can be powered externally).
- Pump-controlled, T-C ducted flow to minimize salinity spiking.
- Depths to 600, 7000, or 10,500 m.
- Data upload, real-time data acquisition, and data processing).
- Next generation Smart Buoys

Payloads of Smart Buoys

- Conductivity, Temperature, Pressure, and up to seven auxiliary sensors.
- Relative Humidity
- Rain fall
- Downwelling Shortwave Radiation
- Barometric Pressure
- Sea Water Temperature
- Sea Water Salinity

- **Moorings** are surface buoys, anchored in place with either a taut-line or slack-line mooring design. The surface float is a fiberglass-over-foam, with a central instrument well. It has an aluminium tower, and a stainless steel bridle. The mooring may include wire rope, nylon, polyolefin floating line, glass float balls, and chain. Usually anchors are recycled train wheels.

Critical specifications of Moorings

- Surface Float: 2.62m diameter
- Buoy System Weight (in air)): ~1800kg
- Net Buoyancy: ~2300kg
- Overall Extent: 6.37m

Applications of Moorings: The CTD (Conductivity, Temperature, and Depth) platform is the workhorse of Sea Systems and is used on 90% of all cruises. Not only does it provide real-time, accurate and precise data from the water column up to 6000m deep, it has the ability to take up to 24 water samples at depths chosen by the operator.

Payloads of Moorings

- Wind speed
- Wind direction
- Air Temperature
- Relative Humidity
- Rain fall

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- Downwelling Shortwave Radiation
- Barometric Pressure
- Sea Water Temperature
- Sea Water Salinity
- Ocean Current

12.3 Voluntary observing ships (VOS)

The international scheme by which ships plying the various oceans and seas of the world are recruited by National Meteorological Services (NMSs) for taking and transmitting meteorological observations is called the World Meteorological Organization (WMO) Voluntary Observing Ships' (VOS) scheme. The forerunner of the scheme dates back as far as 1853, the year in which delegates of ten maritime countries came together at a conference in Brussels, on the initiative of Matthew F. Maury, then director of the United States Navy Hydrographic Office, to discuss his proposal for the establishment of a uniform system for the collection of meteorological and oceanographically data from the oceans and the use of these data for the benefit of shipping in return [8].
Since 1999, the marine activities of WMO, as well as those of the Intergovernmental Oceanographic Commission (IOC) of UNESCO, have been coordinated by the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM).
The VOS Scheme is a core observing program of the Ship Observations Team (SOT) in the Observations Programme Area of JCOMM.
VOSClim is an ongoing project within JCOMM's Voluntary Observing Ships' Scheme. It aims to provide a high-quality subset of marine meteorological data, with extensive associated metadata, to be available in both real-time and delayed mode to support global climate studies.

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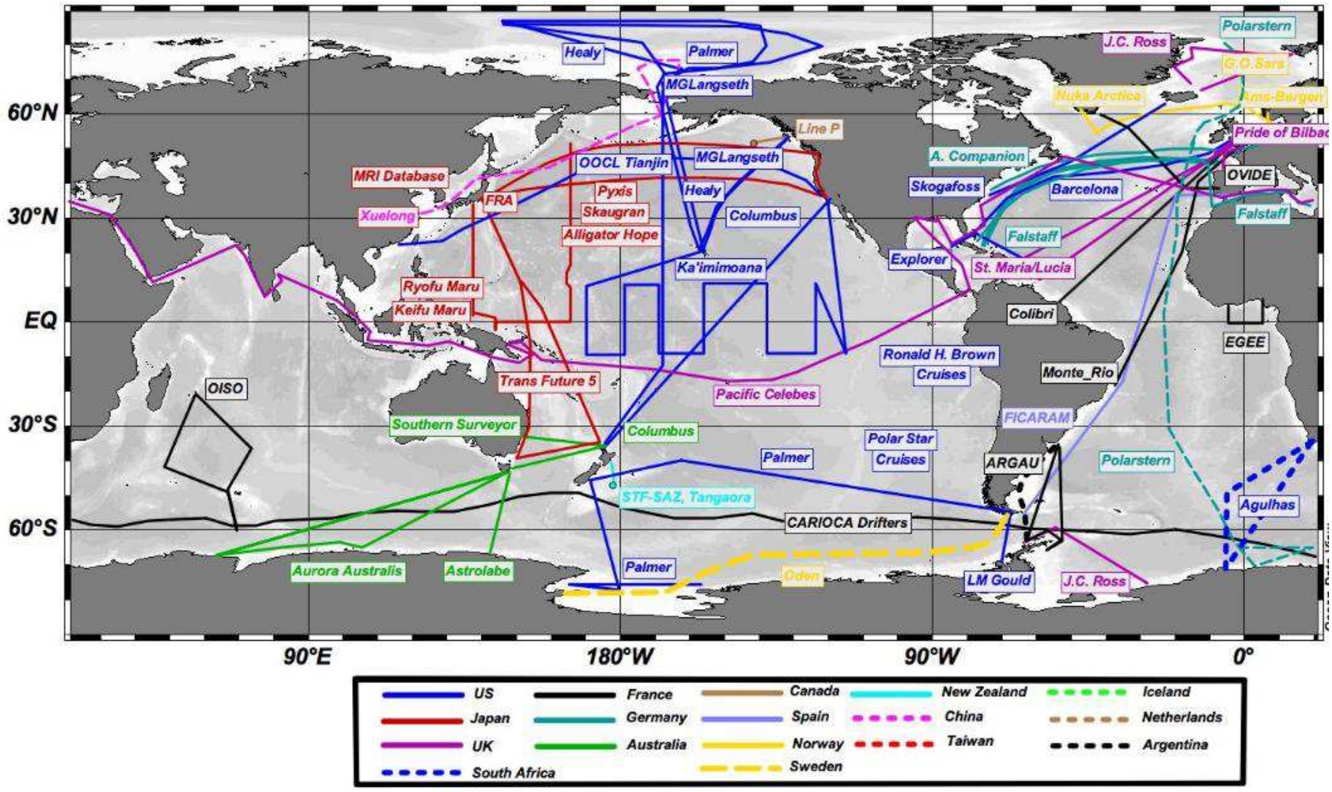

Fig 5: Map of some VOS routes

- **Ship Of Opportunity Program [9]**

The Ship Of Opportunity Program (SOOP) is a component of the Global Ocean Observing System (GOOS), whose mission is to provide a global platform to deploy and operate oceanographic instrumentation from cargo ships, cruise ships and research vessels. The most important of these instruments is the Expendable Bathythermograph (XBT). XBTs are deployed along fixed, pre-established transects, which are repeated at least 4 times per year, to measure the water temperature from the sea surface to a maximum depth of 850 m. On average, approximately 20,000 XBTs are deployed per year. SOOP is also responsible for the installation and operation of TSGs, which are instruments that continuously measure the values of sea surface temperature and salinity along the ship path. In addition this project supports other observational networks, such as the global drifter array, and Argo profiling floats. TSG observations are used in conjunction with pCO2 observations and provide critical information to determine frontal regions and mixed layer depths for ocean acidification assessments. The countries that provide the largest contributions to this program are the United States, Australia, France, South Africa, Brazil, Germany, Italy, and Japan.

- **FerryBoxes: [10]**

Automated instrument packages on Ships of Opportunity, here called "FerryBox", have been in use for many years, starting from the simple 1930's "Continuous Plankton Recorder (CPR)" with the single purpose of collecting plankton samples during regular ship cruises to the most recent sophisticated "FerryBoxes" with an ensemble of different sensors and biogeochemical analysers.
Ferryboxes are packages of instruments that are placed on board commercial ships such as ferries to monitor temperature, salinity and other water properties. This is done by sampling surface water while the ferry is on passage from between ports such as Liverpool and Dublin crossing the Irish Sea,

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and on ships between Portsmouth and Bilbao or Plymouth and Santander, crossing the Bay of Biscay, to detect long-term changes.

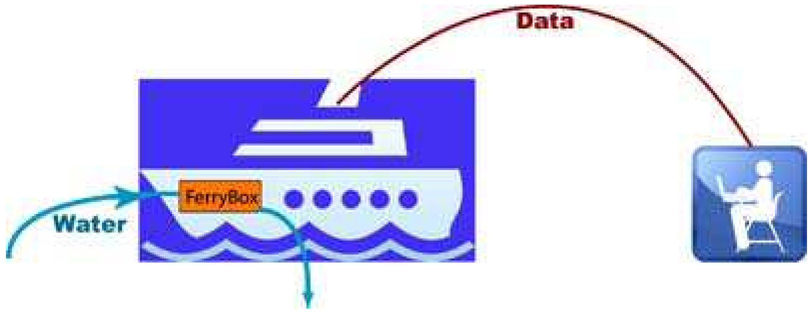

Fig 6: The Ferrybox principle

FerryBoxes offer the following advantages:

- enough energy on the ships --> more complicated analyser system can be used
- sheltered conditions inside the ship --> sophisticated equipment can be installed
- easy maintenance in the harbour --> no additional ship time is needed
- the information from a transect is often better than from a single location

All these points speak for the use of FerryBoxes in areas where suitable ship routes are in operation.

Fig 7: Ferries with Ferrybox equipment on them.

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11 OTHER INTERNATIONAL VOS PROGRAMS

- **[USA] Marine Meteorology and Oceanography Programme (MMOP) [11]:** With the development of scientifically based maritime weather forecasting, the tentative efforts of the small group of pioneers at Brussels ultimately led to the establishment of the present Marine Meteorology and Oceanography Programme (MMOP), under the auspicious of the World Meteorological Organization (WMO). One of the main features of the MMOP is the scheme whereby each national Meteorological Service involved assumes responsibility for an agreed area of the high seas and coastal waters. The weather and sea bulletins, which they broadcast by the Global maritime Distress and Safety System (GMDSS) at regular intervals, provide information for the mariners on the location, movement and probably development of weather systems and on the associated weather and ocean conditions; special warnings are given of hazardous situations. Seafarers themselves contribute to the success of the Programme by providing weather observations under WMO Voluntary Observing Ships' Scheme, in response to the International Convention for the safety of Life at Sea (SOLAS) which specified that "the Contracting Governments undertake the encourage the collection of meteorological data by the ships at sea, and to arrange for their examination, dissemination and exchange in the manner most suitable for the purpose of aiding navigation".

- **[AUS] Marine Observations in the Bureau of Meteorology [16]:** A specialist Marine Observations Unit was established by the Australian Bureau of Meteorology in 1997 to manage its marine observing networks, including the Australian Voluntary Observing Fleet and Port Meteorological Agents; Ship-of-Opportunity Program; drifting, moored and waverider buoy programs; automated shipboard weather observing systems; and any other operational marine networks developed in the future. The Australian Voluntary Observing Fleet (AVOF) is a network of approximately 90 ships operating mainly in the Australian region, that are recruited to take, record and transmit routine weather observations whilst at sea, including sea state and swell conditions. The AVOF consists of Australian and foreign owned merchant, research, passenger and private vessels. The Bureau supplies the necessary meteorological equipment and stationery to the recruited vessels and provides the crew with any additional training that may be necessary. Most observations from ships of the AVOF are transmitted using the Inmarsat satellite communication system. The AVOF forms part of the World Meteorological Organization's fleet of approximately 7000 Voluntary Observing Ships worldwide.

- **[CA] Canadian Voluntary Observing Ships Program [13]:** The Voluntary Observing Ships' program (VOS) is an international initiative by which ocean-going ships are recruited by National Meteorological services to record and transmit shipboard weather. AXYS and Environment Canada partnered to develop AVOS – an automated weather station that transmits VOS program reports. Errors and standard reporting biases are eliminated through the use of touch screen technology, intuitive software, and automated quality control protocols.

Key Features Include:

- Automatic data collection
- Proven WatchMan500 processor
- AVOS controller processor
- Wind measurement
- Water temperature

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- Temperature and relative humidity
- Fluxgate compass
- Digital barometer
- GPS receiver
- Iridium or INMARSAT satellite telemetry
- Touchscreen user interface

- [HK] **Hong Kong Voluntary Observing Ships Scheme [14]:** The aim is to provide weather forecasts and issue warnings to the public, special users, the shipping community, aircraft and aviation groups in order to reduce loss of life and damage to property, and minimise disruption to economic and social activities during hazardous weather. The Hong Kong Observatory's Central Forecasting Office and Airport Meteorological Office are responsible for the preparation and issue of weather information, forecasts and various warnings on hazardous weather to the public, shipping community and aviation groups. The Hong Kong Observatory also promotes public awareness of, and community preparedness for, natural disasters. This work involves:
  - Operating a network of mostly automated weather stations;
  - Carrying out real-time exchange of data with meteorological centers in the world;
  - Receiving meteorological satellite imageries and operating weather radar systems;
  - Analyzing meteorological data and computing the future weather by numerical modelling;
  - Disseminating weather information by a diversity of means;
  - Issuing warnings on hazardous weather such as tropical cyclones, storm surges, rainstorms, landslips, flooding, thunderstorms, winds hear, fire danger and extreme hot and cold conditions; and conducting public talks, interviews and training courses as well as producing publicity material on hazardous weather phenomena.

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