Study on costs, benefits and nature of an extended European Ocean Observing System

Final Report

MRAG ltd:Conor O'Kane, Sébastien Metz, Dan Skerritt, Hannah Richardson, Nick French
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Contact: Anja Detant

E-mail: anja.detant@ec.europa.eu

DG MARE

Contact: Iain Shepherd

E-mail: iain.shepherd@ec.europa.eu

European Commission
B-1049 Brussels

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Acronyms

Acronym	Definition
ABNJ	Areas Beyond National Jurisdiction
AIS	Automatic Identification System
AODN	Australian Ocean Data Network
AOOS	Alaska Ocean Observing System
ATN	Animal Telemetry Network
AUV	Autonomous Underwater Vehicles
CARD	Cost Analysis Requirements Description
CARICOOS	Caribbean Coastal Ocean Observing System
CCS	*Carbon Capture and Storage*
CGOFS	Chinese Global operational Oceanography Forecasting System
CMOC	Centre for Marine-Meteorological and Oceanographic Climate Data
CTD	Conductivity, Temperature, and Depth
DAC	Data Assembly Centre
DIF	Directory Interchange Format
ECV	Essential Climate Variables
EEZ	Exclusive Economic Zone
EOV	Essential Ocean Variables
ENSO	El Niño–Southern Oscillation
EOOS	European Ocean Observing System
EUR	Euro €
EuroGOOS	European Global Ocean Observing System
FAO	Food and Agriculture Organization (of the United Nations)
FTE	Full-time equivalent
GBP	British Pounds £
GBR	Great Barrier Reef
GCOOS	Gulf of Mexico Coastal Ocean Observing System
GEO	Group on Earth Observation
GFS	Global Forecast System
GLOS	Great Lakes Observing System
GOOS	Global Ocean Observing System
GPS	Global Positioning System
GVA	Gross Value Added
HFR	High Frequency Radar
ICOOS	Integrated Coastal and Ocean Observation System
IMOS	Integrated Marine Observing System
IOOS	Integrated Ocean Observing System
ISO	International Organization for Standardization
JAMSTEC	Japan Agency for Marine-Earth Science and Technology
MARACOOS	Mid-Atlantic Regional Association Coastal Ocean Observing System
MARPOL	International Convention for the Prevention of Pollution from Ships

Acronym	Definition
MPA	Marine Protected Areas
MSFD	Marine Strategy Framework Directive
NAM	North American Mesoscale Forecast System
NANOOS	Northwest Association of Networked Ocean Observing Systems
NEAR-GOOS	North-East Asian Regional Global Ocean Observing System
NERACOOS	North-eastern Regional Association for Coastal Ocean Observing Systems
NMDIS	National Marine Data and Information Service
NMEFC	National Marine Environmental Forecasting Center
NOAA	National Oceanic and Atmospheric Administration
NOK	Norwegian Krone
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development
OOS	Ocean Observing System
ROV	Remotely Operated Vehicle
RTDB	Real Time Data Base
SCCOS	Southern California Coastal Ocean Observing System
SECOORA	Southeast Coastal Ocean Observing Regional Association
SEK	Swedish krona
SOA	State Oceanic Administration
SWD	Staff Working Document
USD	United States Dollar $
WRF	Weather Research and Forecasting
WFD	Water Framework Directive

Executive summary

The vision for an European Ocean Observation System (EOOS) is "*a coordinating framework designed to align and integrate Europe's ocean observing capacity in the long-term; to promote a systematic and collaborative approach to collecting sustained information on the state and variability of our seas; and to underpin sustainable management of the marine environment and its resources" as* set out in a consultation by European Marine Board and European Global Ocean Observing System (EuroGOOS) (European Marine Board and EuroGOOS, 2016). The Global Ocean Observing System (GOOS) programme has a framework for ocean observation, which includes the defintion of essential ocean variables (EOV). The EOV are expected to be collected as a minimum requirement of the EOOS and are divided into three broad domains; physics, biogeochemistry and biology and ecosystems, of the three domains the physics and biogeochemistry variables are the most established, with many of the biological and ecosystem variables still emerging. As a consequence, many of the activities identified in this report focused on the more mature physics and biogeochemistry domains.

The objective of this study was to provide evidence to help guide the options for the establishment of an (EOOS) by exploring the potential costs and benefits. The study tasks were: task 1 to estimate the spending in EU Member States and Norway, task 2 to compare these estimates with a selection of third countries, task 3 to review existing studies on economic and societal befits of system integration and task 4 to identify needs over and above existing observation.

Within task 1 we identified *in situ* spending on ocean observation in EU and Norway by focusing on the organisations that are part of the EuroGOOS and therefore most likely to contribute to the EOOS. The type of activities that were identified as ocean observation included operation of platforms, such as buoys and moorings, autonomous underwater vehicles, floats and subsurface drifters, and conducting surveys such as hydrographic, geological and biological, and research cruises that may simultaneously be carrying out multiple activities, and maintaining platforms. The search for information was initially online, identifying websites and annual reports that contained financial information. From the initial searches it was not always possible to disaggregate information by activity, therefore additional requests for information were made to organisations identified. Five responses were received, but these were not always disaggregated by activity. To enable cross-country comparisons, data from the Euro Ocean Marine Infrastructure database was combined with cost information identified from web searches and subsequently analysed. Estimates of the operational and capital cost of the infrastructure in the database could then be generated.

Within task 2 we examined how ocean observations are organised and the accessibility of data in the US, Australia, China and Japan. Australia and the US both operate integrated ocean observation systems that are simultaneously national and GOOS regional alliances (GRAs). The situation in the US has the most parallels with the establishment of EOOS, as it has many organisations contributing to the integrated ocean observation system at different levels of autonomy. The US has conducted a cost benefit exercise and developed tools that may be useful to the operation of an EOOS.

Access to data in the US is good, however the large number of different organisations providing data can make it challenging to consolidate the data. In Australia, the central portal provided a simple mechanism to identify data and provide the necessary metadata to use it. In Japan, there are two central portals that make the data accessible, however the quality of metadata is not as consistent as Australia, and so information on licencing and restrictions are not always clear. In China, access to data is more limited, there appear to be initiatives under way to make the data more integrated, but it remains to be seen if it will become more accessible.

Within task 3 a summary of studies is provided that identify economic and societal benefits of an ocean observation system (OOS). Many consider the establishment of an OOS as a public good, and therefore a justification for public spending. However, as observation technologies advance, a cost benefit analysis on a case by case basis may be required. To date many of the benefits attributed to OOS have been described in case studies, but the methods used to evaluate these case studies are not consistent, meaning that results may not be comparable. Differences identified include: objectives are diverse, evaluations use different approaches and methodologies and geographical and temporal differences in scope. The classification of benefits in studies also varies depending on the audience. More recent studies have classified the benefits as 'use-' and 'non-use benefits', with use benefits separated into direct and indirect use, and non-use benefits comprising option value, altruistic value, bequest value and the existence value, as summarised in the table below.

Use-benefits and non-use benefits of ocean observation.

Type of benefit	Sub-components of benefits	Applications	Examples of improvements
Use benefit	Direct use	Marine weather forecasts of sea-state and meteorological conditions	• Renewable energy • Defence-related operations • Agricultural use • Energy management • Coastal management • Facilities planning • Disaster risk reduction • Public health risk reduction • Search, rescue • Other sectors (e.g. conservation, mining, subsea technologies)
		Long-term monitoring in climate and ocean modelling	• For improved environmental management of marine, coastal and land operations • Improving the management, mitigation, and adaptation of environmental change and climate; global environmental policy
	Indirect use	Book and newspaper readers - TV and documentaries audiences	• Understanding of marine ecosystems as part of sustained life on Earth
Non-use benefit	Option value	As "use benefits", only in the future	• Better protection of the marine environment for future individual use
	Altruistic value	Long-term monitoring in	• Better protection of the marine environment for the use of others

	Bequest value		• Better protection of the marine environment for the use of future generations
	Existence value		• Better protection of the marine environment for the sake of their existence

Adapted from Report of AtlantOS-OECD Scoping Workshop on the Economic Potential of Data from Ocean Observatories (Liebender & Jolly, 2016).

Examples of direct-use benefits, identified in previous studies, include; fishing industry, aquaculture, and shipping, offshore energy sector. Non-use benefits are not often cited in economic studies, but examples identified include protection of marine life and protection of heritage.

From an economic perspective, the development of an OOS may lead to gains in terms of improved productivity and reduced redundancies that could benefit data users. Potential users identified include; maritime transport, food, nutrition, health and ecosystems services, energy and raw material producers, recreational users, coastal protection and maritime monitoring and surveillance.

The implementation of an OOS may promote innovation in two different ways, by developing new data collection capabilities, such as new sensors, or through better availability of marine data creating new applications. Examples of innovations that have been identified due to better availability of data include; improved routeing of marine traffic, and improved forecasting of storm surges using bathymetry and tidal data. Recent Horizon 2020 projects were analysed to determine if they could potentially benefit from an OOS, 92 projects with a funding of 322 Million Euro were identified as deriving some benefit.

An operational OOS may also provide benefits by reducing uncertainty. The types of benefits identified include avoidance of lost earnings, increase in profitability and reduction in costs. An OOS would also benefit the Essential Climate Variables (EVC), by providing in situ data for the validation of models, and calibration of satellite data. Contribution that an OOS could make to reducing uncertainty were identified for:

- Better precision of the bathymetry;
- Short term weather forecast;
- Long term weather forecast;
- Ocean forecast and climate records
- Better information on sea-rise level;
- Better information on seabed (sediments and geology); and
- Better information on wave height.

The purpose of the work done under task 4 was to identify needs over and above current levels; this includes a gap analysis that summarises the critical and correctable gaps found in European sea basins. Collection of biological data remains a consistent gap, and may be a function of the biology and ecosystem variables of the EOV being generally at the conceptual stage. A cost analysis is presented for filling one of the gaps identified for high frequency radar coverage, demonstrating the cost by country to match the scale of the US system. The final section of the report identifies examples of technologies that may be used to fill the gaps identified, including high frequency radar for wave and current data, Light Detection and Ranging (LiDAR) for costal bathymetry, autonomous underwater vehicles for spatial gaps in hard to reach areas such as under ice, and environmental DNA as a tool to address some of the gaps in biological data.

The potential scope for a study of this nature is considerable, so for each task there were areas where it was not feasible, to gather and analyse all of the available information. For task 1 much of the analysis was focused on the infrastructure used for physical oceanography, it was harder to identify costs associated with collection of biological, hydrological, and geological data. For Task 2, the availability of cost information was variable between the countries selected, and not as comprehensive as the data identified in Europe. Task 3 was always intended as a summary of studies, rather than actual cost benefit analysis, but the methods outlined in that chapter could be useful to future analysis. Task 4 identifies some of the gaps, and a limited number technologies that may fill them, but more information on technologies and the cost associated with using them could be collected.

1 Introduction

The objective of this study is to provide evidence to help guide the options for the establishment of a European Ocean Observation System (EOOS) by looking at the potential costs and benefits. The potential scope of an exhaustive cost-benefit analysis is considerable, and would go beyond the timescale and budget of this study. Therefore, rather than being exhaustive in its identification of relevant material, this study will identify the most critical sources of information in order to provide an evaluation of the costs and benefits of an integrated EOOS. To focus the study scope four tasks have been specified:

1. Estimate the spending of EU Member States on ocean observation;
2. Summarise the cost and organisation of ocean observation strategies in the US, China, Japan and Australia;
3. Review and summarise existing studies on the economic and societal benefits of ocean observation; and
4. Identify the needs for observation, over and above what is already being done.

The vision for the EOOS has been set out during the EOOS consultation process as "*a coordinating framework designed to align and integrate Europe's ocean observing capacity in the long-term; to promote a systematic and collaborative approach to collecting sustained information on the state and variability of our seas; and to underpin sustainable management of the marine environment and its resources.*" (European Marine Board and EuroGOOS, 2016). The strategy for the EOOS is being jointly lead by the European Marine Board, and the EuroGOOS. This European system will sit within existing international systems such as the Global Ocean Observing System (GOOS) and the Group on Earth Observation (GEO), that promote the collection, analysis and management of observation data to improve decision making. GOOS has a Framework for Ocean Observing that has 5 key concepts; Requirements, Essential Ocean Variables[1] (EOV), Observations, Improving Readiness and System Evaluation.

The requirements of the framework come from societal issues or scientific problems that need addressing. The requirements are further refined into the EOV's as a way of defining the requirements for ocean observation and to help define plans that will provide the most cost effective global assessment of a variable. The EOV are expected to be the minimum requirements of the EOOS and are divided into three broad domains, physics, biogeochemistry, biology and ecosystems, of the three domains the physics and biogeochemistry variables are the most established, with many of the biological and ecosystem variables still emerging.

The third concept within the framework is the observation. These are the facilities and management that enable the EOVs to be collected and generate the outputs that fulfil the requirements. This study has collected data on the cost of making those observations, and what the benefits may be in collecting the data in terms of how well they may fulfil the societal benefit.

[1] Essential Ocean Variables

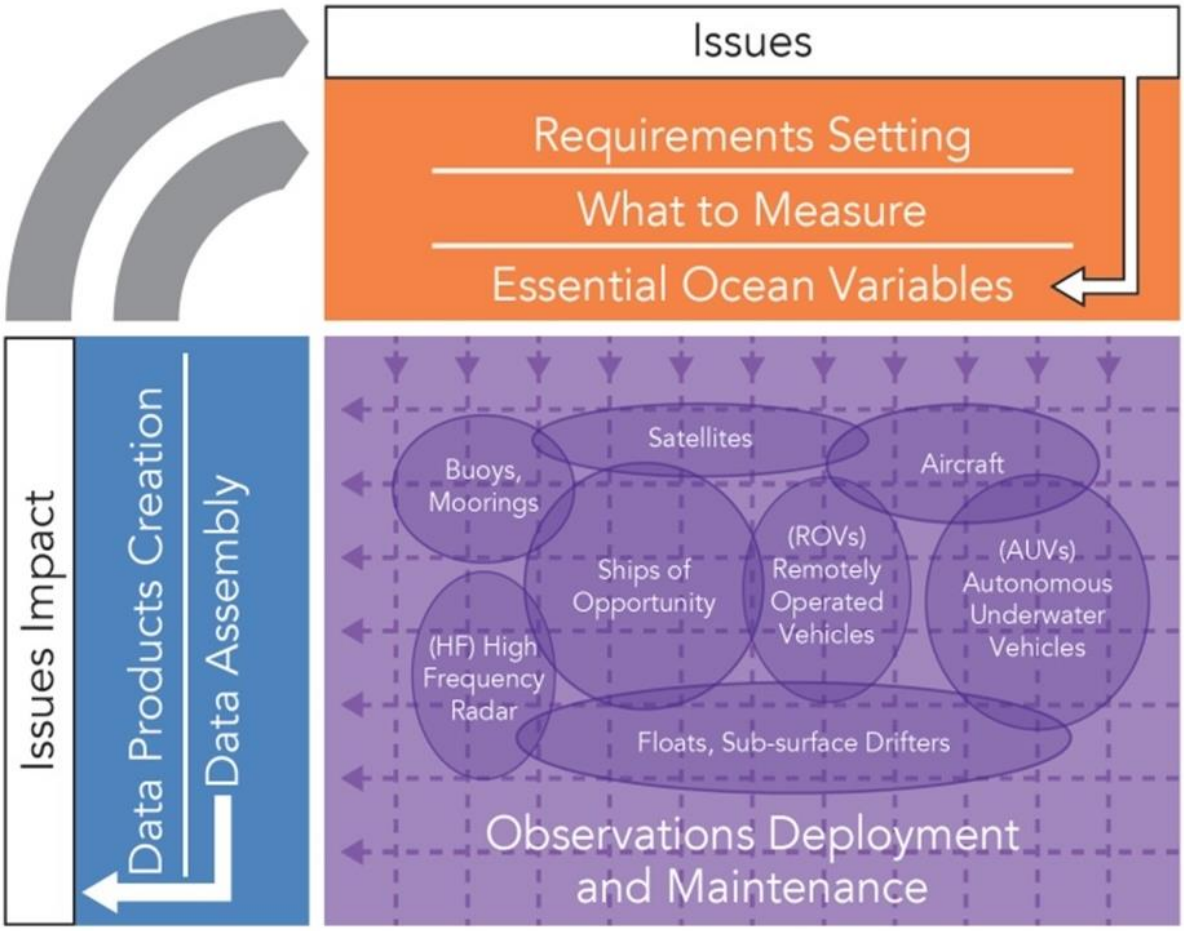

Figure 1 Framework for ocean observation process diagram from the GOOS/IOC framework. (GOOS/IOC) [2]

The process diagrams in **Figure 1** from the GOOS framework show the relationship between the requirements, EOV and the observations, and how they feed into the outputs that will ultimately address the issues.

The study will first examine the Observations, Deployments and Maintenance in **Figure 1** that are required to conduct ocean observation and obtain information on the associated costs in tasks 1 for Europe and task 2 for selected third countries. The study will then examine what benefits they may achieve in task 3 before finally looking at the gaps in task 4.

[2] http://www.goosocean.org/index.php?option=com_content&view=article&id=125&Itemid=113

2 Objective 1: EU and Norway spending on ocean observation

This task focused on identifying the *in situ* spending on ocean observation in Europe and Norway. In the context of the framework shown in **Figure 1**, these are the activities that are taking place to collect the information required within the framework. Some examples in the diagram include platforms collecting information such as buoys and moorings, autonomous underwater vehicles, floats and subsurface drifters. However the full range of activities that take place is much wider and include hydrographic, geological and biological surveys and research cruises that may simultaneously be carrying out multiple activities. The activities considered, were any that would contribute to the parameter disciplines defined under **Table 1**.

In order to determine the spending in the EU and Norway on ocean observation, three methods of information collation were implemented:

1. Web searches of EuroGOOS members and private organisations;
2. Requests for further information from identified contacts; and
3. Analysis of the Euro Ocean Marine Infrastructure database. [3]

2.1 Web searches

The searches conducted for this task started by approaching the institutions identified as part of the EuroGOOS network. The EuroGOOS network is jointly leading the strategy for the EOOS, and the organisations that make up the network are likely to be significant members of a future EOOS. The organisations are also currently responsible for many of the activities that would be expected to fall within the remit of an EOOS and so their current activities are likely to be the most relevant.

Institutional websites have been searched, firstly, for annual reports (or equivalent) which often have financial information and descriptions of activities. Contact details for each of the institutions were also collated to enable requests for further information to be made where required.

2.1.1 EuroGOOS members

Searches for information focused on the public organisations that are members of EuroGOOS, as these will be the most likely to contribute to a European Ocean Observation system. Forty-two organisations across 18 EU Member States and Norway were identified and general web searches were completed to identify information on the activities that the originations are involved in. To classify the information in a consistent manner activities identified were listed using the SeaDataNet controlled vocabulary on parameter disciplines[4], as shown in **Table 1**.

Table 1: Parameter Disciplines.

Concept ID	Label	Description
DS01	Biological oceanography	The biological oceanographic science domain
DS02	Chemical oceanography	The chemical oceanographic science domain
DS03	Physical oceanography	The physical oceanographic science domain

[3] http://rid.eurocean.org/

[4] http://seadatanet.maris2.nl/v_bodc_vocab_v2/browse.asp?order=conceptid&formname=search&screen=0&lib=p08&v0_0=&v1_0=conceptid%2C

Concept ID	Label	Description
DS04	Marine geology	The marine geological science domain
DS05	Atmosphere	The atmospheric sciences domain
DS06	Cross-discipline	No specific association with an identified domain
DS07	Administration and dimensions	Parameters related to spatial and temporal co-ordinates, entity referencing (e.g. record numbering and keys) and access control
DS08	Terrestrial	The terrestrial science domain
DS09	Cryosphere	The cryosphere science domain, including ice on both land and sea
DS10	Environment	The domain documenting the habitat (physical, biological or chemical conditions) surrounding an organism or a group of organisms, or factors affecting any part of the earth ecosystem past and present.
DS12	Human activities	The domain documenting the activities of man that have an effect on the Earth System.

In addition to the activities undertaken, the searches also identified what platforms (equipment used to mount sensors that collect data) were being used by each organisation. These were classified according to the SeaDataNet controlled vocabulary on platforms[5], these are shown in Annex 1.

To identify the costs associated with the organisations, the searches identified any financial information relevant to the operation of the organisations. These where generally in the form of budgets within annual reports. Where possible, the costs are disaggregated by activity or platform type, although in practice this was often not feasible. In addition, data on the number of staff or full-time equivalent (FTE) in the organisations was collected.

2.1.2 Private Organisations

Web searches using the same platform and activity codes were conducted for private companies, and similar information on the numbers of staff where collected along with financial information such as turnover. The Ocean enterprise report (ERISS Corp; The Martime Alliance, 2016) identifies the two categories of private organisation that may participate in an OOS; providers of infrastructure and intermediaries that make use of observations and add value for end uses. The report also identifies that in situ data such as physical oceanography, bathymetry and geo physical data are most often used by intermediaries.

2.2 Requests for further information from identified contacts

In addition to information collected during the web searches as described in section 2.1, contact information was also collected. The purpose of this was to ask for additional information that may not be in the public domain, and to ask for information in a standard manner that might enable better comparisons to be made between organisations. From initial web searches it was apparent that the diversity of the types of information collected would make direct comparisons difficult. The request for additional information also included a table, based on the activities described in **Table 1** with space

[5] SeaVoX Platform Categories

for information on budgets and numbers of staff for the recipient to complete. Of the 52 request sent only 5 responses were received, however not all respondents were able to disaggregate the information by activities. The table requesting the additional information and the contact log of the stakeholder organisations contacted and their responses is presented in Annex 3.

2.3 Analysis of Euro Ocean Marine Infrastructure database

The objective of the Euro Ocean Marine Infrastructure database is to provide a comprehensive list of all the facilities dedicated to marine science and the operators of those facilities. The operators within the database were matched with the organisations identified as participating in EuroGOOS, in section 2.1. The classes of infrastructure identified in the database were mapped to the platform codes in Annex 1. To assist in the mapping, additional codes where added to the platforms in Annex 1, so that all the revenant infrastructure in the database could be given a code. Finally, where possible, a typical capital cost and operations cost were identified for each platform, these came from either, literature searches or from information identified in sections 2.1 and/ or 2.2. The costs were then converted into Euros using the average exchange rate for the year that the information was published.

The table of costs identified and their sources are shown in Table 2.

Table 2 Platform types with identified capital and operational costs.

Platform	Original Capital Cost	Capital Cost in €	Original Operational Cost	Operational Cost €	Capital Cost Source	Operational Cost Source
Coastal structure			EUR 340,000/14 stations in the year 2016	EUR 2,428		Irish response to request based on Tidal gauges
Autonomous underwater vehicle	GBP 26,975	EUR 30,933	3000 USD /Day	EUR 2,263	http://www.robotshop.com	http://oceanexplorer.noaa.gov
Sub-surface gliders	USD 150,000	EUR 113,031	150,000 USD/Year	EUR 113,031	noaa glider network	
Research vessel (Ocean going)	GBP 75,000,000	EUR 88,329,000	EUR 4,700,000 (EUR 20,000 per day)*235 operational days per year	EUR 4,700,000	RRS Discovery	Cost Of Day Average Sea days
Research vessel (Costal)	EUR 12,500,500	EUR 12,500,500	EUR 1,175,000 EUR 5,000 per day)*235 operational days per year	EUR 1,175,000	Multidisciplinary coastal research vessel Simon Stevin	Cost of day from EuroGoos Average Sea days

Vessel of opportunity on fixed route (ferry box)	EUR 37,000 (cheapest standard ferry box)+ EUR 4,000 cheapest Installation	EUR 41,000	EUR 5,100	EUR 5,100	Eurogoos FerryBoxs	
Moored surface buoy	EUR 501,000	EUR 501,000	EUR 731,000 /year	EUR 731,000	http://www.fixo3.eu	
Drifting subsurface profiling float (Argos)	USD 15,000	EUR 13,555	USD 7,500 /Year	EUR 6,777	Argos	
HF Radar	250,000 USD	EUR 188385	USD 45,000 /Year	EUR 33,909	http://gcoos.tamu.edu/?p=8229.	
Organism Satellite Tags	4000 USD	EUR 3400	EUR 250 to 500/year	EUR 250 to 500/year	http://www.microwavetelemetry.com/fish/price.cfm	Information provided by DG GROW
Archival Tags			€51 per deployed tag to €439 per deployed conventional tag	€51 per deployed tag to €439 per deployed conventional tag		Cost benefit analysis of the ICCAT GBYP tagging programme
Unmanned Aerial Vehicle	EUR 25000	EUR 25000	EUR 1000/day	EUR 1000/day	https://droneapps.co/price-wars-the-cost-of-drones-planes-and-satellites/	

In the resulting spreadsheet called InfrastructureData.xlsx in Annex 2 the costs in **Table 2** have been multiplied by the numbers of each piece of infrastructure identified in the database, to give an estimated cost for the types of platform. The organisations that are currently part of EuroGOOS, have been identified separately, so a comparison can be made between organisations most likely to contribute to the European Ocean Observation System and the wider marine observation community.

Archival tags are not recorded in Euro Ocean Marine Infrastructure database, but are often used in the collection of biological data and so some data on the cost per deployment is included in **Table 2**. The cost of a tagging programme can vary greatly depending on many factors including whether a vessel needs to be hired, the species being tagged, the location of the programme and what type of tags are used. For example the Grande Bluefin Tuna Year Programme is a six year programme initiated in 2010 which involved deploying nearly 25,000 tags on more than 16,000 Atlantic Bluefin tuna. The total cost of this programme over the six years amounted to €3,678,941.51, with the greatest cost attributed to field activities at €2,838,040.11. For the field activities there was a large variation on success rates of tagging missions which meant that costs ranged from €51 per deployed tag to €439 per deployed conventional tag, and from €177 to €3000 per deployed electronic tag (Righton, et al., 2016). This makes it hard to estimate the cost of a tagging programme as tag rates can be so variable. In contrast to this programme, the Scientific Support for Oceanic Fisheries Management project in the Western and Central Pacific Ocean, which tagged tropical tuna and South Pacific Albacore cost African, Caribbean and Pacific countries €1,266,000 and Overseas Countries and Territories €350,000[6] in 2010. Another report shows that the Pacific Tuna Tagging Programme in the Western and Central Pacific in 2007 was proposed to cost USD 9,800,000[7] over a five year period. The biggest cost for this programme (USD 3,959,000, excluding in-kind support) was tagging vessel operations which included charter costs for a vessel, vessel modifications, bait purchase and vessel

2.4 Results

The sources of information used to generate the result are focused on the operational capacity of ocean observation. It are these activities such as the collection of the essential ocean variables for physical and biogeochemistry domains that are the most mature and therefore have the most information available.

The full dataset and summary pivot tables are embedded in Annex 2. The results from section 2.2, requests for further information, have been combined with the web searches in section 2.1 the spreadsheet with these results is called SearchesAndContacts.xlsx. The private organisations are in their own spreadsheet called PrivateOrganisations.xlsx and the results of the combination of the infrastructure database and cost information in 2.3 are in the spreadsheet InfrastructureData.xlsx.

A summary of the results is presented below the charts 2 and 3 and table 3, 4 and 5.

[6] http://www.spc.int/Oceanfish/en/major-projects/scifish/190-budget-summary

[7] WCPFC Regional tagging project steering group.2007. PACIFIC TUNA TAGGING PROGRAMME – PHASE 2:WESTERN AND CENTRAL PACIFIC

Table 3 summary of European institutions involved in ocean observation parameter disciplines participating in, and spending

Country	Organisation	Parameter Disciplines										Currency	Amount	Year	Source
		Atmosphere	Biological oceanography	Chemical oceanography	Cross-discipline	Cryosphere	Environment	Human activities	Marine geology	Physical oceanography	Terrestrial				
Belgium	Agency for Maritime and Coastal Services (MDK), Coastal Division							✓	✓	✓					
Belgium	Royal Belgian Institute of Natural		✓	✓						✓		EUR	36,633,000	2016	Annual Report

	Sciences (RBINS), OD NATURE														
Bulgaria	Institute of Oceanology		✓	✓			✓		✓	✓					
Croatia	Croatian Meteorological and Hydrological Service (DHMZ)	✓								✓					
Croatia	Institue of Oceanography and Fisheries	✓	✓	✓						✓					
Cyprus	Oceanography Center, University of Cyprus (OC-UCY)	✓	✓	✓						✓					
Denmark	Danish Meteorological Institute (DMI)	✓				✓				✓					
Denmark	Defence Centre for Operational Oceanography (FCOO)	✓								✓					
Estonia	Tallinn University of Technology, Marine Systems Institute (MSI)	✓	✓	✓					✓	✓		EUR	368,000,000	2015	Annual Report
Finland	Finnish Meteorological Institute (FMI)	✓		✓						✓		EUR	118,000,000	2016	Web Portal
France	Ifremer	✓	✓	✓					✓	✓		EUR	463,084,894	2016	Annual Report
France	Mercator Ocean	✓	✓	✓						✓					
Germany	Helmholtz-Zentrum Geesthacht	✓	✓	✓				✓	✓	✓		EUR	4,600,000	2017	Response

Germany	BSH		✓	✓		✓			✓	✓		EUR	75,519,000	2015	Annual Report
Ireland	Marine Institute	✓	✓							✓		EUR	13,060,000	2017	Respon se
Italy	Euro-Mediterranean Center on Climate Change (CMCC)	✓	✓	✓						✓					
Italy	CNR		✓	✓	✓	✓			✓	✓		EUR	900,000,00 0		Web Portal
Italy	Italian National Institute for Environmental Protection and Research (ISPRA)		✓				✓		✓	✓					
Italy	Liguria Cluster of Marine Technology (DLTM)											EUR	6,834,762	2015	Web Portal
Italy	National Institute of Geophysics and Volcanology (INGV)									✓		EUR	81,567,648	2016	Web Portal
Italy	National Institute of Oceanography and Experimental Geophysics (OGS)		✓	✓			✓		✓	✓		EUR	39,333,841	2017	Web Portal
Latvia	Latvian Environment, Geology and Meteorology Agency – LEGMA					✓				✓					
Latvia	Latvian Institute of Aquatic Ecology		✓		✓		✓					EUR	120,000		Web Portal
Latvia	University of Lativa											EUR	21,800,000	2014	Web Portal
Lithuanian	Environmental Protection Agency, Department of Marine Research	✓	✓	✓	✓	✓			✓	✓		EUR	403,860	2017	Respon se

Lithuanian	Klaipeda University				✓										
Malta	University of Malta		✓									LM	24,682,524	2007	Annual report
Netherlands	Deltares								✓	✓		EUR	109,000,000	2016	Annual report
Netherlands	Rijkswaterstaat	✓	✓	✓						✓		EUR	74,357,000	2016	Annual report
Netherlands	Royal Netherlands Meteorological Institute (KNMI)	✓							✓	✓			48,000,000	2016	Annual report
Norway	Institute of Marine Research (IMR)		✓	✓	✓		✓			✓					
Norway	Nansen Environmental and Remote Sensing Center (NERSC)	✓			✓	✓	✓			✓		NOK	141,589,000	2016	Annual report
Norway	Norwegian Meteorological Institute (MET Norway)	✓				✓				✓					
Poland	Institute of Meteorology and Water Management (IMGW-PIB)	✓			✓					✓					
Poland	Institute of Oceanology, Polish Academy of Sciences (IO PAN)	✓	✓	✓	✓		✓			✓					
Poland	Maritime Institute in Gdansk (MIG)		✓	✓	✓		✓		✓	✓		EUR	14,662,820		Response
Portugal	Hydrographic Institute (IH)		✓	✓					✓	✓					
Portugal	Portuguese Institute for the Ocean and	✓	✓							✓	✓				

	Atmosphere (IPMA)														
Romania	National Institute for Marine Research and Development		✓	✓			✓			✓					
Slovenia	National Institute of Biology (NIB)		✓	✓			✓			✓			12,743,388	2015	Annual report
Slovenia	Slovenian Environment Agency	✓	✓				✓			✓	✓		200,000		Respon se
Spain	Puertos del Estado		✓							✓					
Spain	Spanish Institute of Oceanography (IEO)	✓	✓	✓			✓		✓	✓					
Sweden	Swedish Meteorological and Hydrological Institute (SMHI)	✓	✓	✓		✓	✓			✓		SEK	640,000,00 0	2015 (last update s)	Web Portal
United Kingdom	Centre for Environment, Fisheries and Aquaculture Science (CEFAS)		✓	✓			✓	✓	✓	✓			95,611,000	2016-2017	Annual report
United Kingdom	Met Office			✓		✓				✓					
United Kingdom	National Oceanography Centre (NOC)	✓	✓	✓		✓	✓		✓	✓		GBP	61,188,295	2016-2017	Respon se
United Kingdom	Natural Environment Research Council (NERC)		✓	✓		✓	✓		✓	✓	✓	GBP	994,141,00 0	2016-2017	Annual Report (for all sector not just marine)

Table 3 summary of European institutions involved in ocean observation parameter disciplines participating in, and spending a summary of the institutions involved in ocean observation in each country, with an indication of which types of observations the organisation is active in identified by the parameter disciplines defined in **Table 1**. The table also has a summary of the spending identified for that organisation, with the year that it is applicable to and the source of the information. The full table is available in the SearchesAndContacts.xlxs spreadsheet.

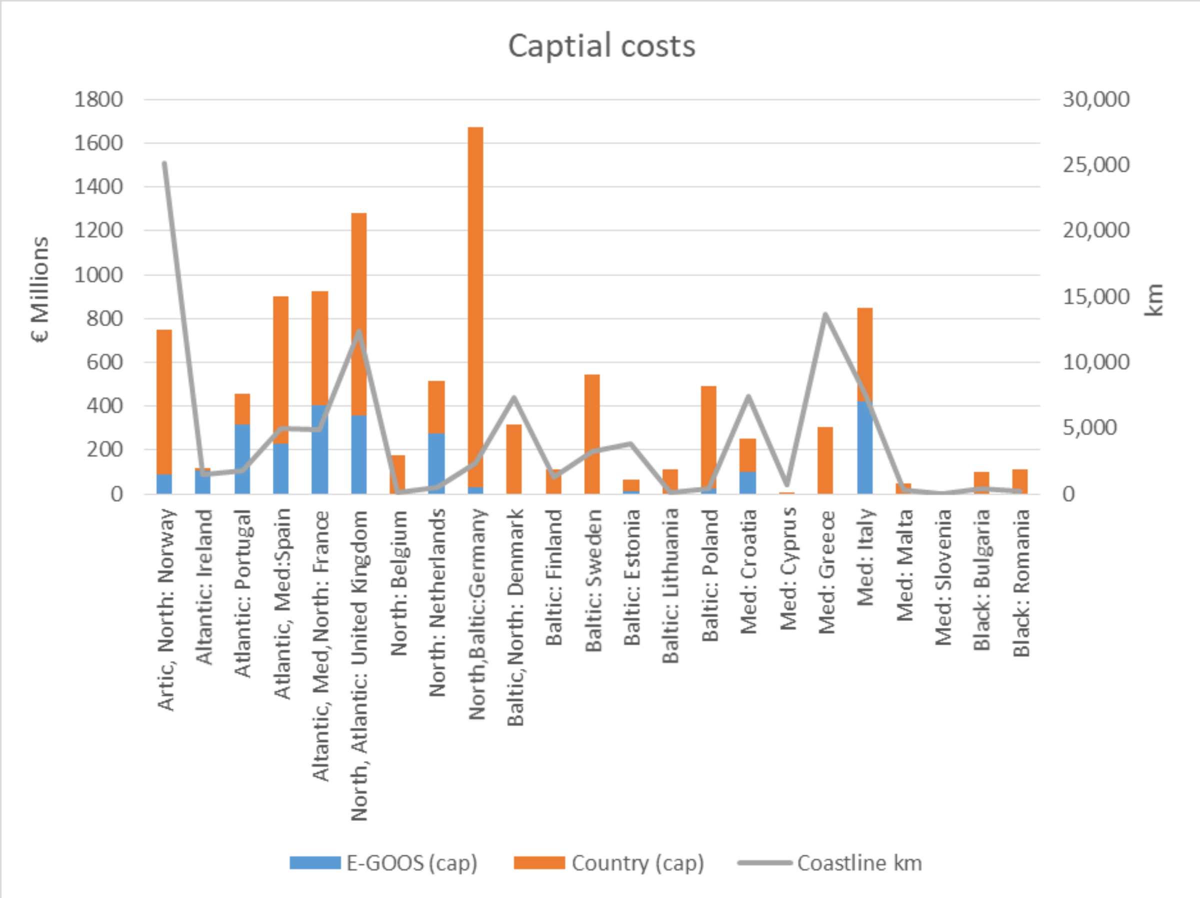

Figure 2 Estimate of capital cost of infrastructure of European countries identifying proportion spent by organisations participating in EuroGOOS with indication of length of coast line

Figure 2 gives an estimate of the capital cost of infrastructure identified in the Euro Ocean Marine Infrastructure database, combined with the costs identified in **Table 2**. The costs are split by the organisations identified in each country that are participating in EuroGOOS, and the wider ocean observation activities occurring in each country. The countries are grouped by sea basin and indication of the length of coastline is also given. **Table 4** provides a summary of the estimated cost for each country broken down by platform. **Figure 3** and **Table 5** provides the same summaries but for operational costs.

Table 4 Estimate of Capital cost by platform in Million Euros

Country	autonomous underwater vehicle	coastal structure	drifting subsurface profiling float	moored surface buoy	sub-surface gliders	vessel of opportunity on fixed route	HF Radar	research vessel (ocean)	research vessel (Costal)	Total Capital Cost
Belgium								176.7		176.7
Bulgaria								88.3	12.5	100.8
Croatia								176.7	75.0	251.7
Cyprus					0.2					0.2
Denmark								265.0	50.0	315.0
Estonia									62.5	62.5
Finland					0.1			88.3	25.0	113.4
France	0.1		0.9	15.5	1.6	0.1		706.6	200.0	924.8
Germany	0.1		0.9	8.0	1.5	0.4		1501.6	162.5	1674.9
Greece				1.0		0.0		265.0	37.5	303.5
Ireland			0.0	3.0	0.1			88.3	25.0	116.5
Italy	0.1		0.0	5.0	1.2		0.4	706.6	137.5	850.9
Lithuania								88.3	25.0	113.3
Malta									50.0	50.0
Netherlands			0.1					441.6	75.0	516.8
Norway	0.0		0.0	2.5	0.7	0.3		618.3	125.0	746.9
Poland				0.5				441.6	50.0	492.1
Portugal	0.2			0.5				353.3	100.0	454.0
Romania								88.3	25.0	113.3
Slovenia				0.5					12.5	13.0
Spain	0.1		0.1	5.5	0.1			795.0	100.0	900.8
Sweden				1.5				441.6	100.0	543.1

United Kingdom	0.2		0.6	16.5	4.1			1148.3	112.5	1282.2

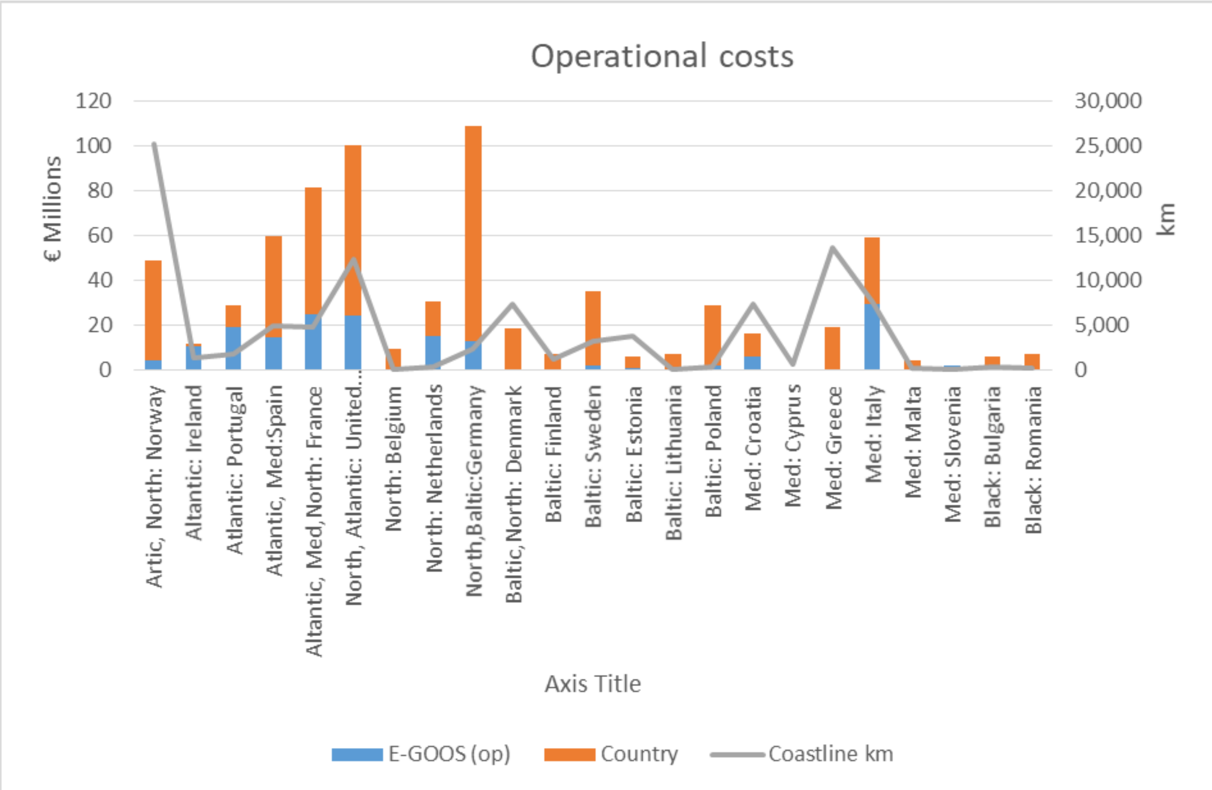

Figure 3 Estimate of operational cost of infrastructure of European countries identifying proportion spent by organisations participating in EuroGOOS with indication of length of coast line

Table 5 Estimate of operational cost by platform in Million Euros

Country	autonomous underwater vehicle	coastal structure	drifting subsurface profiling float	moored surface buoy	sub-surface gliders	vessel of opportunity on fixed route	HF Radar	research vessel (ocean)	research vessel (Costal)	Total operational Cost
Belgium								9.4		9.4
Bulgaria								4.7	1.2	5.9
Croatia		0.0						9.4	7.1	16.5
Cyprus		0.0			0.2					0.2

Denmark		0.1						14.1	4.7	18.9
Estonia									5.9	5.9
Finland					0.1			4.7	2.4	7.2
France	0.0	0.1	0.4	22.7	1.6	0.0		37.6	18.8	81.2
Germany	0.0		0.4	11.7	1.5	0.0		79.9	15.3	108.8
Greece		0.0		1.5		0.0		14.1	3.5	19.1
Ireland		0.0	0.0	4.4	0.1			4.7	2.4	11.6
Italy	0.0	0.2	0.0	7.3	1.2		0.1	37.6	12.9	59.3
Lithuania								4.7	2.4	7.1
Malta		0.0							4.7	4.7
Netherlands			0.1					23.5	7.1	30.6
Norway	0.0	0.1	0.0	3.7	0.7	0.0		32.9	11.8	49.1
Poland				0.7				23.5	4.7	28.9
Portugal	0.0			0.7				18.8	9.4	28.9
Romania								4.7	2.4	7.1
Slovenia				0.7					1.2	1.9
Spain	0.0	0.0	0.0	8.0	0.1			42.3	9.4	59.9
Sweden		0.0		2.2				23.5	9.4	35.1
United Kingdom	0.0		0.3	24.1	4.1			61.1	10.6	100.2

3 Objective 2: Cost and organisations in United States, China, Japan and Australia

3.1 Compiling and analysing costs

Web searches, using the same method used in Section 2.1, were conducted for the additional countries; the US, China, Japan and Australia. Where possible, the activities and platform descriptions used previously were employed, but only where direct comparison was possible. The results of the searches are recorded in Annex 2 in the spreadsheet entitled 3rdCountries.xlsx. To provide additional context for these four countries, diagrams have been created that show how ocean observations are organised in each country and what platforms are being used. The diagrams can be viewed in Annex 3.

3.2 Analysis of planning

3.2.1 Australia

The key organisation when considering planning for ocean observation in Australia is the Integrated Marine Observation system (IMOS). The plans of the system are laid out at different levels of details and timescales. There is a 10 year strategic plan (IMOS, 2014) that sets out the vision for the system, a 5 year plan (IMOS, 2016) that defines the drivers and future priorities for the system, and an annual business plan that contains the detail budgets of the system.

The IMOS was identified as part of the Australian National Collaborative Research Infrastructure Strategy Strategic Roadmap in 2006 (Australian Govement, Department of Education and Training, 2006), and was established later that year. In the first ten years of operation the IMOS has moved through several stages and entered its ongoing "survival" stage in 2013. In 2014 a strategy for IMOS second decade of operation was published, with the stated vision of "by 2025, Australia will have a continuously growing time series of essential ocean variables for marine and coastal environments. This will enable cutting edge research on contemporary problems and provide a scientific basis for informed decision making about our vast and valuable marine estate." In conjunction to the strategy, in 2016, the IMOS published its 5 year plan running from 2017 to 2022. The plan splits the IMOS into 4 components; broad-scale, backbone, regional, and program level, the facilities in each components are show in **Table 6**

Table 6 Components and facilities of IMOS.

Broad-scale	Backbone	Regional level	Program level
- Argo profiling floats - Satellite Animal Tracking - Ships of Opportunity, for physics - Ships of Opportunity, for biogeochemistry and biology and ecosystems, and - Satellite Remote Sensing calibration/validation/reception and national products	- Deepwater Moorings (transport arrays) - Deepwater Moorings (time series) - National Reference Station Network (including ocean acidification and passive acoustics) - Acoustic Animal Tracking - Autonomous Underwater	- Ocean Gliders - Ocean Radar - Moorings Network (continental shelf and coastal) - Wireless Sensor Network (GBR) - Satellite Animal Tracking	- IMOS Offices - Australian Ocean Data Network (AODN), - IMOS Ocean Current portal

Broad-scale	Backbone	Regional level	Program level
	Vehicles (AUV)		

Each component and its facilities are considered for how they relate to the drivers and what feedback is generated from within the system. Feedback identified includes deferred capital replacement, cost effectiveness and dependencies.

The final section of the plan is an overview to ensure that the components of the plan are balanced between the components, the continuation of existing facilities and enhancements and extensions.

The plan includes a split between the different facilities, that indicates which may expect the most investment. The split is shown in **Figure 4** for existing facilities and in **Figure 5** for expected enhancement and extensions taken from the 5 year plan (IMOS, 2016, p. 39).

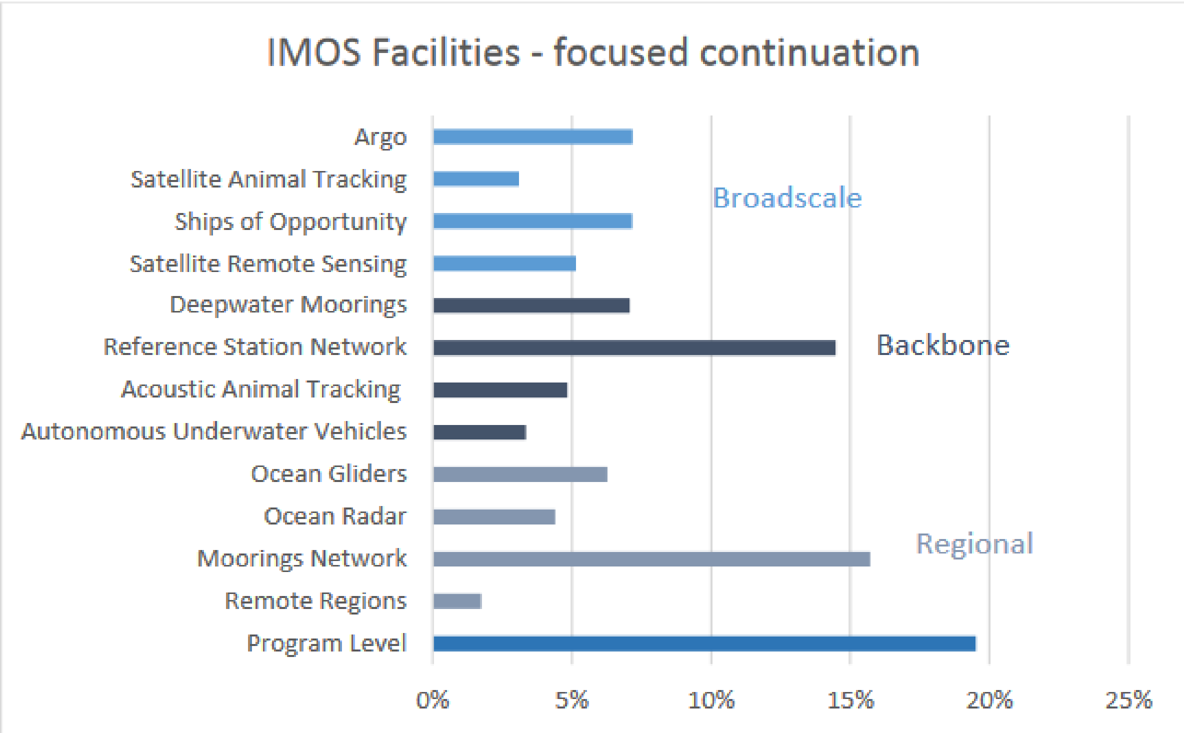

Figure 4 Proportion of budget in 5 year plan for existing facilities of IMOS

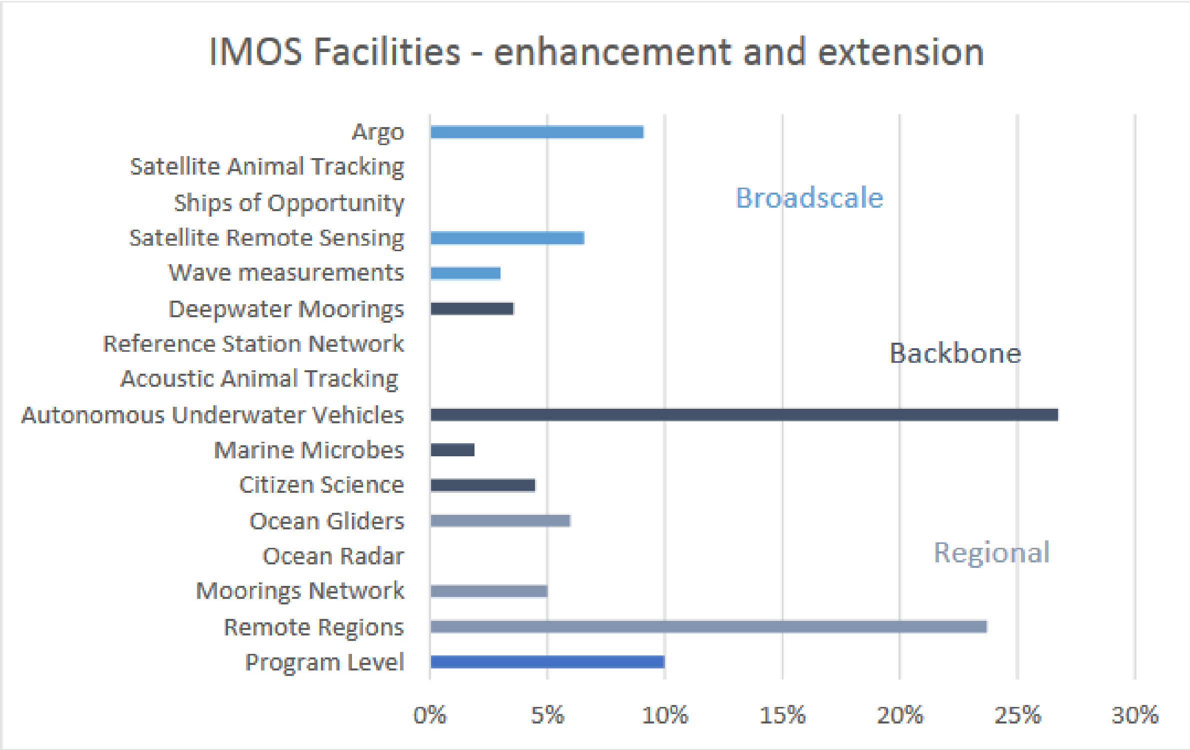

Figure 5 Proportion of budget in 5 year plan for Enhanced facilities of IMOS

The annual business plans contain a detailed breakdown of the expected budget by the facilities (as identified in the 5 year plan) and makes several reference and linkages with the 5 year plan.

3.2.2 China

In China, the key ocean observation organisation is the State Oceanic Administration (SOA). It is responsible for drafting plans with relevant departments on strategic development of the sea and its main functional zones, plans on environmental protection, marine economic development, island protection and development of uninhabited islands. Various institutes for oceanography, and two key organisations feed into the SOA, the National Marine Data and Information Service (NMDIS) and National Marine Environmental Forecasting Centre (NMEFC).

The key marine environment observation system of SOA, known as the China Real Time Data Base (RTDB) includes real-time observation, real-time transmission and real-time monitoring. As one part of the NEAR-GOOS (the North-East Asian Regional Global Ocean Observing System), it provides forecasting, data, monitoring, planning and indicators, and is largely operated by NMEFC, supported by NMDIS. All the data are derived from the ocean stations, buoys, radars, ship observations, satellite, and coastal observing stations. NMDIS is a government funded public institution that supports SOA directly. It is responsible for the management of national marine data and information resources, providing guidance and scientific stewardship for the national marine data and information and providing information and technical support for marine economy, marine management, public service and marine environmental protection and conducting related research. NMEFC is financially supported by Chinese government. Their primary function is forecasting and warning and operation management.

In terms of planning, there is little information easily accessible specifically regarding ocean observation. However, every five years, China releases a new maritime transformation plan. This change in strategic outlook may affect policies governing national defence, diplomacy, commerce, industry, and society. This document is much briefer than previous iterations.

The proposed plan calls for further geographic expansion of China's maritime activities. It states that China will "expand space for the blue economy". In an SOA article, this was interpreted to mean that China will "make full use of maritime space all around the world."

3.2.3 Japan

The lead organisation for ocean observation in Japan, is the Japan Agency for Marine-Earth Science and Technology, JAMSTEC[8]. Their main objective is to contribute to the advancement of academic research in addition to the improvement of marine science and technology. In 2008, they established their long-term 'vision', which was subsequently updated in 2009 up to 2014, the latest publication is their medium-term plan (JAMSTEC, 2013) for the next 15 years.

In the long-term vision of 2008, JAMSTEC identified three priority research objectives; to advance the observation of global environmental changes and to analyse the cause, and actively contribute to protecting society from global environmental changes; to determine the basic principles regarding the dynamics of Earth's interior, that cause earthquakes, tsunamis and volcanic phenomena; and to elucidate the unique biological and ecological adaptations of life existing in the mesopelagic zone, deep-sea floor, and crust. These remain at the core of their future activities, however, JAMSTEC has decided to reconsider its goals and approaches and redefined them as the new vision.

The Japanese government formulated the Basic Act on Ocean Policy in 2007, emphasising the importance of establishing a new maritime nation. In response, JAMSTEC plan that the country will become an entirely ocean-based nation. They focus on developing new scientific and technological capabilities which contribute to the sustainable development and responsible maintenance. JAMSTEC will continue to develop an integrated and comprehensive understanding of the Ocean, Earth, and Life, as such, JAMSTEC plan to address the following:

- An integrated understanding and prediction of global environmental changes;
- The establishment of an advanced understanding of the Earth's interior, and its application for the mitigation of earthquake and tsunami disasters; and
- A comprehensive study of the evolution of life and the history of the Earth.

JAMSTEC aims to enhance all Japanese research and development capabilities, through a close cooperation with domestic and foreign universities, research institutes, and industries.

3.2.4 United States

The US has a national-regional partnership, known as the Integrated Ocean Observing System (IOOS), this represents a consortium of governmental and nongovernmental stakeholders. The US IOOS Program Office is organised into two divisions that implement policies, protocols, and standards to implement IOOS and oversee the daily operations and coordination of the System: Operations Division; and Regions, Budget, and Policy. The Operations Division coordinates the contributions of Federally-owned observing and modelling systems and develops and integrates non-federal observing and modelling capacity. The "Regions, Budget and Policy" oversees management, budgeting, execution, policy and regional and external affairs to further the advancement of IOOS.

[8] http://www.jamstec.go.jp/e/

In 2010, guided by the Integrated Coastal and Ocean Observation System (ICOOS) Act of 2009, the US IOOS released its 'Blueprint' (U.S. IOOS Office, 2010) to address the need for centralised coordination and stewardship of IOOS development that enables distributed national and regional IOOS implementation. The Blueprint describes a number of functions, including 'User Councils', which provide input / feedback on plans for and execution of US IOOS. The 'User Councils' also provide a forum for discussion of IOOS user needs keyed to specific areas of interest. The 'Plans and Operations' division manage the plans and operations supporting the full range of IOOS activities related to modelling and analysis, R&D, training and education, and change management, and create and manage plans that coordinate activities at an international level that may include members of some or all user councils or other entities with an interest (e.g., U.S. participation in an international ocean observing plan). In addition, the IOOS Program Office planned a 10-year build-out to full capability of observing assets, core functions, and data assembly, following the finalisation and approval of the implementation plan. This 'Blueprint' towards full capacity is nearing the end of its implementation, and as such, IOOS are beginning to build their new strategic plan to carry IOOS to the next level.

IOOS supports and is supported by various organisations and by eleven regional associations. They develop plans for build-out of capabilities and services on a yearly basis. Because of limited funding, it is difficult for the regional associations to plan much farther than the current budget year.

There are eleven regional associations in total, they are;

1. AOOS – the Alaska Ocean Observing System[9];
2. PaCOOS – the Pacific Coast Ocean Observing System[10];
3. NANOOS – the Northwest Association of Networked Ocean Observing Systems[11];
4. CeNCOSS – the Central and Northern California Ocean Observing System[12];
5. SCCOS – Southern California Coastal Ocean Observing System[13];
6. GLOS – Great Lakes Observing System[14];
7. GCOOS – Gulf of Mexico Coastal Ocean Observing System;
8. NERACOOS – the North-eastern Regional Association for Coastal Ocean Observing Systems[15];
9. MARACOOS – Mid-Atlantic Regional Association Coastal Ocean Observing System[16];
10. SECOORA – Southeast Coastal Ocean Observing Regional Association[17]; and
11. CARICOOS – the Caribbean Coastal Ocean Observing System[18];

In March 2011, IOOS, released their 'Cost Analysis Requirements Description' (CARD) (U.S. IOOS, 2011), which aims to help develop realistic estimates for budgeting and planning. It documents assumptions, presents technical, functional, and physical descriptions of program elements; it provides a schedule for development and acquisition; describes the support concept and operational needs in terms of fuel, power, chemicals, labour, facilities, tools, security, and so on; and defines the life-cycle length.

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[9] http://www.aoos.org/
[10] http://pacoos.org/
[11] http://www.nanoos.org/
[12] http://www.cencoos.org/
[13] http://sccoos.org/
[14] https://www.glos.us/
[15] http://neracoos.org/
[16] https://maracoos.org/
[17] http://portal.secoora.org/
[18] http://portal.secoora.org/

3.3 Access to data

3.3.1 Australia

All the data collected under the Integrated Marine Observing System (IMOS), are required to be made available through the Australian Ocean Data Network (AODN) Portal. The portal provides a means of discovery and download service for marine and climate related data. The data collections in the portal can be searched by; parameters (Physical-Water, Biological, Chemical, Physical-Atmosphere), organisation, platform, dates, geographic boundaries or by keywords. The portal itself is based on the open source GeoNetwork[19] that uses open standards such as the ISO 19115 and Dublin core metadata standards. Each data set has a metadata record that will describe under what licence the data is available. The portal states that the majority of the data is available under the Creative Commons Attribution Licence[20]. The AODN and the IMOS data policies are similar, and the AODN implement many aspects of the IMOS policy (IMOS, 2016). In addition to providing access to the data IMOS also provided a series of tools[21], products and software that can be used in conjunction with the data on the AODN portal.

3.3.2 China

National Marine Data and Information Service of China, provide data service under the State Oceanic Administration (SOA) of China. It hosts a portal[22] where data is catalogued on buoys, stations, volunteer vessels, environmental data, surveys, data from ARGOS floats, as well as remote sensing data. However the access to the actual data is limited. The information service is also engaged on a Big Data[23] project that is planning on increasing the utility of the marine data that it holds.

3.3.3 Japan

Japan Agency for Marine-Earth Science and Technology (JAMSTEC) has two portals for discovering and accessing data. The JAMSTEC data search portal is a geographical search portal, and the JAMSTEC data catalogue uses a tree structure to organise the data sets. The search portal allows data sets to be searched for according to location, date, a predefined list of variable such as bathymetry, cruise tracks, bottle samples and research vessel involved. The location of the datasets are plotted, and a summary table of the datasets conforming to the search criteria is displayed showing the exact location, dates, and additional information such as station name or ship name. The summary table will also have a link to the dataset, or metadata about the records set; however the format of the metadata is variable.

The JAMSTEC data catalogue that can be interrogated through a directory structure of keywords such as Atmosphere, Cryosphere, and biological classification. The Catalogue uses the Directory Interchange Format (DIF) metadata standard that is used by NASA's Global Change Master Directory. The data catalogue appears be a more complete and consistent record of the JAMSTEC datasets. The JAMSTEC data catalogue also has a defined data policy [24]. The policy states that in most cases the data held by JAMSTEC is to be used for research purposes to the benefit of all. The data policy contains references to several potential restrictions that may be placed on the data, these include a memorandum on some of the data to give the scientist that have collected the data

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[19] http://geonetwork-opensource.org/
[20] https://creativecommons.org/licenses/by/4.0/
[21] http://imos.org.au/imosdatatools/
[22] http://mds.nmdis.org.cn/
[23] Status and Trends of Marine Big Data in China
[24] http://www.jamstec.go.jp/e/database/data_policy.html

priority, and the principle that industrial users of the data may be charged for the use of the data.

3.3.4 United States

The IOOS has a core data management and communications team that help to coordinate access to data and promote the general principle of sharing data. However the data is delivered through a mixture of regional and central portals. There are 11 regional portals that each have a different look and feel, and offer different ranges of data, and products. Most of the regional portals do not have a clear data policy. Supplementing the regional portal, IOOS has a central master directory of datasets, and promote standards and tools to accept data to a central inventory. The data set can be searched by Organizations, Formats, Keywords and geographic boundaries. Record sets have ISO 19115 metadata associated with them, however no searches of the central inventory provided information on the licence that the data was made available under.

In addition to the regional portals and central inventory, IOOS also provides a number of central portals that provide access to data according to more general themes, such as The Environmental Sensor Map, Environmental Data Server Model Viewer, Marine Biodiversity Observing Network Portal, High Frequency Radar (HFR) Data Assembly Centre (DAC), IOOS Underwater Glider Data Assembly Centre, Animal Telemetry Network (ATN) Data Portal. Each portal has different functions, and use a variety of metadata, and discovery methods to find data. Some such as the Animal Telemetry Network have a specific published data policy[25], but in general most of the portals do not have clear policies. IOOS does have a portal that is dedicated to providing advice on tools that can be used with the data across the portals.

3.4 Application to EOOS

Of the four countries outside of Europe examined, both the US and Australia are operating integrated oceans observation systems that are also GOOS regional alliances (GRAs) of which Euro GOOS is also member. A European integrated system may therefore be expected to have similar requirement and challenges. Although both the US and Australia are single countries there are differences in how the integrated observation systems operate. In the US, there are a large number of federal and state agencies, coordinated through the lead agency the National Oceanic and Atmospheric Administration (NOAA). However, when it comes to accessing the data, there are large number of portals that work in different ways. So while the raw access to data is very good, it can be difficult to get a comprehensive overview. In Australia, there is also a mixture of federal and state agencies, however the number is much smaller than in the US. Accessing data in Australia is facilitated through a single central data portal with comprehensive and consistent metadata, which facilitates both the discovery and use of datasets. For a European system a coordinated system of access to data will be important and the EMODnet portals and the standards and metadata behind them should be well placed to fulfil this role.

The larger number of organisations involved in planning in the US means that production of detailed budgeted plans for the whole of the ocean observation system, like those produced for the Australian system, are not practical. Tools such as the Cost Analysis Requirements Description (CARD) are used instead. As the situation is likely to be similar for a European ocean observation system, similar tools may be useful.

In Japan, the structure of the ocean observation systems is simple and information on planning and budgeting are clear. The access to data is not as transparent, with there

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[25] http://mola.stanford.edu/atnbackenddocs/DATA_POLICY_ECTION_EXCERPT_FROM_THE_ATN_IMPLEMENTATION_PLAN.pdf

being more apparent restrictions on data than in the US and Australia. Discovery of data in Japan is good, but is complicated by the two different portals using different metadata standards and different classifications of datasets.

In China there are 5 year maritime transformation plans that include marine observation, however the details are not clear. What is apparent from the activities of the institutes that are part of the broader SOA, is that there are initiatives planned to use big data techniques to increase the utilisation of ocean data in China.

4 Objective 3: Summary of studies on economic and societal benefits

This section summarises existing information, in order to show the economic and societal benefits of ocean observation, while focusing on the feasibility of:

- Identifying innovations resulting from better availability of data; and
- Estimating the benefit of reducing uncertainty.

The first section highlights the various sectors for which benefits have been identified and in some cases, evaluated and summarises how they have been valued.

The second section focuses on the transition from ocean observations collected partly by private entities as private goods (i.e. not accessible to other stakeholders) to an Ocean Observing System (OOS), where marine data becomes a public good. The aim is to show where private cost reductions could be obtained, by introducing a public-funded Ocean Observing System.

The third section shows how innovation may be fostered by the development of an integrated OOS.

The fourth section focuses on the potential reduction of uncertainties based on the existence of an operational OOS.

4.1 Summarising information on identified economic and social benefits

4.1.1 The economic nature of an Ocean Observing System

Defining the benefits derived from the implementation of an OOS has been the subject of publications for at least 25 years (Wood, et al., 1996)

From a theoretical perspective, a functioning Ocean Observing System can be considered as a public good. Once the information is produced, it is almost costless to distribute it to any stakeholder interested, with no stakeholder group able to exclude other groups from using it (non-excludability). The use of the information by a stakeholder, or a sector, cannot reduce the benefits other stakeholders / sectors can derive from the use of the same information (non-excludability). The argument of OOS as a public good has been used in several studies to justify government funding (see notably (Adams, et al., 2000) and (Willis, 2009)).

The existence of positive network externalities is one of the arguments used to support this (see notably (Willis, 2009)). A positive network externality exists "in products for which the utility that a user derives from consumption of that good increases with the number of other agents consuming that good" (Katz & Shapiro, 1985). In some specific cases, positive network effects can generate very large returns (see **Figure 6**). When considering positive network externalities, the value of the OOS is many times that of its individual parts, leaving no real incentive for any private company to fund the creation of the system (Adams, et al., 2000): as the information is public, private companies would have trouble to be compensated for the external benefits they are generating.

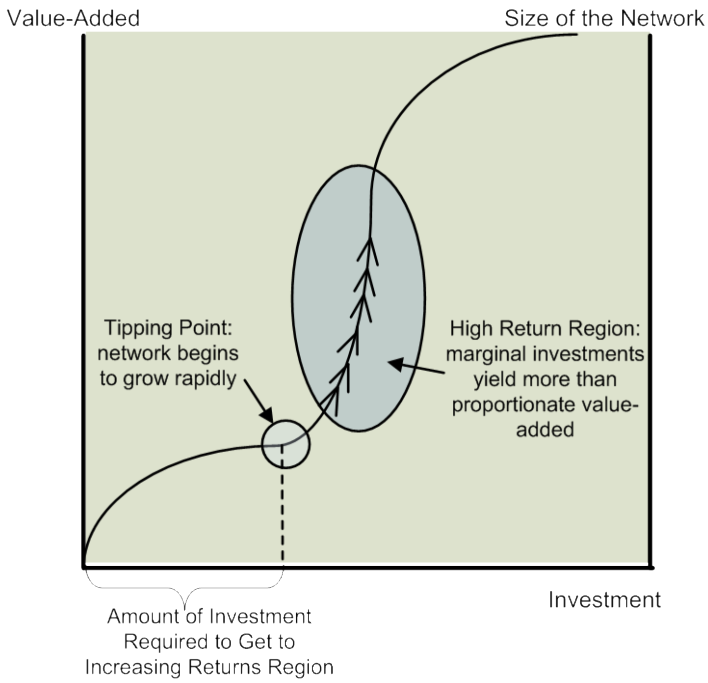

Figure 6: Relationship between investment level and value-added generated in presence of positive network externality, from Willis (2009)

Some authors have, however, criticised the approach of public good (Weiher, 2008), as the public goods theory provides a rationale for publically supplied information, but the level of production, notably the level of details, cannot be derived from this theory. They argue that cost-benefit analysis is therefore needed to decide how much data should be produced, by comparing net benefits among data / observing systems and other public goods. They also point out that advances in the technology and economics of observing systems should be assessed case by case to evaluate whether the public goods argument is sound and justifies government funding.

4.1.2 Evaluating social and economic benefits arising from an OOS

Since the 1990s, the case study for improving ocean observations has been built on the potential benefits arising from a more integrated system. According to Flemming, Kester had already showed in 1993 that the improvement of ocean-atmosphere predictability could generate additional benefits, depending on the time-horizon considered for the data collection (**Figure 7**) (Flemming, 2001, pp. 66-84).

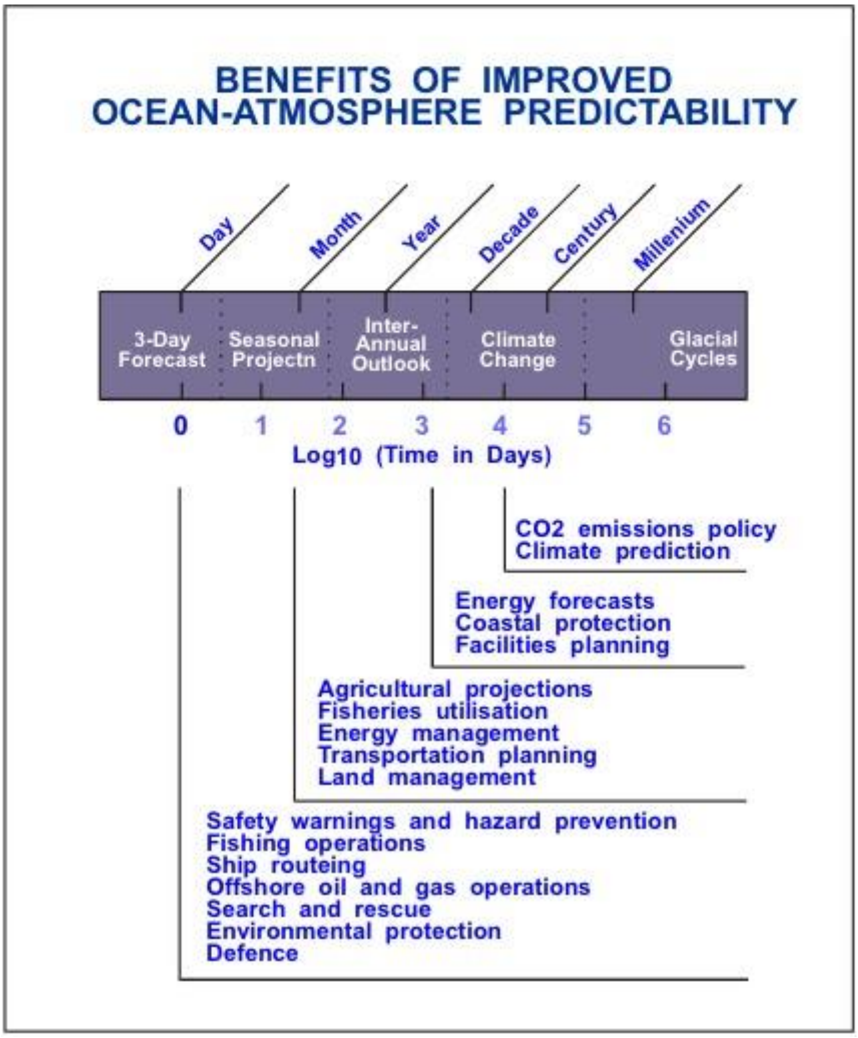

Figure 7: Timescale of different kinds of predictability and activities and services which would benefit. Adapted from Kester 1993, in Flemming (2001).

It is noted in several studies and presentations (see notably (Flemming, 2007)), that since the beginning of ocean observing systems deployment, the estimation of benefits of such systems have been mostly limited to specific case studies describing benefits for direct applications (e.g. improvement of search and rescue operations, beach closures, better routing in the shipping sector), but never for all likely benefits. Several types of benefits were not always considered in the different evaluations, notably those related to better environmental management, as well as various non-market benefits (e.g. policy improvements, adaptation to climate change) (see (Fritz, 2016), but also **Figure 8**). Jolly highlighted in a presentation that studies could be separated by different socio-economic beneficiaries (Jolly, 2016)):

1. Most of studies focus on market-driven efficiency information (benefits to user);
2. Few studies focus on improved environmental management;
3. Few studies focus on environmental and welfare issues, improved regulations, non-market values and public good benefits;
4. Few studies focus on planetary public goods, improving the management, mitigation, and adaptation of environmental change and climate; global environmental policy on the grand scale.

PUBLIC GOOD BENEFITS	• Improved scientific understanding • Better understanding of the natural capital and ecosystem benefits of the oceans • Better understanding of the role of the oceans in the overall earth system and especially their role in weather and climate • Supporting the formulation of policy, monitoring of policy compliance and effectiveness associated with measures to protect the environment of regulate ocean uses • Education benefits
PUBLIC GOOD AND COMMERCIAL BENEFITS	• Supporting safety and emergency response
COMMERCIAL BENEFITS	• Supporting protection of coastal communities • Underpinning the metocean information needs of commercial maritime activities and operations.

Figure 8: Benefits of ocean observation, from (Fritz, 2016, p. 134).

This may cause a fundamental issue in terms of cost-benefit evaluation: if these studies are used to assess the validity of the existence of an OOS, they may potentially miss the largest benefit areas, as some researchers argue that the supply of public goods is the largest benefit generated by an OOS.

Several authors insist on the fact that the methods used to evaluate these case studies do not converge and that the different results may not be comparable. Jolly has identified more than thirty economic impact studies of ocean observation which have fundamental differences (Jolly, 2016):

- Objectives are quite diverse: prove expenditure, investment, find maximum level of expenditure;
- Funders of studies do not have the same status;
- The overall approach to the evaluation is sector-specific vs. wider public good, micro vs. macro analysis;
- Geographical scope: some evaluations focus on regions, other look at entire countries (Australia, Ireland);
- There is currently no consensus on the method applied: Cash-flow Net Present Value (NPV), Cost-Benefit Analysis, One-sided analysis (only benefits or only costs); and
- Time-scale of return considered in the studies also show a high variety, ranging from 5 to 30 years, which has a huge impact on the potential net present value that can be extracted from the studies.

With such a variety in design, the two main issues identified by Jolly are that results are hardly comparable, even at sectoral level and that benefits of different studies can’t be aggregated to obtain a complete picture of potential benefits from OOS.

In terms of methods implemented, it is striking that despite using different approaches, many studies from the 1990's and 2000's end up estimating benefits using the same 1% approach, which is sometimes called the "Zero-th Order Calculation". This method is based on economic assessments of weather and climate forecast conducted in the 1980s, notably by Nordhaus (Nordhaus, 1986). It consists in evaluating the size of the sector considered, most of the time in terms of gross value added (GVA) generated, sometimes in terms of revenue (turnover), and assume that implementing an OOS would increase the GVA (or turnover) by 1%. In some cases, the 1% rule is applied to cost reduction or to savings. For example, the work from Kite-Powell and Cogan on the potential economic benefits of coastal ocean observing systems in the Gulf of Maine entirely relies on this 1% method (Kite-Powell & Cogan, 2001). It should be noted that presenting the results in terms of revenue gains is not a pertinent option as it does not allow direct comparisons between sectors, which means that estimations should always be translated into GVA gains as GVA is the only economic measure comparable between economic sectors.

Nolan indicated that in the first years of OOS, the economic justification was weak, based on the assumption that the socio-economic benefits were justifying the expenditure on marine scientific research and operational oceanography, without providing any robust estimation of those benefits (Nolan, 2016). Citing the FP6-SEPRISE project[26], Nolan's perspective is that the 1% approach is not good enough and should be replaced by a more detailed cost and benefit approach, which would produce stronger estimates of the potential benefits of an OOS.

There is a fundamental research question in this debate: are these simplistic "back-of-the-envelope" estimations sufficient to estimate the benefits or is there a real need for more detailed (and costlier) evaluations. No author has showed at this point that the 1% assumption was a complete overestimation of the benefits or that the benefits evaluated with the 1% assumption were not sufficient to cover the potential costs of an OOS at a national level, thus deferring its implementation to future research showing sufficient benefits. Kite-Powell and Cogan used the 1% approach in several regional case studies in the USA and compared them to subsequent analysis using more explicit Bayesian models and showed that both methods had the same order of magnitude, suggesting that the range of estimates is reasonable in their case (Kite-Powell, et al., 2005). Despite deploying far more detailed descriptions of potential improvement gains from the initial studies, some recent studies still rely on estimations of benefits based on efficiency improvement in order of few percentage points, with variations depending on the maturity of the sector around 1% for established sectors, with higher levels for sectors in development.

4.1.3 Social and economic benefits identification

Since the 1990s, identification of specific sectors benefiting from ocean observations has been central to the different studies detailing the economic importance of ocean observations.

Depending on authors, benefit classifications have differed, most of the time being targeted at the specific regional audience of the report. In the business case for improving NOAA (Willis, 2009), thirty impact areas are classed according to four groups: energy, environment, safety and health, and commercial (**Table 7**).

[26] http://www.copernicus.eu/projects/seprise

Table 7: Impact areas identified in the business case for improving NOAA.

Impact Areas Identified			
Energy	Environment	Safety and Health	Commercial
• Wind energy • Hydroelectric generation, transmission, and distribution • Electricity power generation • Offshore power generation • Energy forecasting	• CO_2 emission policy • Climate prediction • Meteorological services • Hydrological services • Environmental education • Management of endangered species • Scientific research • Coastal protection and management	• Storm forecasts • Search and rescue operations • Oil spill response • Water quality • Famine prevention • National defence	• Weather forecasts • Tourism • Recreation • Oil and gas production • Maritime operations • Vessel management operations • Fisheries • Trade • Development • Land management • Transportation

Adapted from (Willis, 2009).

More recent studies try to classify the benefits in use and non-use benefits, with use benefits separated in direct and indirect use, and non-use benefits comprising option value, altruistic value, bequest value and the existence value e.g. (Liebender & Jolly, 2016) (see **Table 8**).

Table 8: Use-benefits and non-use benefits of ocean observation.

Type of benefit	Sub-components of benefits	Applications	Examples of improvements
Use benefit	Direct use	Marine weather forecasts of sea-state and meteorological conditions	• Renewable energy • Defence-related operations • Agricultural use • Energy management • Coastal management • Facilities planning • Disaster risk reduction • Public health risk reduction • Search, rescue • Other sectors (e.g. conservation, mining, subsea technologies)
		Long-term monitoring in climate and ocean modelling	• For improved environmental management of marine, coastal and land operations • Improving the management, mitigation, and adaptation of environmental change and climate; global environmental policy
	Indirect use	Book and newspaper readers - TV and documentaries audiences	• Understanding of marine ecosystems as part of sustained life on Earth
Non-use benefit	Option value	As "use benefits", only in the future	• Better protection of the marine environment for future individual use
	Altruistic value	Long-term monitoring in climate and ocean studies for scientific research and strategic planning	• Better protection of the marine environment for the use of others
	Bequest value		• Better protection of the marine environment for the use of future generations
	Existence value		• Better protection of the marine environment for the sake of their existence

Adapted from (Liebender & Jolly, 2016).

To avoid unnecessary duplication of references in the following paragraphs, the list of studies constituting the core of this analysis are:

- (Kite-Powell, et al., 2005): Kite-Powell H, *et al.,* "Estimating the Economic Benefits of Regional Ocean Observing Systems," April 2005.
- (Anon, 2006): "Economics of Australia's sustained ocean observation system, benefits and rationale for public funding". Report for the Australian Academy of Technological Sciences and Engineering and the Western Australian Global Ocean Observing System Inc.
- (Willis, 2009): Zdenka Willis, 2009 "The Business Case for Improving NOAA's Management and Integration of Ocean and Coastal Data - Integrated Ocean Observing System". NOAA IOOS Program.

Despite not evaluating an OOS but the opportunity to develop an extensive marine mapping programme, a fifth study has been integrated in the analysis, as it provides specific information completing the studies focusing on OOS:

- (PWC, 2008): PriceWaterhouseCoopers 2008, INFOMAR: marine mapping study. Options appraisal report: final report. Economic and public policy.

In the following paragraphs, benefits estimators are summarised for each sector for which benefits have been identified in the literature. Highlighting what kind of data may be needed for each sector, but also assumptions that may have been used in publications to estimate the benefit an OOS would have generated.

4.1.3.1 *Commercial/Resource Benefits*

Fishing industry

The fishing industry would benefit from an OOS by the definition of better management measures derived from a better knowledge of the environment, notably for species impacted by environmental variability gaining more information. Gains in efficiencies, reduction in gear losses and better protection of vulnerable fish stages (e.g. juveniles, spawning areas) are also seen as potential benefits deriving from an OOS.

In terms of information, the main needs rely on several key data and products potentially by OOS: habitat maps, geology maps, primary productivity maps (especially for pelagic species), but also improved weather forecasts.

PriceWaterhouseCoopers estimate benefits based on the increase of the GVA generated by the sector, using three impact scenarios: low impact (1% increase), medium impact (2% increase) or high impact (3% increase) (PWC, 2008). The impact is similar to what is evaluated in North-American examples: integrate a potential 1% increase in fishing time. It should be noted however, that in the European context, where a large share of the fish stocks are managed by TACs, there may not be a potential for increase for all stocks.

Kite-Powell et al. also present various estimates for several regions of the US, based on different benefits: better use of available resources (capital/ labour) or increased catch, with different indicators to measure benefits: producer surplus or wholesale value (Kite-Powell, et al., 2005).

Aquaculture

The aquaculture sector notably requires habitat maps to understand where suitable sites may be, as well as bathymetry and current maps, and bio-contaminants and pollution maps. Furthermore, some shellfish aquaculture relies on primary production maps. The combination of this information may notably improve estimation of carrying capacity and foster efficient site designation.

PriceWaterhouseCoopers details also that the impact for the fishing industry is to be a small increase of the GVA generated by the sector (PWC, 2008). As the sector is in development in Ireland, the impact is supposed to be more important than for fisheries: 2%, 4% and 6% of GVA per annum in the low, medium and high impact scenarios.

Biodiversity

PriceWaterhouseCoopers define a biodiversity sector, despite the boundaries of this sector not being well defined, nor its importance (PWC, 2008). According to their description, it encompasses all sectors that would benefit directly of the biodiversity by exploiting it (removal). There is no direct valuation for GVA generated by the "biodiversity sector" in Ireland to build the analysis on, the seaweed sector is used as a proxy. Apart for (PWC, 2008), this sector is usually only mentioned, no value being attached to its development, notably due to its highly speculative status. There is no guarantee that such sectors would develop in other cases

Benefits are derived from a better use of the seaweed resources that can be found in Irish waters (for the (PWC, 2008) case).

As with other sectors detailed in PWC 2008, the estimation of economic benefits is based on three scenarios linking the GVA to potential impacts: Low / medium / high impact scenarios with an increase of 5% / 10% / 15% GVA per annum.

Offshore Energy Sector

Several studies highlight benefits for various subparts of the energy sectors operating offshore: e.g. wind energy and offshore oil:

- Wind energy producers rely on bathymetric, geology, local current information to identify the best potential locations and the optimum design of the windfarm in terms of foundation design and subsea cable network.
- Offshore oil developers rely on survey maps of the seafloor to define target sites (notably information on geology, bathymetry etc.).

Both sectors also rely on habitat maps to perform the different environmental impact assessments during the lifetime of the project (design, construction, exploitation and dismantling).

Moreover, offshore operations are sensitive to weather and / or surface and subsurface ocean conditions. These include operations of heavy lifts, pipe-laying, pipe-trenching, tie-ins, remotely operated vehicle (ROV) operations and deep-water pile driving. There are for example several types of offshore operations that need little wind or wave to operate. This is notably the case for crane barges capable of lifting 10,000 tonnes at a single lift or seismic vessels. These operations need forecasts of 10 to 20 days if possible.

In the Irish case (PWC, 2008), as the wind energy sector is considered as an emerging and promising sector, potential benefits associated to its development are linked to the current GVA with future development scenarios. In (PWC, 2008), three scenarios are evaluated based on the current GVA generated by the offshore wind sector and three scenarios of low / medium / high impact with an increase in GVA of 10%, 20%, and 30%.

For the Irish case (PWC, 2008) , oil / gas sector has still a potential growth in Irish waters, which implies the definition of three scenarios of GVA increase by 5%, 10%, and 15%, depending on the impact scenario (low / medium / high).

Shipping

The shipping industry derives benefits from marine weather forecasts and reports on current conditions, which help them to optimise the path ships have to follow, as well as the speed they have to maintain (Kite-Powell, et al., 2005) as fuel saving is one of the main objective for this industry.

Among the tools needed, authors highlight storm forecasts, reports on currents and wave conditions, reports on water levels in ports, and reports on visibility.

A large share of commercial ocean transits takes advantage of weather-based vessel routing services. These services rely on wind and wave models that are calibrated with sea surface pressure and other observations. (Kite-Powell & Cogan, 2001) have estimated that these services were saving on the order of USD 300 million in transportation costs annually. The implementation of an OOS with the possibility of real-time (or near-real time) information about ocean wind, waves and current is expected to increase these savings.

Kite-Powell et al. present also several regional estimates of potential gains due to faster routes obtained by improved of marine conditions information, using either a reduction in variable cost by 1% or the saving of 1 hour of daily operating costs for 1% of the ships transiting through the area (Gulf of Mexico) (Kite-Powell, et al., 2005).

Aggregate sector (sand & gravel)

PriceWaterhouseCoopers identified the aggregate sector as beneficiary of a thorough marine mapping programme in Ireland, especially during the identification of potential sites but also when performing environmental surveys at all stages of the projects (ex-ante evaluation, exploitation and ex-post evaluation) (PWC, 2008).

The main information needs for this sector are:

- Survey maps of the seafloor and hydrodynamic maps to help define target sites; and
- Habitat maps to perform the environmental assessments.

As for other sectors, PriceWaterhouseCoopers evaluated the potential impact of a marine mapping programme by linking current GVA value to three scenarios with a GVA increase evaluated at 5%, 10%, and 15% (low / medium / high impact) (PWC, 2008).

Water-based tourism and leisure

This sector would benefit from a better knowledge of local conditions (weather and sea state) but also from the improvement of coastal maps that could foster a development of the sector (bathymetry, hydrology and geology), from the extension of existing activities (Kite 2004 highlighted recreational fishing), the development of new activities or by the implementation of new resorts. There is also the need for planners and regulators to have a better understanding of the determinants of the water quality.

In (PWC, 2008), these benefits are considered to be too speculative to be evaluated in the report.

In (Kite-Powell, et al., 2005), benefits for this sector are linked to the water quality and the potential for beach closures (notably the decrease in false negatives) and from the improved spatial / temporal accuracy of the recreational fishing and recreational boating condition forecasts. However, the different regional estimates are not comparable as they are based on several economic measures: consumer surplus or total expenditures for both cases (beach closures and recreational fishing). The authors of the regional studies summarized in (Kite-Powell, et al., 2005) used a detailed approach for evaluating each benefit, by estimating annual surplus or total expenditure in combining information on an average trip cost and the number of annual visits that can be estimated in specific location.

4.1.3.2 *Indirect Benefits*

Non-marine sectors can also benefit from the implementation of an OOS and the improvement of marine-related data, notably through improved understanding of meteorological phenomenon.

Renewable energy production

In the climatic context of the US, the influence of the El Niño Southern Oscillation (ENSO) variations is important in terms of modifications in the seasonal potential of hydroelectric power generation, due to the seasonality of precipitations. Although Europe is less sensitive to such variations, climatic variations are expected to have an impact on the potential production of hydroelectric energy, especially in a context where the water retained by hydroelectric dams has other uses: maintaining a river level, irrigation etc. For example, in France, there is an obligation for the managers of dams to maintain a predefined minimal flow in the down-stream river to maintain biotic conditions for the aquatic fauna and flora. In some cases, this flow may be higher than what would be required to produce electricity[27].

Electric power production

More generally, electric production planning relies on short term weather forecast as localised events (e.g. rainfall, snowfall) may have an impact on energy efficiency. Precise short-term rain forecast may help understand the electricity demand, notably in areas where air conditioning is a large part of the electricity consumption. For example, in Arizona: severe afternoon rainfall can reduce peak demand by up to 30% due to the drop in temperature (Willis, 2009). These short term forecasts benefit also from improved climate remodelling which are also highly dependent on better ocean observations (notably in situ monitoring). Gaining a better understanding of these phenomena is key for energy planning as there is a technical latency in energy production, which would result in a reduced efficiency of electricity producers. Although this example may not be directly transferable to Europe, it illustrates the potential connections between ocean observations and electric production.

Agriculture

Agriculture is not part of the sectors identified by (Kite-Powell, et al., 2005), nor by (PWC, 2008). It is, however, a sector that may vastly benefit from better ocean knowledge, notably in the US where decision support tools based on a better understanding of seasonal variations (ENSO) may benefit farmers in terms of planting decisions (type of crops), but also storage decisions. Estimation of productivity improvements in the Australian agriculture sector following the implementation of an OOS are all close to 1.5% of the production value.

Protective management of the coastal zones

The characterisation of local currents is important for defining contaminant flows especially in areas where coastal tourism is important. Bad water conditions may lead to beach and bay closures, which is an important economic loss for the tourism industry. It is therefore important to properly assess local conditions when implanting a new sewage outfall, notably the bathymetry and the hydrology of the area, in order to avoid any unintended concentration of contaminants and/ or pollutants in a beach area (Willis, 2009).

Short term weather forecasts

Weather forecasts have an economic value. Taking advantage of favourable weather and reducing the impacts of unfavourable weather may both generate value. Although this benefit is identified by some studies, there are no specific evaluations of the extent of the benefit in existing studies.

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[27] http://www.france-hydro-electricite.fr/lenergie-hydraulique/l-hydroelectricite-en-france/le-debit-reserve

Storm forecast

Improved storm predictions have reduced the property damage for major storms in the US and reduced injury and death from such storms (e.g. hurricanes and tornadoes). Continental Europe is less sensitive to such events. However, several outermost regions of the EU are in inter-tropical areas where violent storms may happen every year (notably Guadeloupe, Martinique, Guyane, Saint Martin, La Réunion and Mayotte).

Construction

In the US, some authors consider that the construction sector may benefit from better weather forecasts by being able to plan more accurately construction projects (Willis, 2009). The same observation has been made in Australia (Anon, 2006). No valuation of benefit has been made in either study.

4.1.3.3 *Knowledge Benefits*

Benefits of research collaboration:

It has been identified by PriceWaterhouseCoopers that developing a coherent network of seabed mapping initiatives may trigger more scientific cooperation, which would increase the attractiveness of the Irish research sector (PWC, 2008). Such benefit could be extended also to the implementation of a complete OOS. However, the evaluation of the benefit arising from the thorough seabed mapping seems unrealistic. At the time of the study, research funding was valued at EUR 2 million per year, with an impact of the introduction of a seabed mapping programme estimated to range between 50% and 150% increase in research funding based on the three impact scenarios defined in the (PWC, 2008) study (low / medium / high impact).

From an economic perspective, the question seems slightly more complex. Financing large research projects is largely a question of public fund distribution. If a sector, or a specific subject, is able to attract more research funds over the years, it is not certain that there would be a net influx of research fund, but rather redistribution between subjects.

Niche High Tech Industries

Niche High Tech Industries are identified as potential beneficiaries of the implementation of a seabed mapping programme (PWC, 2008), which by extension could also correspond to the implementation of an OOS. Benefits are however not quantified due to the highly speculative nature of innovations.

Legislative compliance

The PWC 2008 study focused on the potential fines avoided by improving seabed mapping, which would be linked to a better understanding of marine space. The fine would be issued by the EC, for bad application of EU law, like for example the Water Framework Directive (WFD) or the Marine Strategy Framework Directive (MSFD). Estimating that in the long term, Ireland would pay on average EUR 10 million per year, the study highlights a potential 10% saving due to the implementation of a seabed mapping programme. The implementation of an OOS could generate the same level of benefits.

No other publication has considered this type of benefit, which seems highly speculative. If the lifetime of the project is between 20 and 30 years, it is difficult to understand why Ireland would support a stable level of fines for non-compliance.

Environmental Clean-up Liability

Under the International Convention for the Prevention of Pollution from Ships (MARPOL), a state is liable of the total costs of clean-up, vessel and cargo loss if it can be demonstrated that poor charting in their national waters is the main cause for the accident. By providing improved information, notably on the bathymetry and the hydrology, an OOS can largely improve the accuracy of official maps, reducing the possibility for poor charting. No study has however valued this benefit.

Navigation Safety

Several associated benefits, all linked to improved safety, are highlighted in (PWC, 2008), without being valued, including:

- Improvement of the safety of trading routes; and
- Improvement of the safety of charting in areas close to ports, and notably maintaining accurate information on the bathymetry of shipping channels, bays and harbours.

Kite-Poweel et al. also include an estimation of potential benefits in terms of search and rescue, based on an estimation of the number of life saved by improving knowledge of coastal zone (Kite-Powell, et al., 2005). The estimation is based on a 1% increase in number of life saved and on an economic value of life of USD 4 million, which is higher than the value of preventing a fatality usually used in cost benefit analysis in Europe (DG Environment, 2001)

Identification of ports of refuge

The designation of ports of refuge may benefit from improved information on bathymetry and hydrology, which is also a benefit not valued (only mentioned by (PWC, 2008)).

4.1.3.4 *Non-use Benefits*

As noted earlier, non-use benefits are not often cited in economic studies highlighting potential benefits of an OOS.

Protection of marine life

Better understanding of the spatial distribution of habitats and human activities, which can be both covered by an OOS, is expected to improve the level of protection of marine life, notably due to:

- Improved designation process of MPAs in the inshore area;
- The implementation of best practices in fishing and aquaculture by avoiding specific areas even outside MPAs; and
- Definition of least environmentally disruptive areas for other commercial activities (question of mitigation).

Protection of heritage

Marine archaeology may benefit from more accurate surveys: shipwrecks currently not identified could be discovered by searching for discrepancies in the seabed identified during detailed surveys.

Information on coastal erosion and climate change.

Combining information on bathymetry, hydrology and habitats can improve the understanding on the geomorphologic evolution of coastal area, but also on the evolution of the distribution of specific species (e.g. fish, algae's) that can be used as bio-indicators for climate change.

4.2 Benefit from Reducing Transactional Costs and Redundant Expenditure

From an economic perspective, the development of an OOS may lead to gains in terms of improved productivity and reduced redundancies. The Commission Staff Working Document (European Commission (SWD), 2014) focuses notably on the improved productivity that could benefit data users in the case of an integrated data infrastructure. The method detailed to evaluate the savings to each stakeholder group is the base of the work performed in this study.

The method proposed in the Commission Staff Working Document relies on the estimation of the total savings for each stakeholder group *G* that can be expressed as:

$$S^G = \sum_{i=1,N} (\alpha_i^G \cdot \beta_i^G + (1 - \alpha_i^G)\gamma_i^G) \cdot \theta_i^G \cdot C^G$$

Where:

C^G is the total cost of data to stakeholder group *G* including the collection of new data and the processing of existing data;

θ_i^G is the fractional contribution of a particular type of data *i* (geological, physical, chemical etc.) to the total cost to stakeholder group *G*;

α_i^G is the proportion of the cost that is due to data that cannot be found and needs to be collected;

β_i^G is the proportion of the data that has already been acquired by other stakeholders but that cannot be accessed at present;

γ_i^G is the savings in processing existing data because they are accessible, catalogued and standardized, expressed as a proportion of the total cost.

The same document highlights the potential gains estimated that could arise from the implementation of an OOS by not surveying multiple times the same areas, using this framework. A first estimation of the benefit of an OOS shows a potential gain of 25% of the costs currently spent, highlighting that marine observations remain private goods as long as their results are not published in the public domain. One could argue that the value used to quantify the savings in processing existing data (γ_i^G) may be sometimes overestimated due to the patchiness of the data that could actually fall in the public domain. However, there is no information currently available that would improve the estimation made in 2013 or would imply it is out of scope.

Developing an integrated approach at the European level will certainly generate cost savings as it would generate economies of scale by avoiding redundancies of in situ monitoring in areas where multiple member states have neighbouring Exclusive Economic Zones (EEZ), like the Baltic Sea, the middle of the North Sea or the Celtic Sea. This coordinated approach would generate savings, both in terms of investments and running costs at the European level

It would also allow to mutualise funds for the development of drifters, floats and sensors at the European level rather than creating a constellation of national champions on limited national markets. Such coordination would allow to improve the interoperability of sensors, reducing again the costs for integrating data at the European level.

Table 9: Estimation of potential savings following the implementation of an Ocean Observing System.

	Sectors								Total
	Private		Public		Hydrography		Research		
Total cost	3 000 m EUR		225 m EUR		150 m EUR		2 000 m EUR		5 375 m EUR
	Geology	Rest	Geology	Rest	Geology	Rest	Geology	Rest	
α_i^G	0.75	0.25	0.75	0.25	0.67	0.67	0.75	0.25	
β_i^G	0.50	0.50	0.50	0.50	0.10	0.20	0.50	0.50	
γ_i^G	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	
θ_i^G	0.75	0.25	0.75	0.25	0.90	0.10	0.75	0.25	
Savings	1 219 m EUR		55 m EUR		23 m EUR		200 m EUR		1 497 m EUR

Source: Commission Staff Working Document (2014)

However, not all sectors are gathering and processing primary data, either because of financial constraints (surveys too expensive) or because they may not need such level of details and can rely on the existing data, even the quality is sub-optimal.

Maritime transport function

Overall, the maritime transport industry is expected not to collect primary marine data but to rely on solutions provided by service companies that would cover the specific aspects of data integration into routing systems. It is not expected that these service providers develop their own data collection at the oceanic level; they rely on data produced by existing observation systems. Agencies controlling the shipping industry are also partially relying on service providers to get data on specific emissions, such as bilge water, sulphur emissions or discharges.

Food, nutrition, health and ecosystems services function

For the food, nutrition, health and ecosystems services, the fishing sector is gathering data. It should however, be noted that only the researcher data may be transferable and aggregated at a higher level. Fishers rely on published marine maps that are updated by their own navigation system. Fishing software providers introduced more than fifteen years ago the ability for the navigation system to save and integrate all the information generated by various instruments: Global Positioning System (GPS), sonars and radars all feed into these system to update on the fly the map in the close vicinity of the fishing vessel. Combining all these data allow fishers to generate their own up-to-date maps of the bathymetry and sometimes of the nature of the seabed. At least one of these software companies is offering fishers the ability to share anonymously the data generated for the bathymetry and seabed nature. This has allowed this company to offer its users up-to-date information in their specific fisheries area (Hell, et al., 2012).

Energy and raw material function

The energy and raw material function is believed to be the one that is deploying considerable private efforts to collect information on seabed (e.g. bathymetry, geology), on sea conditions (hydrology notably) but also on habitat characterisation.

Some EU Member States have decided to allocate the offshore windfarms zones after a competitive bid involving a necessary pre-assessment of the area by windfarm developers. Example can be drawn from recent bidding processes in France where several companies had to design the potential windfarm they would be constructing, with the final layout of the windmills and electric cables as part of the bid. From the offshore wind developer's perspective, such process cannot be completed if precise marine data is unavailable. In the case of such bidding process, every developer has to collect its own data in the absence of a public access to OOS, implying the replication of identical survey in a very short period of time. In the case an OOS existed, developers could rely (at least partially) on the public dataset to perform their first assessment, then refine their first designs by targeting specific areas of the windfarm zones they would like to exploit. Once the bidding process is complete, windfarm operators still have to assess the evolution of the local conditions following potential disturbance, notably the bathymetry and the habitat evolution, for which they need precise data that is not expected to come from an OOS.

The oil and gas, aggregate mining and marine mineral resources sectors are facing similar constraints in terms of survey needs, which rely heavily on bathymetry and geology to understand the best potential exploitation location. All these sectors have also a need for hydrology information, but for different purposes: Oil and gas need to understand the potential constraints a platform could be exposed to; aggregate mining are looking for specific gyres that would recharge the aggregate depots they want to target and marine mineral resources need to understand the hydrological constraints they may face, just above seabed.

As the operations of these various sector is spatially limited, it is expected that they will continue to need ad-hoc surveys even if an OOS is implemented, which means that the values associated with the variables α_i^G (0.75) and β_i^G (0.50) are expected to be close to those defined in the Staff Working Document at least for the geology and the seabed nature dimensions.

In terms of other type of information (e.g. habitats, wind, waves), the development of an OOS would be of high relevance for them, as they would not have individually the capabilities or the funding to track these dimensions at the regional or sea-basin level. They may perform some localised measures for physical variables (e.g. waves, wind), but would not need to deploy a full set of buoys or a survey vessel in the close vicinity of their installations. There are currently service providers offering to deploy specific buoys close to oil and gas platform to perform most of the local measures that are needed to complete information generated by a regional OOS low value for α_i^G

Leisure, working and living function

Most of the sectors that are part of the leisure, working and living function are not expected to collect specific marine related data as they can rely on existing data, even if incomplete.

It is estimated that specific data collection will only be performed when important developments are planned: port extensions, marinas and coastal tourism developments. Due to the localised nature of these developments, it is expected that localised surveys will have to be completed for each project unless a future OOS would present high levels of precision in coastal areas for several dimensions, notably bathymetry, geology, hydrology and habitats.

Coastal Protection function

Sub-functions from the coastal protection function are expected to perform specific surveys to identify the best locations to install coastal protections against flood and erosion, although on limited areas due to the nature of the developments. Such coastal protections mainly need bathymetry, geology and hydrology information, with also habitat and biology information to evaluate the potential impact on local fauna and flora. It is expected that an OOS would offer enough granularity in terms of hydrology and geology to identify the zones that are the most exposed to potential erosion and would benefit from further protective development.

In terms of protection of habitats, the identification of sites to be protected would certainly benefit from an OOS, especially if the habitat mapping and the human activities dimension are integrated. This would allow to identify more robustly existing features that have not been deteriorated and could be protected before further extension of human activities (e.g. fishing vessels, offshore wind, oil and gas) or to identify where some specific habitats are currently degraded and should be protected (e.g. Maerl). Light surveys could complete the existing information provided by OOS to define more precisely the limits of the protected area, although the intensity of these surveys would strongly depend from the OOS granularity.

Maritime Monitoring and Surveillance function

The only sub-function expected to perform specific surveys is the environmental monitoring, although these data collections are for the most part integrated into regional or national observatories, notably because Member States have to comply with the Water Framework Directive and the Marine Strategy Framework Directive. These observatories are expected to feed into a future OOS at the European level, which would then cover almost all requirements for this particular sub-function. Moreover, agencies monitoring climate change will also rely on information provided by a future OOS, such as the evolution of sea level, of heat content for cyclonic extreme events, but also the level of acidification and eutrophication.

A summary of the above section is provided in **Table 10**

Table 10: Marine sub-functions requiring ad hoc data collection.

Marine functions	Sub functions	Gathering raw data	Using raw data	Using processed data
1.Maritime Transport and Shipbuilding	1.1 Deep-sea shipping			x
	1.2 Short-sea shipping			x
	1.3 Passenger ferry services			x
	1.4 Inland shipping (sea-borne cargoes)			x
2. Food, nutrition, health and ecosystems services	2.1 Fish for human consumption	fishermen researchers		x
	2.2 Catching fish for animal feeding	fishermen researchers		x
	2.3 Growing aquatic products	X	x	x
	2.4 High value use of marine resources			
	2.5 Agriculture on saline soils			
3. Energy and raw materials	3.1 Oil, gas and methane hydrates production	X	x	x
	3.2 Offshore Wind energy	X	x	x
	3.3 Ocean renewable energy resources	X	x	x
	3.4 Carbon capture & Storage (CCS)			x
	3.5 Marine aggregate mining	X	x	x
	3.6 Marine mineral resources	X	x	x
	3.7 Securing fresh water supply (desalinisation)			
4. Leisure, Working and Living	4.1 Coastline tourism	x - for development	x - for development	x
	4.2 Yachting including marinas	x - for development	x - for development	x
	4.3 Cruise including port cities	x - for development	x - for development	x
	4.4 Working			
	4.5 Living			
5. Coastal Protection	5.1 Coastal protection against flooding and erosion	x - for development	x - for development	x
	5.2 Preventing saltwater intrusion			x
	5.3 Protection of habitats	x - for site identification	x - for site identification	x
6. Maritime Monitoring and Surveillance	6.1 Traceability and security of goods supply chain			
	6.2 Prevent and protect against illegal movement of goods and people			
	6.3. Environmental monitoring	X	x	x

Note: the list of functions and sub-functions is extracted from the Blue Growth study.

4.3 Better availability of data and innovation

(Wallace, et al., 2014) highlighted that long-term "monitoring" observations may be seen as a "routine" process and not as "innovation" which would reduce the interest in funding by public research centres and deciders. In fact, innovations may happen at two different stages of the implementation of an OOS:

- Innovations are necessary to improve existing data collection processes but also to develop new data collection capabilities: new sensors, new buoy systems may collect data which is not currently in the scope of an OOS but which could prove extremely valuable in terms of environment monitoring and climate change tracking. Such innovations may not be funded if they would not be destined to be part of an OOS, although the information they generate may be essential for other projects to emerge.
- Innovations may also derive from the data collected by the OOS, as a better availability of marine data is often seen as a vector for new applications. This is the more visible part of innovations, which are usually showcased when the benefits of OOS have to be demonstrated.

Most of the studies evaluating the potential benefits of OOS are building their case on the fact that the better availability of data would lead to small improvements and sometimes innovations which would save costs or generate additional benefits. Among the first descriptions of potential gains, there are notably mentions of several potential innovations (Adams, et al., 2000):

- better routing services for the shipping industry: potential cost reductions were highlighted very early in OOS publications;
- better understanding of local coastal weather conditions, with a direct effect on tourism and coastal activities, notably recreational fishing; and
- Improved design of marine structures, based on a better understanding of extreme conditions in specific locations (e.g. winds, tide and waves).

Some of these improvements described as potential at the end of the 1990s have since been at least partially achieved:

- There are currently several providers offering specific routing appliances and /or routing software that are integrating some of the information currently available (e.g. bathymetry and tides), despite the lack of precision and/or coverage for some areas. With the development of complete and integrated OOS, these services may generate more efficiencies by further reducing transit time.
- Several services providers are offering detailed forecasts of wind and tide conditions for precise locations along the coast, initially for surf and windsurf applications. These services are based on the integration of public domain weather models (GFS: Global Forecast System, NAM: North American Mesoscale Forecast System, WRF: Weather Research and Forecasting…) and wave models (notably NWW3: NOAA WaveWatch III) in user-friendly tools displaying *ad hoc* outputs. The use of these tools is however more widespread than its original target as more businesses in the touristic sector tend to rely on it to attract more customers. The existence of these companies is the perfect demonstration that teams with very limited resources (some are one-man businesses) can tap into the available data to develop viable services providing new products to the mass market.

(COWI and Ernst&Young, 2013) detail the potential benefits innovations could generate, notably highlighting 1- Avoidance of revenue / production losses; 2- Increase in profitability; 3- Reduction in costs; and 4- Regional economic impacts.

Among previous studies, only the COWI study details the benefits that could arise from specific innovations, focusing on few sectors (the innovations detailed in the COWI study are mentioned for references) that would benefit even partially from the implementation of an OOS:

- Innovations that could reduce risks to aquaculture production, based notably on a better understanding of hydrology, marine weather or level of ocean acidity ("Early warning device for jellyfish blooms"; "Offshore aquaculture: new sea-cage design"; and "Understand and address ocean acidification");
- Innovations allowing insurance companies to better assess risks, based mainly on physical data sometimes obtained at a high resolution: better nautical charts, hydrography, wave heights… ("Insurance discounts through improved marine safety information"; "Managing natural disaster risk in Europe's coastal regions"; and "Improving the certification process for offshore wind projects");
- Innovations extending the coastal tourism depend highly on a better understanding of local conditions: local weather, bathymetry, topography, waves ("Coastal clean up and awareness raising to attract and develop sustainable eco-tourism"; "Artificial reefs: surf and diving opportunities"; and "Protection against coast erosion");
- Discovery of new bio-economy products are partly dependent on data produced by OOS, notably to help focus on areas where potential organisms may be discovered (bioprospecting), but also to gain a better understanding of the environmental conditions suitable for exploited resources (seaweed notably) ("Development of seaweed based products"; "Innovation aquatic pharmacy products"; and "Protecting Biodiversity for Tomorrow's Blue Economy")
- Innovation for new offshore developments, are partially based on a better understanding of the seabed and of sea-state parameters ("Sea-bed mining, mineral resources"; "Data to optimise offshore wind energy yield"; "Optimisation of turbine foundation design").

Looking at recent H2020 projects, a first selection on key words[28] led to consider 617 projects (representing 1,2 billion euros in total funding) of the 13 644 projects (worth 28,7 billion euros in total funding) listed in the extract available in September 2017 on the Commission website [29]. These 617 projects were individually checked to identify those which are building on existing information from current Oceanic Observations, but also those which are completing the available information by ad hoc observations, due notably to the absence of an OOS.

During this process, 92 projects were identified as potentially depending on the existence of an OOS, representing 322 million euro of total funding. Of the 92, 12 projects are considered to be developing data collection activities to complement existing data, which could have been covered even partially by the implementation of an OOS. Based on expert judgement, a share of the funding of each of these 12 projects was estimated covering the cost for collecting new data, ranging from 5% to 20% of the total funding, based on the information gathered in the description of the project objective. Overall it is estimated that these projects dedicate 8% of their total funding to complete the information currently available across Europe, representing 2,6 million euro (compared to a total funding of 30,6 million euro for these 12 projects). Most of the projects do not devote any resource to a specific data collection. It is anticipated that for

[28] keywords such as ocean*, fish*, marine*

[29] http://data.europa.eu/euodp/en/data/dataset/cordisH2020projects

some of these projects, data collection at the sea-basin or at the oceanic level is financially out of reach, as it would consume most of the funds available for the specific calls, thus limiting the research teams to use sub-optimal available information.

Projects were then grouped based on the potential benefit an OOS would have on the potential innovation they could generate. Several levels of benefit are considered:

- Precondition: without an OOS (or the perspective of an existing OOS), the research project would not be possible. This category entails notably projects that are fostering the adoption of large scale observation programs by end-users (such as Copernicus), but also the implementation of new Observation Systems (such as the Arctic Observation System);
- High dependence: the existence of an OOS would benefit highly to the innovation, as patchy data would hinder the development of a new product/process initiated by the research project;
- Dependence: existing measurements are not limiting the potential innovation, but the implementation of an OOS would allow a more streamlined development of the new product/process; and
- Minor dependence: existing uncomplete measurements can be used for developing the innovation, with limited impact from the implementation of an OOS. Some of the projects in this category may develop products potentially contributing to the implementation of a future OOS.

An OOS currently active or in development is a precondition for three projects, for a combined funding of 42.1 million euro. These projects were dedicated to the implementation of specific OOSs (AtlantOS, INTAROS) or served as pre-operational Marine Service before the effective launch of new systems (MyOcean FO). The main innovation arising from these projects are the OOS themselves, but also potentially sensors or buoys that may be developed for the deployment of these OOS.

Eight projects have been identified as highly dependent on the existence of an OOS, for a combined funding of 37.8 million euro. These different projects may not have been possible if the available data had not been partly integrated and if the prospect of a more coherent OOS was not foreseeable by the different research teams. The innovation arising from these projects may therefore not exist in the absence of an OOS.

Some of these projects are focused on the adoption of existing systems by end-users, such as Copernicus (Copernicus App Lab, MCEP, ODIP 2). These projects provide an interface allowing end-users to access more intelligible data, as the data feeds provided by Copernicus may require filtering, aggregation and statistical treatments before being usable. The innovation arises from the increased dissemination that would allow all kinds of stakeholders to access to the data. The underlying assumption is that access to data may lead companies and research teams to test new approaches that could provide innovations as highlighted in the Commission Staff Working Document (European Commission (SWD), 2014). The example of a specific platform for surfing conditions is a good example of SMEs using publicly available data to create new services for specific markets.

Other projects build specifically on these existing systems (Copernicus notably). For example, ECOPOTENTIAL aims at providing information on ecosystem services, based on the integration of public data (earth-observation data and Copernicus) in a set of ecological models. MARINE-EO was designed to test EO-based services connected to Marine Monitoring and Security Copernicus thematic areas. These projects may not have been realised if Copernicus (or a similar system) was not available for their inception.

55 projects have been identified as dependent on the existence of an OOS, for a combined funding of 138 million euros. These projects integrate marine data in their

workflow, but have currently to rely on sub-optimal data feeds. As noted before, the implementation of an OOS may be highly beneficial to the projects, as the research teams could avoid integrating data from various sources with all the limitations entailed (different resolutions, different timeframe, real-time versus batch collection) for a higher cost. The innovation arising from these projects may therefore still exist even in the absence of an OOS, but their impact is expected to be less important, notably in terms of a cost benefit analysis, as the OSS is expected to drive important cost reductions for the research teams due to the availability of data.

A first sub-group is composed of projects that are integrating ocean data at a large scale (sea-basin at least) to provide data portals or APIs offering partially processed verified data to a large variety of end-users (companies, researchers, administrations). These projects are currently developed without a functional EOOS but are destined to aggregate as much as possible the available data. The projects BigDataOcean and EOMORES are examples of such projects. EOMORES focuses on inland and coastal water quality monitoring, based on satellite observation, *in-situ* monitoring and ecological modelling, while BigDataOcean's aim is to provide a platform where companies will be able to mix their private data with publically available information.

A second sub-group is composed of research projects focusing on environmental and/or climate modeling in several locations (e.g. Blue-Action, BIGSEA, CoupledIceClim, ARCDIV). These projects have been scoped to use the data available at the time of the specific calls, and are therefore not directly dependent of the implementation of an OOS. Depending on the status of the data accessed during the project (public data, private data, time-limited data), all these research teams may not be able to capitalize on the research project to develop viable applications once the projects are over.

26 projects are considered to have a minor dependence on the existence of an OOS; for a combined funding of 103 million euros. The innovation arising from these projects will exist independently of the implementation of an OOS. Some of these innovations may also benefit an OOS by providing new measurement techniques.

Some projects supporting the emergence of research networks focusing on marine research are part of this group as they build on existing observation systems to initiate and maintain cooperation among research teams.

Most of the projects part of this group are designed to integrate currently available data, even if patchy and sub-optimal. The reliance on an OOS can be considered as minor, because marine data is not the most important data feed used in the projects (AQUACOSM) or is not used for the core developments of the projects, like with marine energy developments (OpTiCA, DEMOTIDE). The implementation of an EOOS would have only a limited impact on these projects.

Some of these projects are also building on the current data-poor situation, such as BASE-Platform, aiming at providing satellite-derived bathymetric data for coastal application. In this particular case, the innovation generated during the project is destined to become a commercial application (for the offshore industry, for coastal developers…), while providing potentially a new data gathering technique for a future OOS. The project LAkHsMI is also focusing on the development of smart sensors gathering information on temperature, differential pressure of the seafloor, and other physical parameters that could integrate existing OOS. For these projects, the implementation of an OOS may be beneficial in terms of market opportunities.

4.4 Benefit of reducing uncertainty

Several studies have highlighted that the implementation of an OSS is expected to reduce uncertainty, mainly as the result of better data availability allowing operators to modify their behaviour. Several types of benefits are associated with a reduction in uncertainty (COWI and Ernst&Young, 2013):

- Avoidance of lost earnings;
- Increase in profitability; and
- Reduction in costs.

When cross-referencing the different studies describing the benefits of an OOS, several features of the OOS are seen as potentially reducing uncertainty (see also **Table 11**):

- Better precision of the bathymetry;
- Short term weather forecast;
- Long term weather forecast;
- Ocean forecast and climate records;
- Better information on sea-rise level;
- Better information on seabed (sediments and geology); and
- Better information on wave height.

Better precision of the bathymetry:

The improved precision of the bathymetry is a central element of an integrated OOS and has implications for lots of marine sectors.

A higher bathymetric precision would highly benefit the shipping industry. Uncertainty in navigation maps is limiting the ability for shipping companies to optimise the transit time, but also to limit collision, thus reducing insurance premiums. NOAA estimated for one additional foot of draught would lead to an increased profit per transit to Tampa estimated between USD 36,000 and USD 288,000 (NOAA, 2000). The range of benefit is however highly variable depending on the local seabed conditions. Cruise vessels would obtain the same kind of benefits from improved nautical maps.

The aquaculture sector would also benefit from improvements in bathymetric information as it would reduce the time spent to identify potential fish farm sites. The same analysis can be applied to marinas, port cities and all developments requiring sea constructions or moorings. Bathymetric information generated by an OOS may not be sufficient for the entire duration of the project, but would at least reduce the cost of site pre-selection and would serve as a base for directing *ad-hoc* survey to specific areas.

Better precision in the bathymetry is also important for the energy sector, especially in the pre-selection of potential sites. The current technology used in wind farms imposes a maximum of depth of 40 metres. Aggregate mining developers can also quickly identify seabed features presenting interesting characteristics before focusing expensive *ad-hoc* surveys on these particular zones. This kind of benefit is also applicable to other offshore energy sectors.

Seabed (sediments and geology):

Uncertainty on the seabed structure can be detrimental for the safety of offshore energy operations. The stability of the different constructions (e.g. oil platform, windfarms) is notably linked to the nature of the seabed. A better understanding of the geology of a specific zone may have a huge impact on the wind-turbine foundation design leading to significant cost reductions.

(COWI and Ernst&Young, 2013) also highlighted that understanding the nature of the seabed is of huge importance for all sectors deploying subsea cables:

- Energy producers: offshore wind farms;
- Energy networks: connections between different member states: France-UK, UK-Ireland, Belgium-UK; within member states: UK and some of its small islands; and with neighbouring countries: Netherland-Norway; and
- Communication networks: subsea cables in the North Sea, the English Channel.

Except for the different landing sites of these cables, precise seabed surveys are usually not performed due to prohibitive costs. Reducing the uncertainty on the sediment nature and on the underlying geology may benefit largely these sectors as it would improve the potential for better protection, either by adapting the route to deploy the cable on soft sediment that would allow burial, or by adapting the cable protections.

However it should be noted that the estimation made by (COWI and Ernst&Young, 2013) might be an overestimation of the risk: not all offshore turbines are connected to mainland. Usually a windfarm has an internal subsea cable network linking each turbine to one or two sub-stations, depending on size of the windfarm. Usually navigation is restricted inside windfarms, limiting the potential of accidental failure due to human activities. Based on the most recent data published, they were 3,589 turbines installed at the end of 2016 in 81 offshore farms with an average distance to shore of 44 km, which gives a total distance of 3,564 km of cables outside windfarms perimeter, compared to 48,198 km estimated in the Cowi and Ernst&Young study. This would lead to 3 to 4 failures per year which would result in lost earnings of EUR 0.5 billion, compared to the EUR 6.9 billion estimated by Cowi and Ernst&Young.

Weather forecast:

Short-term weather forecasts are essential for the safety of sea operations. Shipping vessels, fishing vessels, cruise vessels, yachts and coastal touristic activities have all specific safety thresholds in terms of wind force and rainfall. However, imprecise forecasts may lead to false negative situations: when operators decide to postpone a trip due to bad weather forecast when the actual conditions were in the safety range of the vessel. Improving short term forecast will limit the number of false negatives and would avoid losing days at sea. For this type of uncertainty, there is a direct translation from the forecast improvement to the operator’s benefits: the reduction of false negative by one day leads to one more day at sea. This should however, be nuanced for the fishing sector that may not be able to spend an additional day at sea due to management restrictions (notably in the case of a days at sea regime).

It has already been identified that some sectors particularly, rely on the stable weather to plan some activities: seismic surveys, heaving lifting at sea (e.g. windfarms, oil platforms), are activities that cannot operate if the sea conditions are not extremely favourable for several days in a row (sometimes up to 20 days), especially in terms of wave heights. The reduction of false positives will also lead to the increase of the potential favourable periods these vessels can operate.

Storm surges have the potential to cause widespread damage and loss of life, so good forecasting of surges are required to mitigate risks. In the UK, the Met office has developed a model[30] that uses a combination of ocean observations, using tides, wind and air pressures in combination with bathymetry data to model potential storm surges and provide warnings.

[30] Marine data and observations for storm surge forecasting and other Met Office ocean modelling

Environmental monitoring is also reliant on short-term and long-term weather forecasts as they may help predict potential localised toxic algae blooms or jellyfish invasions, which may have an important impact on the aquaculture sector and on coastal tourism.

Long-term weather forecasts may also be improved by a better understanding of several ocean dynamics (e.g. heat exchanges) that are of interest for several marine sectors that are highly dependent on the climatic variations, such as the aquaculture sector (variation in primary production for shellfish farming notably), the offshore wind sector (production planning), but also non-marine sectors: agriculture and energy being often cited in studies to be the sectors the most affected by weather variations.

Ocean forecast and climate records

A coherent network of in situ sensors (buoys and other systems) are providing invaluable information allowing the calibration of other monitoring devices (notably satellites or radars), but also the calibration of models (weather, climate). The Global Climate Observing System (GCOS) is collecting 54 Essential Climate Variables (ECVs) considered to be key for sustainable climate observations. These ECVs are mostly outputs of climate reanalysis models, which are heavily reliant on in situ data collection to reduce the level of uncertainties associated with these models (Mogensen, et al., 2012). ECVs that benefit the most of in-situ monitoring are those that can be directly measured by sensors: notably sea surface temperature, salinity, sea surface height, velocity/current, ocean colour.

Reducing the uncertainties associated with the different climate reanalyses is extremely important in climate monitoring programmes, notably to extract the long timescale variability of essential climate variables.

The energy industry is also heavily reliant on climate reanalysis. Combined with local weather, ocean forecast and sometimes in situ observations, these reanalyses are implemented to evaluate where to place new production sites (dams, solar panels, wind farms) but also to define the production level needed to maintain a balanced electrical grid[31].

Better information on sea-level rise

Sea-level rise is a global threat for all coastal areas. However, there are currently lots of uncertainties about the range of the rise that can be expected over the next century. Current coastal developments are factoring the sea-level rise in the development designs, with the current uncertainty associated. The Blue Growth functions also entail an entire sub-function dedicated to the implementation of coastal defences. According to a Commission Staff Working Document, a 25% reduction in uncertainty in future sea-level rise is expected to save EUR 100 million a year in constructing coastal defences. (European Commision SWD, 2010) There is however, no clear connection between the amounts of data collected by an operational OOS and the level of reduction in uncertainty.

[31]https://climate.copernicus.eu/news-and-media/press-room/press-resources/infographics/applications-energy-sector

Table 11: Marine sub-functions benefitting from a requiring *ad hoc* data collection.

Marine functions	Sub functions	Better precision of the bathymetry	Seabed (sediments and geology)	Short term weather forecast	Long term weather forecast	Sea-rise level
1.Maritime Transport and Shipbuilding	1.1 Deep-sea shipping	x		x		
	1.2 Short-sea shipping	x		x		
	1.3 Passenger ferry services	x		x		
	1.4 Inland shipping (sea-borne cargoes)	x		x		
2. Food, nutrition, health and ecosystems services	2.1 Fish for human consumption			x		
	2.2 Catching fish for animal feeding			x		
	2.3 Growing aquatic products	x		x	x	x
	2.4 High value use of marine resources					
	2.5 Agriculture on saline soils					x
3. Energy and raw materials	3.1 Oil, gas and methane hydrates production	x	x			
	3.2 Offshore Wind energy	x	x	x	x	
	3.3 Ocean renewable energy resources	x	x	x	x	
	3.4 CCS					
	3.5 Marine aggregate mining	x	x			
	3.6 Marine mineral resources	x	x			
	3.7 Securing fresh water supply (desalinisation)					
4. Leisure, Working and Living	4.1 Coastline tourism			x		x
	4.2 Yachting including marinas	x		x		x
	4.3 Cruise including port cities	x				x
	4.4 Working					
	4.5 Living					x
5. Coastal Protection	5.1 Coastal protection against flooding and erosion					x
	5.2 Preventing saltwater intrusion					
	5.3 Protection of habitats					
6. Maritime Monitoring and Surveillance	6.1 Traceability and security of goods supply chain					
	6.2 Prevent and protect against illegal movement of goods and people					

	6.3. Environmental monitoring			x	x	

5 Objective 4:

5.1 Gap analysis

In the context of the Framework for Ocean Observation, gaps can be considered as information that is missing from the observation networks that does not fulfil the requirements of the system. These gaps can be split into two broad categories as defined in the "Capacities and Gap analysis" (Buch, et al., 2017) of the AtlantOS project; critical gaps were the information is not being collected, and correctable gaps were the information is or could be collected but is not accessible. These gaps may be further refined in to temporal, spatial, or resolution gaps

To identify gaps the sea basin checkpoints and their associated challenges have been examined primarily through the data adequacy reports commissioned under the checkpoint for each of the 6 basins; Arctic (de Vries, et al., 2016), Atlantic (Populus, et al., 2016), Baltic (She, et al., 2016), Black Sea (Pinardi, et al., 2016), Mediterranean Sea (Manzella, et al., 2015) (Pinardi, et al., 2017), North Sea (HR Wallingford, 2014) (HR Wallingford, 2016). The gaps identified have been summarised in **Table 12** and an indication if there are critical or correctable gaps present. However the data adequacy report cannot always distinguish between data that is not collected and data that is not available. Most of the spatial and resolution gaps identified are the types that would be expected due to the difficulty of collecting data at those location, such as the open ocean, within the water column, or on the sea bed. The biological data such as; species distribution, data on plankton and bycatch of fisheries represent the most consistent gap in the parameters identified across challenges and basins. A summary is presented in **Table 12** where a tick indicates that a gap has been identified for a particular challenge.

Table 12: Summary of where data gaps have been identified in sea basin checkpoints data adequacy reports.

Basin		Challenges*											
		Wind Farm	MPAs	Oil leak	Climate & Coast	Climate change	Fisheries management	Fisheries impact	Marine Environment	Eutrophication	River inputs	Bathymetry	Alien Species
Arctic Ocean	Critical					✓		✓			✓		✓
	Correctable					✓	✓				✓		
Atlantic	Critical	✓								✓			✓
	Correctable	✓					✓				✓		
Baltic Sea	Critical						✓				✓		
	Correctable	✓		✓	✓	✓				✓		✓	
Black Sea	Critical	✓				✓				✓			✓
	Correctable	✓										✓	
Mediterranean Sea	Critical	✓	✓	✓			✓		✓				
	Correctable		✓	✓	✓						✓		
North Sea	Critical		✓						✓		✓		
	Correctable	✓		✓	✓		✓		✓				

*Challenges that have been shaded indicate which basins they are applicable to, ticks identify where gaps have been found

Arctic Ocean [32]

Climate change was a challenge where several significant gaps were found for the harder to measure parameters such sea ice mass, and sea bottom temperature. For fisheries management information on bycatch was missing and the resolution of data on fisheries impact was poor. The remoteness of the Artic was also raised as an issues for collecting data on water quality, and may also be a factor explaining why existing alien species database does not fully cover the region.

Atlantic[33]

The wind farm sitting challenge identified gaps in habitat maps, vertical currents and human activity data. Access to fisheries data was low, but may not be a critical gap. Data on pollutant inputs were found to be a significant gap for the eutrophication challenge, and river inputs. Information on alien species was also found to be a gap, although this was put down as a global issue rather that a particular issue for the Atlantic.

Baltic Sea[34]

Coastal data were often cited as experiencing gaps in the Baltic, and were found to be lacking for data on currents, bathymetry, sea level, riverine inputs and for some basins within the Baltic eutrophication data was lacking. Fisheries data on bycatch were also not being collected in a comprehensive manor. Correctable gaps identified included wind observation data and data on phytoplankton.

Black Sea[35]

Significant gaps were found for data on phytoplankton, zooplankton, and alien species. Data on atmospheric conditions were also found to be a gap, but this likely due to lack of access to data. Gaps in bathymetry data are also likely to be due to lack of access, and difficulty in finding data. The data infrastructure in the black sea region as a whole was found to contribute to gaps in the region.

Mediterranean Sea [36] [37]

For wind farm siting there were critical gaps for wave data and bird distributions, there were also correctable gaps for data on human activities such as maritime traffic that exist but are not as accessible as they could be. For marine protected areas (MPA's) habitat data was found to be inadequate and had critical gaps in its temporal and spatial coverage. Wave data was found to have significant spatial and temporal gaps, and could be hard to access due to commercial considerations of Met offices. Access to data from Met offices may also explain the gaps in climate data. Fisheries data for management

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[32] http://www.emodnet-arctic.eu/media/emodnet_arctic/org/documents/final_draft_rapport_sbc_arctic_dar.pdf

[33] http://www.emodnet-atlantic.eu/content/download/29514/200156/file/Altantic_DAR1_revised.pdf

[34] https://webgate.ec.europa.eu/maritimeforum/sites/maritimeforum/files/BSCP_DAR_I_20160915.pdf

[35] https://webgate.ec.europa.eu/maritimeforum/sites/maritimeforum/files/BLACKSEA%20D15.2%20First%20Data%20Adequacy%20Report.pdf

[36] https://webgate.ec.europa.eu/maritimeforum/sites/maritimeforum/files/D11.2-V12_0.pdf

[37] http://www.emodnet.eu/sites/emodnet.eu/files/public/Checkpoints/D11.4_MedSea_2ndDAR.pdf

has critical gaps; this is true for all types of fisheries data not just bycatch. River inputs, particularly sediments, also have significant gaps.

North Sea[38][39]

Lack of spatial datasets for birds and mammal distributions were identified for the wind farm siting, and species/larval distributions for the MPA challenge. Wind data was found to have spatial and resolution gaps, even where there were not gap, the data was not always freely available. For the climate and coastal challenge some data were available but there were spatial gaps. For fisheries data, like in many of the other basins, bycatch was identified as a significant gap. Data on zoobenthos, macrophyte and macro-algae used for the marine environment challenge were also a significant gap in the North Sea. River inputs data was available but only from the year 2010 onwards, and at an annual resolution.

From the summary[40] of the stress tests carried out on the EMODnet sea basin check points it is also possible to identify some critical and correctable gaps across the European sea basins. These are described below:

5.1.1 Critical Gaps

Access to fisheries data was identified as an issue in nearly all the sea basins. Although considerable fisheries data is collected in Europe it is mostly used to provide scientific advice such as stock assessments. Fisheries data that are not directly relevant to the advice, such as bycatch, is often over looked or not collected. There are also gaps in habitats and species distributions, particularly in species and areas that are not commercially exploited.

For numerous parameters in coastal areas important gaps have been identified. In all sea basins data is lacking on riverine inputs, with a combination of data not being collected, or being collected using different methodologies so that it is not comparable. Bathymetry is also missing from many coastal areas, for example in the Baltic. Coastal areas can be more expensive to survey using boat based surveys as the vessels have to operate more cautiously in shallow waters and preform more transects to get the same coverage as in deeper waters. New technologies that may increase the cost effectives such as Lidar as discussed in section 5.3 may have a roll in filling this gap.

The southern Mediterranean shore is another geographical gap identified in the summary of the stress tests, where existing initiatives to identify data sources in North African countries have so far been unsuccessful, this is likely to be a gap that an EOOS would need to address

5.1.2 Correctable gaps

Organisation of data and poor metadata remains a barrier across all the basins, but was highlighted as a particular issue in the Black Sea.

There are gaps caused by the lack of access to data that does exist such as VMS data for fisheries impact and automatic identification system (AIS) for maritime transport. Similarly wind data is not as accessible as it could be due to the data often being charged for by national meteorological offices. Data reported to authorities for impact

[38] http://www.emodnet.eu/sites/emodnet.eu/files/public/North_Sea/images/DLS0342-RT002-R01-00.pdf

[39] https://webgate.ec.europa.eu/maritimeforum/sites/maritimeforum/files/DLS0342-RT016-R01-00-unsecured.pdf

[40] https://webgate.ec.europa.eu/maritimeforum/en/node/4024

assessments, such as for windfarms, was also found to not being reused, even though there was no commercial reason for this.

The coverage of HF which provides data on currents and tides was found to be sparse especially compared to the US. The following section 5.2 provided an analysis of the cost to correct that gap and match the European coverage of HF radar with the US.

5.2 Cost analysis of HF radar

The uses of HF radar systems is increasing, with approximately 400 sites worldwide (MADER, et al., 2016). HF systems provide a potential to fill gaps in ocean observation due to their ability to map ocean surface currents over wide areas (reaching distances from the coast of over 200km) with high spatial (a few Km or higher) and temporal resolution (hourly or higher). The US currently has one of the most comprehensive HF radar networks. **Table 13** shows what the cost would be for the European countries to match the number of HF radar stations per km of coastline.

Table 13: Comparisons of number of HF stations per km of European coasts against the US network.

Country	Coast Line[41] km	Number of stations	To Match US	Difference	Capital Cost To Match US in EUR	Operational Cost To match US in EUR
United States of America	19,924	140	140			
Norway	25,148	1	177	176	33,174,333	5,971,327
Greece	13,676	0	96	96	18,143,333	3,265,771
UK	12,429	4	88	84	15,735,454	2,832,357
Italy	7,600	13	54	41	7,633,572	1,374,031
Croatia	7,368	2	52	50	9,398,024	1,691,629
Denmark	7,314	0	52	52	9,703,154	1,746,552
Spain	4,964	17	35	18	3,382,970	608,929
France	4,853	4	34	30	5,684,716	1,023,240
Estonia	3,794	0	27	27	5,033,329	905,991
Sweden	3,218	0	23	23	4,269,176	768,445
Germany	2,389	3	17	14	2,604,224	468,756
Portugal	1,793	5	13	8	1,436,767	258,616
Ireland	1,448	4	10	6	1,167,456	210,140
Finland	1,250	0	9	9	1,658,319	298,495
Cyprus	648	0	5	5	859,672	154,740
Lativa	498	0	4	4	660,674	118,920
Netherlands	451	2	3	1	221,551	39,879
Poland	440	0	3	3	583,728	105,070
Bulgaria	354	0	2	2	469,636	84,534
Malta	253	2	2	0	-41,378	-7,448
Romania	225	0	2	2	298,497	53,729
Lithuania	90	0	1	1	119,399	21,492
Belgium	67	0	0	0	88,223	15,880

[41] https://www.cia.gov/library/publications/the-world-factbook/

Slovenia	47	1	0	-1	-126,563	-22,781

European stations from European HF Radar Inventory (MADER, et al., 2016) US stations from IOOS[42]

5.3 Areas of special interest

This section intends to go beyond the gap analysis in order to identify a number of 'areas of special interest', with regards to future investment of activities in an integrated EOOS. Clearly, these are in addition to previously identified areas of interest, such as coordination and integration and investment in human capacity. Several key areas of interest, or challenges, have been identified based on existing activities, including the location of offshore energy (wind-farms); the location and monitoring of MPAs; the impacts of climate change; coastal zone protection; eutrophication; the tracking of alien species and changes to species distributions; ecosystem-based fisheries management; and impact monitoring. Additional future challenges, that are not often cited, are the growing impact of marine noise pollution and the possible future requirements for creating refuge from noise (McWhinnie, et al., 2017), and our ability to track and model the distributions and aggregations of micro-plastic pollution (Hardesty, et al., 2017), and to some extent harmful algal blooms, as both become more frequent. Responding to these challenges creates increasing demands on data, especially, for example, the location of wind-farm sites which requires large amounts of data regarding the environment (air, water and bathymetry), biology and human activities.

A recent report suggested that many of the identified challenges could be met, at least partially, with existing data (HR Wallingford, 2016), i.e. that there is no gap in the data, based on results of an extensive gap analysis of the North Sea. However, often only a relatively small proportion of the datasets available are actually useful for meeting the challenges: 17% of the identified datasets that were available, were used. This report suggests that although there may not appear to be a data gaps, detailed analyses of the data can reveal deficiencies – particularly in spatial or temporal coverage and for some sources of data, and regarding data quality. Data availability, in the broadest sense, therefore remains a key overarching area of interest in moving towards an integrated EOOS. Particularly so for biological data, much of Europe's biological observation capability remains disparate, uncoordinated and lag behind that of physical and biogeochemical components.

This is particularly relevant for one of the key areas of interest – the spatial expansion in to new territories. This is both in terms of the expansion of activity taking place in Areas Beyond National Jurisdiction (ABNJ) – where data is often of poorest quality. Further, activities are also expanding towards deeper environments, often in the search for new mining opportunities.

Technological advances are by far the most important future area of interest, both in terms of answering the identified challenges, and supporting the expansion towards further and deeper environments. Below, we describe a number of technologies, but this is not intended to be an exhaustive list:

High Frequency Radar

High Frequency Radar (HFR) is a land-based remote sensing instrument that provides synoptic, high frequency and high resolution data at the ocean-atmosphere interface (Rubio, et al., 2017). Capable of measuring surface currents, waves and winds, and unprecedented potential for integrated coastal management. In Europe, the number of HFR networks has grown significantly over the past 10 years, with over 50 currently deployed and more in the planning stage. One recent initiative provides an up-to-date

[42] https://ioos.noaa.gov/project/hf-radar/

inventory of the existing HFR operational systems in Europe, describing system characteristics, operational products and applications.

Light Detection and Ranging

Light Detection and Ranging (LiDAR), is an airborne remote sensing method used to examine the surface of the Earth (Babichenko, et al., 2016). It principally consists of a laser, a scanner, and a specialised GPS receiver. Bathymetric LiDAR uses water-penetrating green light to measure and map seafloor and riverbed elevations, and manmade environments, with accuracy, precision, and flexibility. It is also possible to measure discharge or accumulations of pollution in seawater - the Hyperspectral Laser Induced Fluorescence (HLIF) LiDAR combines highly sensitive and selective oil-in-water detection with characterisation capabilities. This technique is therefore effective for oil detection in open and coastal waters and has been applied in the Norwegian Sea, Barents Sea, and the Baltic Sea.

Oceanic CO2

Most of the atmospheric CO_2 measurements which have been made over the ocean have focused on the Pacific and Southern Ocean regions and mainly from research vessels. However, these vessels often have limited deployment periods and therefore cannot provide sufficient long term data trends. To try and combat this some studies have begun to use commercial container ships to collect data which means that multiple measurements can be combined into discrete latitude or longitude bands. This provides a time series from several stations collected from a single measurement system, which avoid issues when calibrating offsets from different systems (Pickers, et al., 2017). For example a researcher from the French National Centre for Scientific Research and a team from LOCEAN, collaborated in a European study to map the uptake of atmospheric CO_2 by oceans. Oceanic CO_2 measurement were taken on board a network of cargo vessels on regular routes in the North Atlantic Ocean. Combing their results with other data, the team were able to map CO_2 uptake across the whole North Atlantic Ocean[43].

Autonomous underwater vehicles (Robotics)

Autonomous underwater vehicles, in particular underwater gliders, represent a rapidly maturing technology with large cost-saving potential, particularly for sustained real-time observations (Seto, 2013). The manoeuvrability and controllability of mobile platforms make them preferable for establishing ocean observation networks that will supplement static sensor platforms. As nodes within a sensor network, they provide the potential for great coverage of regional ocean areas, and for access to hard-to-reach areas (e.g. under ice (Katlein, et al., 2017)), or to track moving oceanic events (e.g. harmful algal blooms). They can also support an advance suite of sensors, that otherwise would not be available.

Environmental DNA

Environmental DNA (eDNA) refers to DNA that can be extracted from environmental samples, such as soil or faeces, and importantly from water, without first isolating any target organisms. However, in aquatic environments, the DNA released by an organism can be detected for only a few days. While the potential for detecting fish and their abundances in the marine environment is relatively new, it is being implemented already. The technology promises many applications, from evaluating protections for endangered species to assessing the impacts of offshore wind farms, and could be useful for monitoring the presence of alien species. Through eDNA analysis it is not possible to distinguish individuals of the same species or to acquire information on the number of individuals present, their age, class, size, sex, etc. In addition to eDNA, new tools are being developed which would enable remote and continuous measurement of biological

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[43] http://www2.cnrs.fr/en/1674.htm

and microbial diversity, including measurements with regard to, zooplankton and phyto-plankton, and mega- and meio-fauna in the benthos and the water column. Such tools will probably include genomics, marine biosensors, automated drones or acoustic monitoring.

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Annex 1 Platform Codes and descriptions

Platform Code	Platform Name	Platform Description
0	Unknown	The correct value is not known to
10	land or seafloor	A platform located on the solid surface of the Earth either above or below sea level.
11	fixed benthic node	A collection of oceanographic instruments mounted at a fixed position on the seabed (e.g. POL Monitoring Platform
12	sea bed vehicle	An instrumented platform that is propelled on wheels or tracks on the seabed (e.g benthic crawler).
13	beach/intertidal zone structure	A structure to which instrumentation may be attached that is either in air or under water depending on the state of the tide and weather conditions.
14	land/onshore structure	A fixed man-made structure on land to which instrumentation may be attached (e.g. meteorological tower).
15	land/onshore vehicle	An instrumented vehicle or sample collector that operates on the solid surface of the Earth (e.g. mobile meteorological station
16	offshore structure	A fixed (for the duration of the measurements) man-made structure away from the coast to which instrumentation may be attached (e.g. oil rig
17	coastal structure	A fixed man-made structure permanently linked to land with access to water at all states of the tide to which instrumentation may be attached (e.g. pier).
18	river station	An instrumented structure in a river upstream of its tidal limit.
19	mesocosm bag	A large polythene bag containing a water sample suspended in the natural environment so that it shares ambient physical conditions such as temperature and light levels
20	submersible	A platform operating within a water body.
21	propelled manned submersible	A platform operating in the water column that has both self-contained propulsion and at least one human operator on board (e.g. submarine).
22	propelled unmanned submersible	A platform operating in the water column attached to a mothership by an umbilical with limited propulsion and no human operator on board (e.g. ROV).
23	towed unmanned submersible	A vehicle towed by rigid cable through the water column at fixed or varying depth with no propulsion and no human operator (e.g. Towfish
24	drifting manned submersible	A platform operating in the water column attached to a mothership by an umbilical but with no means of propulsion that has at least one human operator on board (e.g. bathysphere).
25	autonomous underwater vehicle	A free-roving platform operating in the water column with propulsion but no human operator on board (e.g. Autosub
26	lowered unmanned submersible	An unmanned platform lowered and raised vertically by a cable from the mothership. Includes any type of profiling sensor mounting such as Conductivity, Temperature, and

Platform Code	Platform Name	Platform Description
		Depth CTD frames
27	sub-surface gliders	Platforms with buoyancy-based propulsion that are capable of operations at variable depths which are not constrained to be near the sea surface.
30	ship	A large platform operating on the surface of the water column. Objective definitions for guidelines: >50m length (EU)
31	research vessel (ocean going)	A platform of any size operating on the surface of the water column in unpredictable locations that is specifically equipped
310	research vessel (costal)	A platform of any size operating on the surface of the water column in unpredictable locations that is specifically equipped
32	vessel of opportunity	A platform for purpose of commerce of any size operating on the surface of the water column in unpredictable locations that regularly collects scientific (oceanographic and meteorological) data (e.g. an instrumented cargo vessel).
33	self-propelled small boat	A small self-propelled platform operating on the surface of the water column that may be easily removed from the water (e.g. shore-based RIBs
34	vessel at fixed position	A platform of any size occupying a fixed location on the surface of the water column for prolonged periods collecting scientific (oceanographic and meteorological) data as a primary or secondary mission. Includes light vessels and weather ships.
35	vessel of opportunity on fixed route	A platform repeatedly following a predictable fixed track on the surface of the water column that collects scientific (oceanographic and meteorological) data (e.g. an instrumented ferry).
36	fishing vessel	A platform operating on the surface of the water column whose primary purpose is the commercial harvesting of fish or shellfish but may be engaged in scientific activities such as fish stock surveys or mooring deployments and recoveries.
37	self-propelled boat	A small self-propelled platform operating on the surface of the water column in unpredictable locations that is smaller than a ship
38	man-powered boat	A platform operating on the surface of the water column that is manually propelled and may not be easily removed from the water (e.g. trireme).
39	naval vessel	A platform operating on the surface of the water column in unpredictable locations that is primarily equipped
3A	man-powered small boat	A platform operating on the surface of the water column that is manually propelled and may be easily removed from the water (e.g. rowing boat
3B	autonomous surface water vehicle	A self-propelled vehicle operating on the sea surface with no human occupants.
3C	surface gliders	Platforms with buoyancy-based propulsion that operate at a single depth near the sea surface.

Platform Code	Platform Name	Platform Description
3D	drillship	A drillship is a merchant vessel designed for use in exploratory offshore drilling of new oil and gas wells or for scientific drilling purposes.
3Z	surface vessel	A mobile platform with propulsion operating on and restricted to the surface of a water body.
41	moored surface buoy	An unmanned instrumented platform operating on the surface of the water column loosely tethered to the seafloor to maintain a fixed position (e.g. ODAS buoy).
42	drifting surface float	An unmanned instrumented platform operating on the surface of the water column often attached to a drogue to track currents rather than winds (e.g. Argos buoy).
43	subsurface mooring	A collection of oceanographic instruments attached to wires suspended between anchors on the seabed and buoyant spheres in the water column.
44	drifting subsurface float	An unmanned instrumented platform drifting freely in the water column at a depth governed by its density (e.g. Swallow float).
45	fixed subsurface vertical profiler	A platform that periodically makes an automated vertical traverse of the water column at a predetermined fixed location. (e.g. YSI vertical profiler
46	drifting subsurface profiling float	An unmanned instrumented platform drifting freely in the water column that periodically makes vertical traverses through the water column (e.g. Argo float).
47	float	A free-floating platform either on the surface of the water column or at a predetermined depth within the water column.
48	mooring	A tethered collection of oceanographic instruments at a fixed location that may include seafloor
49	surface ice buoy	An undrogued (i.e. no sub-surface parachute) surface float that is deployed in regions where sea ice forms that moves with either ice or water depending upon the time of year.
50	buoyant aircraft	A platform capable of flight in the atmosphere because it is lighter than air.
51	free-rising balloon	A container filled with a gas that is lighter than air
52	free-floating balloon	A container filled with a gas that is lighter than air
53	tethered balloon	A container filled with a gas that is lighter than air
54	airship	A self-propelled container filled with a gas that is lighter than air.
60	non-buoyant aircraft	A platform capable of flight in the atmosphere despite its being heavier than air.
61	research aeroplane	A fixed-wing self-propelled aircraft that is equipped
62	aeroplane	A fixed-wing self-propelled aircraft.
63	rocket	A rocket is a vehicle
64	geostationary orbiting satellite	A vehicle operating beyond the Earth's atmosphere without human occupants that orbits the Earth at the same rate as the Earth's rotation keeping it over a fixed location on the Earth's surface..

Platform Code	Platform Name	Platform Description
65	orbiting satellite	A vehicle operating beyond the Earth's atmosphere without human occupants that orbits the Earth at a different rate to the Earth's rotation so it moves over the Earth's surface..
66	manned spacecraft	A vehicle operating beyond the Earth's atmosphere with human occupants.
67	helicopter	An aircraft without wings that obtains its lift from the rotation of overhead blades.
68	satellite	A vehicle operating beyond the Earth's atmosphere without human occupants that orbits the Earth.
69	autogyro	An aircraft without wings that obtains its lift from the rotation of overhead blades
6A	glider	A fixed-wing aircraft with no propulsion.
6B	kite	An aerofoil tethered to the ground held aloft by the wind.
6C	parachute	A fabric sheet designed to slow the descent of an object through the atmosphere.
6D	unmanned aerial vehicle	Any untethered heavier-than-air aircraft that is not occupied by people: may be a remotely piloted aircraft or an autonomous aircraft. Also referred to as a drone.
6Z	spacecraft	A platform operating beyond the Earth's atmosphere.
70	organism	A living creature carrying instruments or collecting samples.
71	human	A human being without specialised equipment operating on land or the surface of the water column.
72	diver	A human being with self-contained equipment or surface-connected suit enabling operation within the water column.
73	flightless bird	A bird that is unable to fly with the ability to exist within the water column (e.g. penguin).
74	seabird and duck	A flighted bird that is able to exist on the water column surface and dive into the water column (e.g. cormorants
75	cetacean	A mammal that exists within the water column but needing to regularly surface to breathe (i.e. dolphins and whales).
76	fish	A free-swimming creature that exists totally within the water column.
77	land-sea mammals	A mammal that exists both on land and within the water column. Includes seals
90	cryosphere	A frozen body of water on land
91	ice island	A floating ice sheet detached from the coast.
92	ice shelf	A floating ice sheet attached to the coast.
93	pack ice	Sea ice not connected to land with an ice concetration of over 70 per cent.
94	drift ice	Sea ice not connected to land with an ice concetration of under 70 per cent.
95	amphibious vehicle	A self-propelled platform capable of operating on land and within or on the surface of a water body.
96	amphibious crawler	A self-propelled vehicle capable of operation on land or the seabed (e.g. beach crawler).
9A	DUKW	A six-wheel drive amphibious truck developed during the

Platform Code	Platform Name	Platform Description
		second World War.
9B	hovercraft	A craft capable of moving over water or land on a downwardly-propelled cushion of air.
Additional Codes		
100	Marine data	Data centres used for the storage and dissemination of marine data, and data products
101	Land-based facilities	Labs and Building used to support ocean observation activities , but not in situ
102	Facilities for biology and ecosystem	Labs and Building used to support biology/ecosystem activities , but not in situ
103	HF Radar	HF radar systems utilize high frequency radio waves to measure the surface currents in the coastal ocean.

Annex 2 Excel Data sheets

https://www.mragcloud.net/index.php/s/02dpw1X12MKH2cB

password for files:EOOS

Annex 3 Request table and Contact Log

Request for additional information.

Ocean observation activity	Estimated budget/ costs (EUR)	No. staff / FTE	Comments
Biological oceanography		e.g. 0, <10, <50, <250, 250+	
Chemical oceanography			
Physical oceanography			
Marine geology			
Atmospheric sciences			
Cryosphere (including ice on both land and sea)			
Other (Specify)			

Country	Organisation	Contacted by (Phone/Email/Both)	Date Sent	Date Received
Belgium	Agency for Maritime and Coastal Services (MDK), Coastal Division	Both	08/08/2017	-
Belgium	Royal Belgian Institute of Natural Sciences (RBINS), OD NATURE	Both	08/08/2017	-
Croatia	Croatian Meteorological and Hydrological Service (DHMZ)	Both	08/08/2017	-
Croatia	Institue of Oceanography and Fisheries	Phone	08/08/2017	-

Country	Organistation	Contacted by (Phone/Email/Both)	Date Sent	Date Received
Cyprus	Oceanography Center, University of Cyprus (OC-UCY)	Both	09/08/2017	-
Denmark	Danish Meteorological Institute (DMI)	Both	09/08/2017	-
Denmark	Defence Centre for Operational Oceanography (FCOO)	Both	08/08/2017	-
Estonia	Tallinn University of Technology, Marine Systems Institute (MSI)	Both	08/08/2017	-
Finland	Finnish Meteorological Institute (FMI)	Both	08/08/2017	-
France	Ifremer	Emailed	08/08/2017	-
France	Ifremer	Called	08/08/2017	-
France	Mercator Ocean	Emailed	10/08/2017	-
Germany	BSH	Both	09/08/2017	-
Germany	Helmholtz-Zentrum Geesthacht	Emailed	09/08/2017	22/08/2017
Greece	Hellenic National Oceanographic Data Centre	Emailed	10/08/2017	-
Ireland	Marine Institute	Both	08/08/2017	08/09/2017
Italy	CMCC	Emailed	08/08/2017	-
Italy	CNR	Emailed	08/08/2017	-
Italy	Liguria Cluster of Marine Technology (DLTM)	Both	08/08/2017	-

Country	Organistation	Contacted by (Phone/Email/Both)	Date Sent	Date Received
Italy	National Institute of Geophysics and Volcanology (INGV)	Both	08/08/2017	-
Italy	Italian National Institute for Environmental Protection and Research (ISPRA)	Emailed	10/08/2017	-
Italy	National Institute of Oceanography and Experimental Geophysics (OGS)	Both	09/08/2017	-
UK	National Oceanography Centre (NOC)	email	07/08/2017	07/08/2017- forwaded to relevent person
UK	Met Office	both	07/08/2016	-
UK	CEFAS	Reception provided email	04/08/2017	-
Sweden	Swedish Meteorological and Hydrological Institute (SMHI)	Reception provided email	07/08/2017	-
Spain	Puertos del Estado	Emailed	11/08/2017	-
Spain	Spanish Institute of Oceanography (IEO)	Both	11/08/2017	-
Slovenia	Slovenian Environment Agency	Emailed	04/08/2017	17/08/2017
Slovenia	National Institute of Biology (NIB)	Both	10/08/2017	-

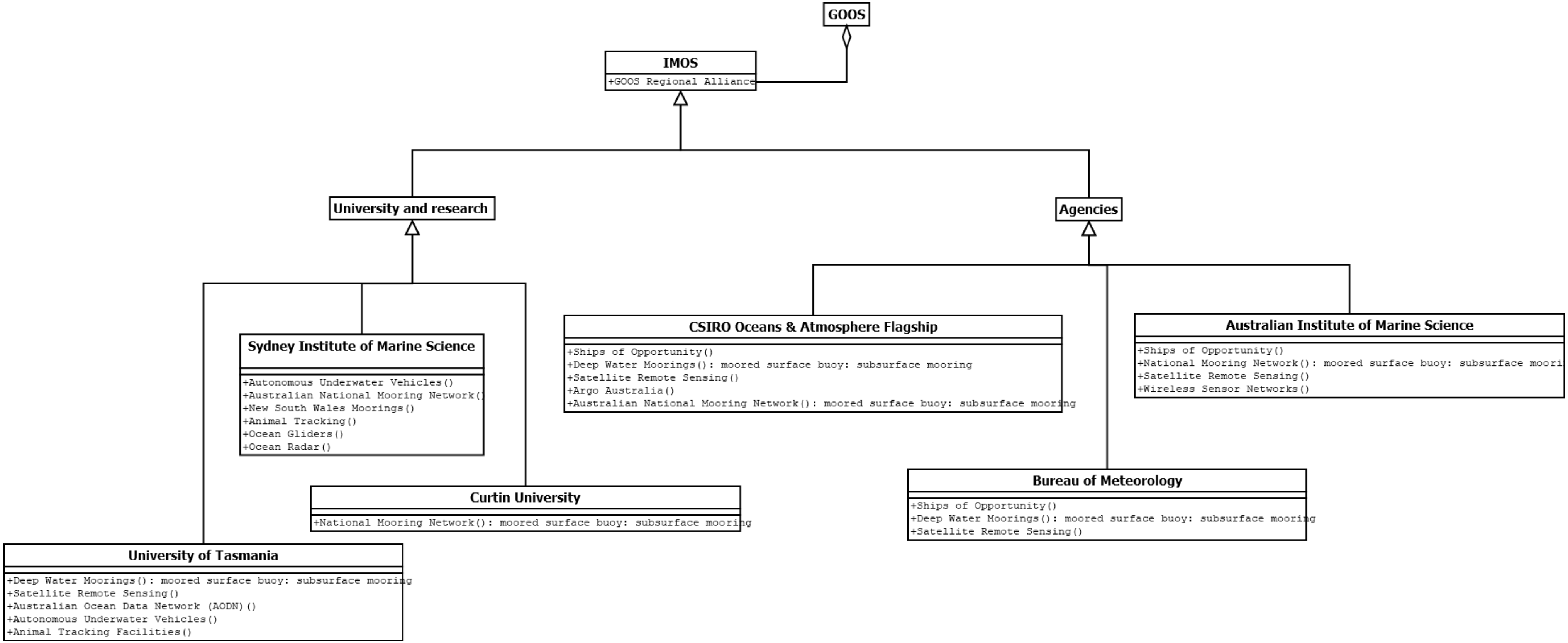
Country	Organisation	Contacted by (Phone/Email/Both)	Date Sent	Date Received
Portugal	Portuguese Institute for the Ocean and Atmosphere (IPMA)	Emailed		-
Portugal	Hydrographic Institute (IH)	Both	11/08/2017	-
Poland	Maritime Institute in Gdansk (MIG)	Emailed	10/08/2017	24/08/2017
Poland	Institute of Oceanology, Polish Academy of Sciences (IO PAN)	Emailed	10/08/2017	-
Poland	Institute of Meteorology and Water Management (IMGW-PIB)	Both	10/08/2017	-
Norway	Norwegian Meteorological Institute (MET Norway)	Emailed	10/08/2017	-
Norway	Nansen Environmental and Remote Sensing Center (NERSC)	Emailed	10/08/2017	-
Norway	Institute of Marine Research (IMR)	Emailed	10/08/2017	-
Netherlands	Royal Netherlands Meteorological Institute (KNMI)	Emailed	10/08/2017	-
Netherlands	Rijkswaterstaat	Both	10/08/2017	-
Netherlands	Deltares	Emailed	10/08/2017	-

Country	Organistation	Contacted by (Phone/Email/Both)	Date Sent	Date Received
Lativa	Latvian Environment, Geology and Meteorology Agency – LEGMA	both	07/08/2017	07/08/2017-forwarded to relevant person
Lativa	University of Lativa	email	07/08/2017	-
Lativa	Latvian Institute of Aquatic Ecology			-
Lithuania	Environmental Protection Agency, Department of Marine Research	email	07/08/2017	05/09/2017
Lithuania	Klaipeda University	both	07/08/2017	-
Malta	University of Malta	Emailed	10/08/2017	-
Bulgaria	Institute of Oceanology	Emailed	10/08/2017	-
Romania	National Institute for Marine Research and Development	both	07/08/2017	-

Country	Organistation	Contacted by (Phone/Email/Both)	Date Sent	Date Received
Romania	National institute for Earth Sciences	Phone	11/08/2017	-

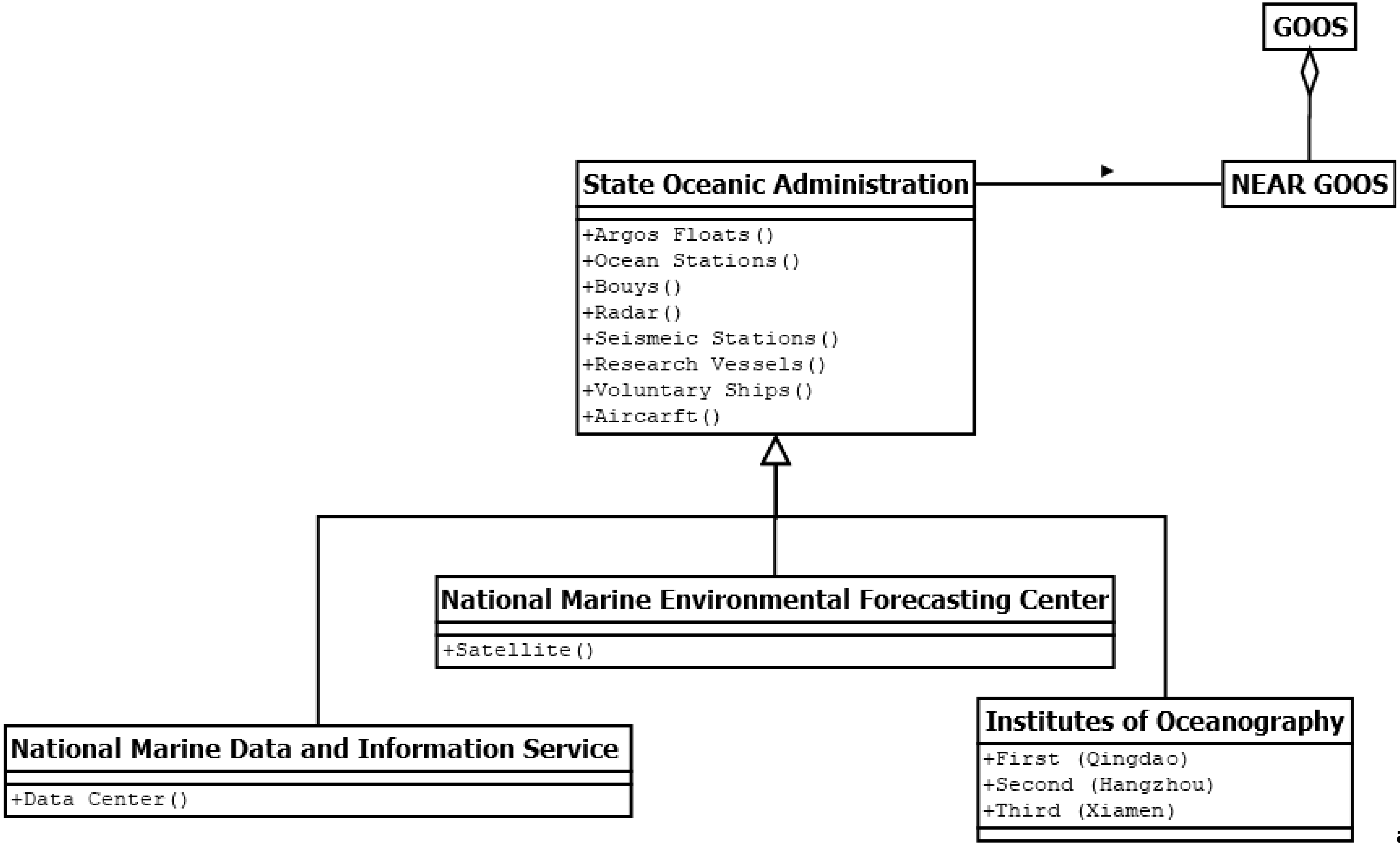
Annex 4 Organisation diagrams for 3rd countries

Australia



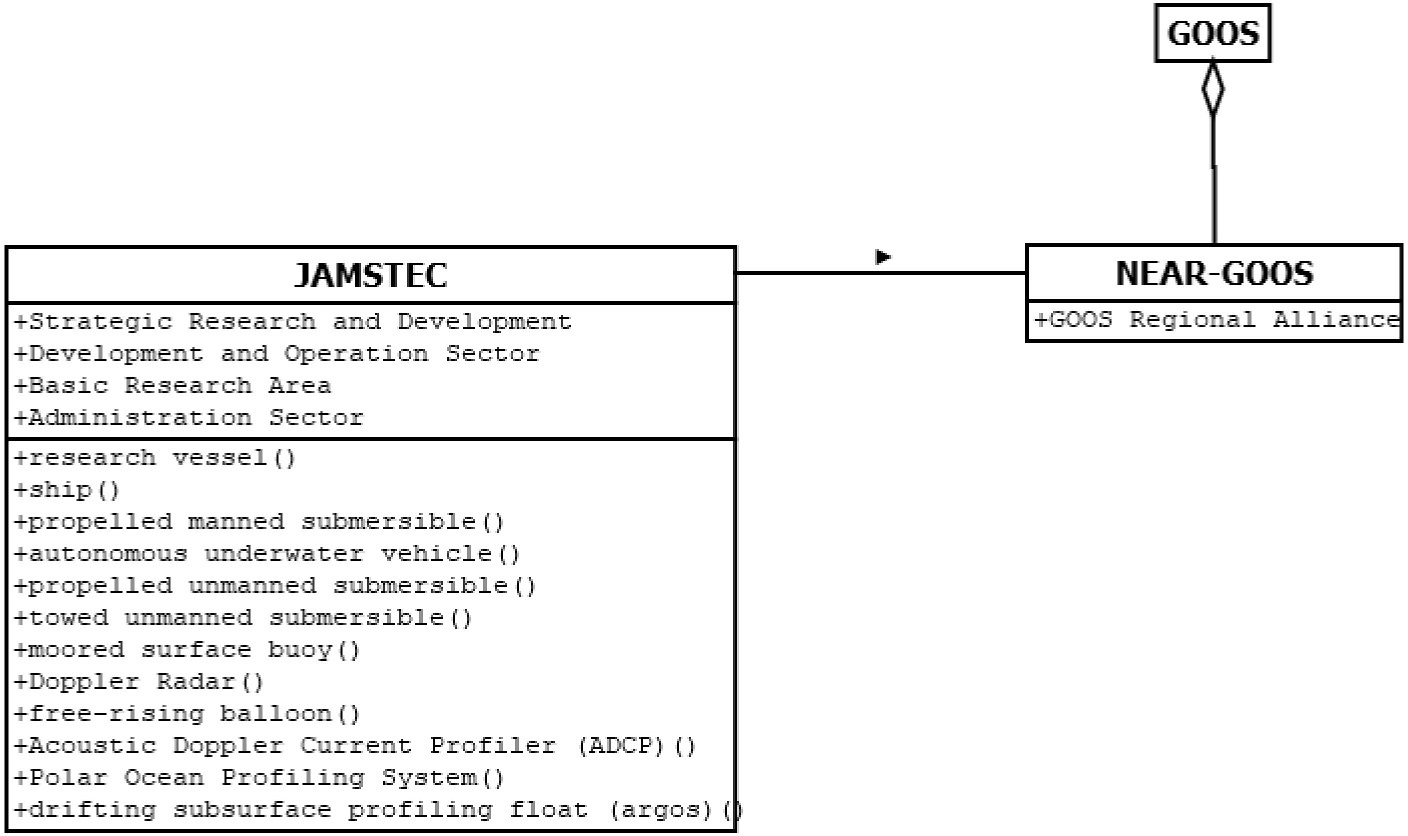
GOOS
IMOS
+GOOS Regional Alliance
University and research
Agencies
Sydney Institute of Marine Science
+Autonomous Underwater Vehicles()
+Australian National Mooring Network()
+New South Wales Moorings()
+Animal Tracking()
+Ocean Gliders()
+Ocean Radar()
CSIRO Oceans & Atmosphere Flagship
+Ships of Opportunity()
+Deep Water Moorings(): moored surface buoy: subsurface mooring
+Satellite Remote Sensing()
+Argo Australia()
+Australian National Mooring Network(): moored surface buoy: subsurface mooring
Australian Institute of Marine Science
+Ships of Opportunity()
+National Mooring Network(): moored surface buoy: subsurface moori
+Satellite Remote Sensing()
+Wireless Sensor Networks()
Curtin University
+National Mooring Network(): moored surface buoy: subsurface mooring
Bureau of Meteorology
+Ships of Opportunity()
+Deep Water Moorings(): moored surface buoy: subsurface mooring
+Satellite Remote Sensing()
University of Tasmania
+Deep Water Moorings(): moored surface buoy: subsurface mooring
+Satellite Remote Sensing()
+Australian Ocean Data Network (AODN)()
+Autonomous Underwater Vehicles()
+Animal Tracking Facilities()

China

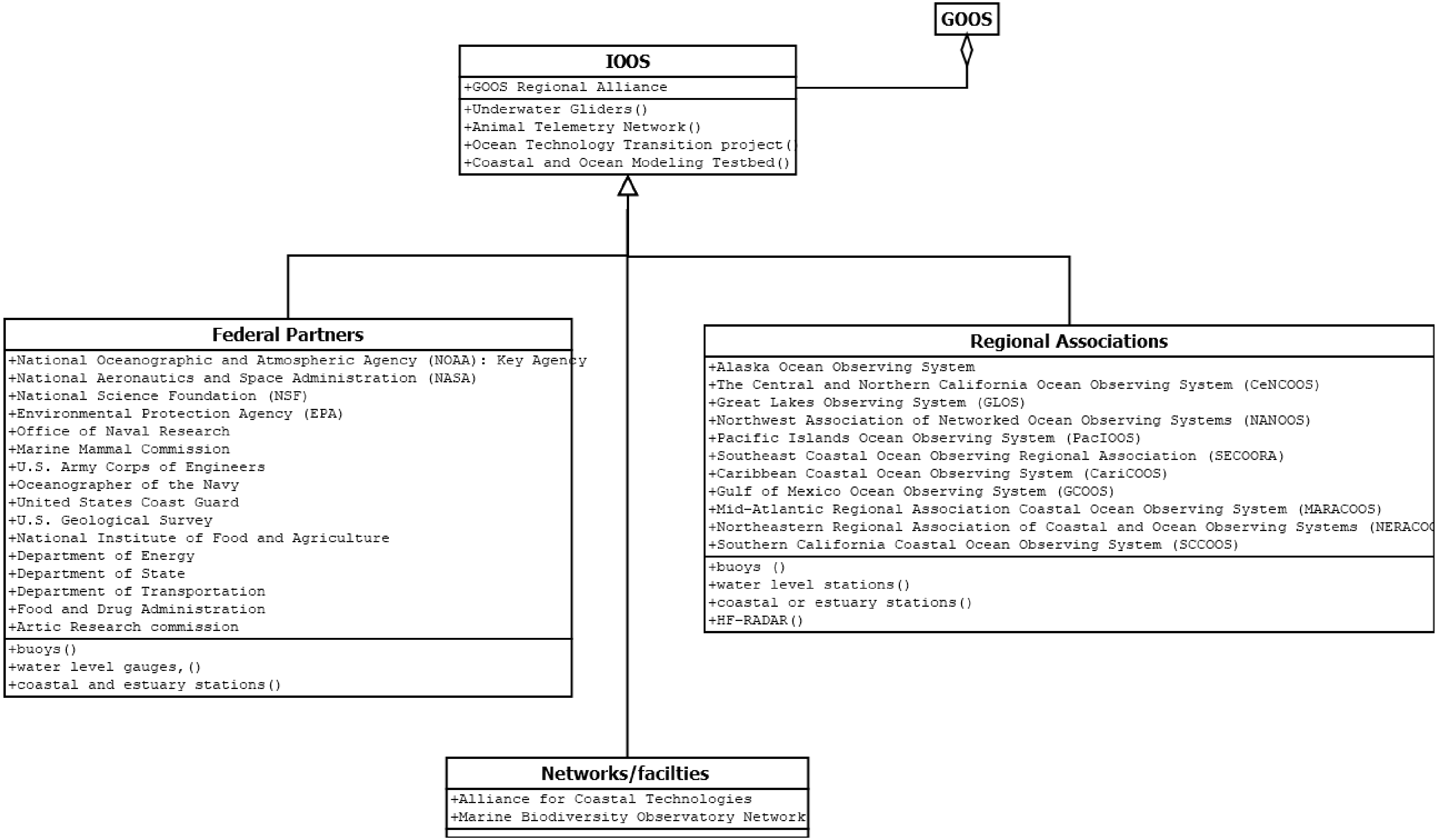

GOOS
State Oceanic Administration
+Argos Floats()
+Ocean Stations()
+Bouys()
+Radar()
+Seismeic Stations()
+Research Vessels()
+Voluntary Ships()
+Aircarft()
NEAR GOOS
National Marine Environmental Forecasting Center
+Satellite()
National Marine Data and Information Service
+Data Center()
Institutes of Oceanography
+First (Qingdao)
+Second (Hangzhou)
+Third (Xiamen)

a

Japan


GOOS
JAMSTEC
+Strategic Research and Development
+Development and Operation Sector
+Basic Research Area
+Administration Sector
+research vessel()
+ship()
+propelled manned submersible()
+autonomous underwater vehicle()
+propelled unmanned submersible()
+towed unmanned submersible()
+moored surface buoy()
+Doppler Radar()
+free-rising balloon()
+Acoustic Doppler Current Profiler (ADCP)()
+Polar Ocean Profiling System()
+drifting subsurface profiling float (argos)()
NEAR-GOOS
+GOOS Regional Alliance

United States



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