
DOUGLAS-WESTWOOD



Global Markets for Ocean Observation Systems

Final Report November 2006

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Introduction

This study was commissioned by the University of Victoria and completed by Douglas-Westwood Limited in September 2006.

Scope of work – the requirements for this OOS international assessment can be summarised as delivery of a comprehensive review of international opportunities in ocean observing systems which will:

- Estimate the worldwide OOS market size, segmentation and niche opportunities, derived from an end-user perspective.
- Present information on the strategic disciplines expected to need or use OOS, the associated market intelligence for both current technologies and those believed to be used or needed in the near future.
- Identify issues that will need further study.

The intended end use of the study is to:

- Assess Canadian strengths and weaknesses in the sector.
- Identify technology development opportunities.
- Define sector goals and develop a strategy.
- Communicate and engage the sector in the strategy.
- Identify any additional opportunities for future work plans.

The methodology used has comprised seven phases:

1. Start up meeting in Montreal
2. Desk research – access information sources worldwide and DWL’s own existing resources on ocean markets.
3. Interview programme – aimed at gathering the views of leading end-users and systems suppliers worldwide on market needs and likely values of the associated business.
4. Market forecasts – the information gained in research and interviews was used to develop a financial model of demand for OOS and forecast likely future values.
5. Strategic considerations – identification of the key issues that require consideration by UVic in developing their strategy for OOS.
6. Reporting – draft report delivered to UVic and following any amendments the final report produced in a form suitable for wider dissemination.

Deliverables comprise:

- Identified OOS organisations, programmes and projects (Excel file).
- Interviewees listing (Excel file).
- Tabulated interview notes (Excel file).
- Presentation of results (PowerPoint file) and.
- The report.

Units: In light of the international nature of this report, unless stated otherwise, all \$ values are US dollars.

Summary

Introduction

Ocean Observation Systems (OOS) allow us to take the pulse of the planet. OOS exist in various forms in most areas of the world, with data from academic and governmental programmes being shared by internet. However, the world market for OOS is enormously diverse – the subject is vast and involves a considerable complexity of interlinked funding and operational organisations, programmes and projects.

International research towards a Global Ocean Observation System has been driven by the UN (UNESCO), through the IOC and the United States' National Research Leadership Council, which includes bodies like NOAA (USA) and JAMSTEC (Japan), or through regional groupings such as countries that share ocean boundaries.

In the United States alone, the Congressional Budget Office estimates expenditure to develop and operate an integrated coastal and ocean observing system will cost between 1.8 billion and 2.2 billion USD over the 2006-2010 period. An additional \$700 million for 2007 has also been announced and is a good example of last-minute, single-year funding approval and an indication of the increased awareness in Congress that OOS is important, but most importantly the heightened sensitivity in the US to sea-based aggression.

OOS represent an evolving market with no formally-accepted definition. During an initial project meeting in Montreal it was decided that 'real-time' systems of gathering data, should be the focus – concentrating on multi-parameter networks involving data distribution, sampling, warehousing, etc. The methodology of this study therefore focuses on evaluating existing and future projects and programmes and then following the market drivers and funding trail to forecast opportunities and trends.

The aim of this report is to value global markets and outline where technology is being applied; now and in the future, considering market drivers, trends and market values. However, it is important to note that OOS often does not conveniently divide itself into sectors. Programmes may source from one and deliver benefits to many.

In addition to the discrete application sectors, a number of sectors may be brought together under the term, 'Ocean Management & Stewardship'. Examples of initiatives include Canada's 'Ocean Management Research Network' (OMRN) and the work ongoing in Norway to monitor environmentally sensitive areas such as the arctic Barents Sea which is very important for both fishing and offshore oil & gas industries.

This report is based on both desk research and a series of in-depth surveys of 56 high level decision-makers in OOS-related organisations in 18 countries worldwide. Some 86% of those interviewed worked for research or equipment manufacturing organisations.

Most interviewees were interested in gathering a very wide range of data. There were very few instances of requirements to measure a single parameter. In short they were very much 'system' oriented. The largest grouping of interviewees was involved in ocean data & models, or the weather / climate area. (However, in practice it can be very difficult to separate the areas.)

Much of the civil sector work we have seen over the years on the subject of OOS has been academic (scientific) research driven – based on a desire to access data mainly for investigation into climate and

tectonic work; or technology driven – a desire to develop and deploy new data gathering systems. There has been much work on the ‘tools’ and technologies involved, from permanently moored subsea or seabed arrays, to drifting buoys, autonomous vehicles, earth observation (by satellite), etc.

There have also been a number of ‘cost-benefit’ analyses which focus on the many and real economic, social, environmental, climate change and disaster avoidance deliverables of OOS. However, there is virtually nothing published on the demand and associated expenditure – in other words “the markets” – the major area addressed by this report.

Global Market Drivers

The global market for OOS is driven by a complex and interrelated set of factors ranging from climate change to the geopolitical, from military to geological. But without doubt, the largest driver for OOS is climate change.

The overall picture is of more and more people being exposed to the potentially disastrous consequences of any severe ‘ocean-event’. Sea levels are rising as glaciers recede, arctic sea-ice melts and increased temperatures raise wind speeds. A series of natural disasters has hit the world in the past few years, some of which, such as the Gulf of Mexico hurricanes of 2005, are thought to be directly due to climate change and its impact on the world’s oceans. Another notable event was the devastating S E Asian tsunami of December 2004. Such events, together with the growing awareness of the importance of measurement of ocean parameters have accelerated the installation of OOS and proposals for many more.

In the military arena, the end of the cold war caused the major powers to re-focus their naval activities from nuclear submarines in the deep ocean, to modern diesel submarines prowling coastal or ‘littoral’ waters. This was reinforced by the US response to 9/11 and the ‘war on terrorism’ may have marked the start of a new type of low-intensity war with occasional flare-ups in different parts of the world. Regional wars and prolonged domestic or ethnic violence create some of the most pronounced shocks to the world economy, due to the substantial costs faced by the countries or regions involved. Increasingly, disputes may involve using the control of a vital commodity, such as oil, against the other party.

Meanwhile growing economic activity in the developing world, most recently in the People’s Republic of China (PRC) is having major impact. One result has been a major growth in many aspects of marine activity, in particular shipping, as greatly increased volumes of imported raw materials and exported manufactured goods are moved across the world. With this comes a growing need for monitoring shipping and indeed providing mariners with more precise weather information.

Energy demand has increased dramatically in the past three years bringing a doubling of the prices of oil, gas and coal. Growth in demand for natural resources from fossil fuels to forest timber and ocean fish has been considerable. It is having a great environmental impact and in particular on the generation of greenhouse gases thought by most to be responsible for global warming and believed to be the cause of climate change.

It is believed that the oceans offer one of the last great unexploited oil & gas resources, particularly in deepwater and in pristine arctic regions, resulting in a need for enhanced levels of environmental monitoring and ocean observation systems. In addition, energy directly generated from wind, waves and tides is sustainable and readily accessible to the growing coastal populations of many countries.

Population growth and increasing levels of disposable income are resulting in a boom in ocean-related recreational activity from cruise vacations to boating, fishing and scuba diving. All of these are in reality also ‘ocean industries’ and greatly dependant upon information on the oceans.

Interview Results

56 in-depth interviews were carried out worldwide over the period May-June 2006. The main focus was the two primary markets (funding sources) for systems providers, North America and Europe, then Asia Pacific. Samples were also taken from other regions.

- The largest proportion of interviews by country were the USA 30% and UK 27%, the rest of Europe accounted for a further 15% followed by Canada at 9%. The interviewees spanned the subject area of OOS. 50% were engaged in some aspect of research – from inter-agency organisations to scientific and applied research and 10 of the organisations interviewed currently maintained an OOS of some type.
- Due to the very wide range of bodies involved in OOS, Organisations were chosen to span the many interest and funding groups. These ranged from NOAA to a Marine Warfare Centre, from Marine Laboratories to the Dubai Municipality and from commercial service providers to individual equipment manufacturers.
- The individuals interviewed were mainly of senior executive level, with job titles ranging from Chairman and CEO to board members of international ocean-related organisations. At practical working level examples of job titles included Project Manager and Senior Advisor Tsunami Unit (IOC).
- The majority of the interviews were concentrated amongst the suppliers of products and services to the OOS community and their customer base – the research organisations. Sample interviews were also held with major users such as forecasters and oil companies.
- Responsibilities ranged from management of global programmes to coordination of regional OOS programmes, from direction of a number of scientific groups to management of an Antarctic project team.
- Interviewees' decision-making status on a self-scored scale of 1-10 (10 being high) averaged 7.5.
- Their suppliers included both product manufacturers (e.g. oceanographic instrumentation) and service providers.
- Most organisations were involved in both national and international activities and to a lesser extent regional. There were also significant partnerships and cooperatives between industry and academia.
- Many of the organisations had a wide span of activities across the application sectors. As identified earlier, research into specific sectors formed the largest activity and in many instances this covered multiple applications.
- Most interviewees were interested in gathering a very wide range of data. There were very few instances of requirements to measure a single parameter.
- The largest grouping of interviewees was involved in ocean data & models and/or the weather / climate area. However, in practice it can be very difficult to separate the areas. A direct output can be hazard warning.

- The overall picture is of great volumes of data being gathered and being made available either direct or via the results from, say, weather models.
- Interviewees stated that in the main, systems had performed to specification. However, many felt that there was considerable room for improvement.
- The predominant funding source is national governments, channelled through various federal and specific operational agencies. Funding is reported to be very difficult to obtain by interviewees worldwide.
- The interviews resulted in a ‘technology users wish list’ and this can be grouped into four areas:
 - improved costs & reliability (acknowledging the trade-off between both)
 - low cost platforms (e.g. autonomous platforms)
 - a strong need for the development of chemical and biological sensors
 - improvements in data transmission, management
 - improved satellite-born sensors.
- Key market drivers are seen as:
 - global warming and climate change and the role of the oceans in this
 - environmental pollution
 - companies have to meet financial obligations
 - an increasingly regulatory environment
 - tsunami warning (however, this received a low score).
- Integration of space-based and in-situ observations was “A very important point and a core issue at international level”.
- There is very strong support for the establishment of OOS standards.
- Improvements are needed in resistance to corrosion and bio-fouling and maintaining very long calibration accuracies.

The impediments to progress in ocean observing are seen as:

- lack of government awareness – and “the need to educate them”
- political sluggishness rather than the fundamental lack of funds
- difficulty in accessing long-term funding
- finding trained people.

Ocean Observation Systems – Key Strategic Considerations

Evolving standards – There is agreement in the need to develop international ocean observing system standards. These include: calibration (methods & frequency), IT standards for cyber infrastructure, data standards, collaborative collection, met data standards, baseline standards, interoperability standards for moving to multi-use and modularity, coordinated expectations and parameters and user and collection guidelines. In the USA, NOAA is expected to take the lead in developing OOS standards over the next two to three years. In the EU, standards are being improved as a result of commercial and government client requests and the WMO.

Infrastructure support is lagging – The infrastructure support requirements include: real time data acquisition software,¹ wireless networks, HF radar, x-band radar, computational resources and communication systems (ranging from PCs to supercomputers and intra-nets to satellite based global telecommunications gateway), wave buoys, wave gauges, oceanographic buoys, CTD, met equipment, gliders, autonomous underwater vehicles, pier-based sampling systems, weather stations, acoustic transmitters and hydrophones.

International initiatives have similar objectives and challenges – There are over 85 variables measured by organizations associated with OOS. The priority variables recommended for global ocean and coastal monitoring as part of initial IOOS are as follows: water level; ocean storage & global transport, carbon, heat, fresh water; air-sea exchange of heat & fresh water; extent & condition of pelagic & benthic environments; abundance & distribution of living marine resources; freshwater flows & fluxes of sediments, nutrients, contaminants.

Development of "appropriate" technology is necessary – There is common international agreement that product improvements are needed in:

- Data acquisition systems to gather better core variable data. Smaller, lighter, less expensive, more robust/longer lasting, less sophisticated (plug & play), interoperable systems. Better communications (i.e. getting data real time from remote locations), lower costs (particularly the “final mile” out to the moorings) and transmit the data safely across long distances.
- Long-term reliability of sensors on surface and subsurface buoys will demand improvement in corrosion and bio-fouling control and in measuring very long-term calibration accuracies.
- Meteorological data gathering must provide high quality and accurate reference data in real time to check, verify and calibrate met measurements.
- Coastal zone observations require development of new products with real time and multi-use features for devices such as acoustic sensors that measure fish and marine mammal population properties.
- Oceanographic sensors for subsurface moorings will need to have mechanical profiling platforms for operating sensors that will be more reliable over long-term operational periods for many years.

“IOOS are collecting the wrong data for water quality management”, states one member of USGOOS’s Steering Committee. “Biological & chemical sensors are the least developed products for global ocean and coastal monitoring purposes. Sensors need to measure pathogens.”

Partnerships are essential for OOS to develop into a viable market – According to a member of staff within NOAA’s Communications & Education office, *“IOOS is still a nebulous concept for many people”* including the important government funding agencies and end users. There is a major challenge in clearly

identifying user applications and value-added education to promote the necessity of OOS. With NOAA as the lead agency, IOOS development will occur through partnering with other federal agencies, regional associations (RAs) and also through international collaborations. The task has been described as “*trying to herd cats*”. A shift is taking place in the reassigning of budgets from other areas that are now to be consolidated under OOS. For example, homeland security has had a huge and immediate effect on activities grouped under OOS.

Finding the people is a challenge – “*There is a difficulty in finding people to work on ocean observing systems*” states a US based technical director. In the US the educational component is being addressed through new ocean observing courses at Texas A&M, University of South Florida and Rutgers University. These courses cover numerical methods, GIS training and data management tasks typically encountered in work situations related to “observing”. EU educational development is, in part, supported through Continuous Professional Development (CPD) initiatives.

Developing IOOS-related partnerships with NASA is challenging – “*IOOS is an operational effort, NASA is a research-orientated mission*”, according to a Technical Director for the GCOOS-RA. There are, however, recent signs of improved collaboration. In 2007, NASA has budgeted \$65 million for continued development through critical design and initial test of the Aquarius satellite to measure global ocean surface salinity for the first time.

An Ocean Surface Topography Mission (OSTM) is scheduled to be launched in 2008. This is an international joint partnership arrangement with the French agency, CNES. The mission will strive to observe changes in ocean surface topography with an accuracy of one to two centimetres. According to a scientific engineer for the NASA program, “*this will require improved space-borne sensors such as advanced high resolution altimeters, salinity sensors and GPS reflections*”.

Integrating space-based and in-situ observations – Other future OOS technologies that integrate space-based and in-situ observations include lidar technologies for coastal and sea level monitoring and GPS/tide gauge geodetic packages, GPS reflections for monitoring ocean microseisms and autonomous aerial vehicles capable of long flights over the ocean. New technology is needed to handle sub-arctic data gathering that will make better use of satellite data for ice-bound areas.

Future technologies are becoming reality – Some of the most exciting future IOOS technologies are autonomous underwater and ocean surface vessels (AUVs, gliders & SUVs) that patrol the coastal and deep ocean. These systems will operate collaboratively with each other; interact with satellites, unmanned and aerial vehicles (UAVs) and adaptively without direct communication. Operational centres will manage these assets. Eventually, robots will replace and refurbish sensors and instruments on moored platforms.

OOS, an emerging market – The primary enabling force of OOS is government funding and supported by environmental regulations, global warning concerns and offshore oil & gas activities.

Government is the key client – Many of the players / end-users do not directly purchase OOS data but instead receive it free of charge. A typical exception to this would be a custom weather forecast delivered by a commercial organisation to a commercial client. For example, a 2004 survey of the commercial exploitation of EO satellite data in Europe and Canada estimated 2002 revenues as \$317 million of which 78% of sales were to Government and other public sector clients.²

² The State and Health of the European and Canadian EO Service Industry – ESA, VEGA, Booz, Allen and Hamilton – August 2004.

Canada

About 62% of those interviewed in our survey have had some experience of working with Canadian organisations in various situations from supplier to partnering in a research project and these individuals seem to have had a very positive experience:

- *“Better and more co-operative to work with than the Americans.”*
- *“Would like to work with Canadians.”*
- *“Would be very keen to work with Canadian companies.”*
- *“Canada has strong academic programs in GPS geodesy.”*

Furthermore, 90% of those able to answer saw no restrictions to working with Canadian companies. In the case of those that did, this related to a lack of knowledge about their organisation’s policy towards purchasing foreign goods & services. (It is of note that these ‘policy issues’ were raised by US organisations and not in Europe!)

However, there is a lack of international awareness about Canadian OOS-related projects (other than Neptune Canada and some university applied R&D activities) and a belief that Canada represents a small potential market.

Canada is, however, recognized in the academic community as a leader in spatial information software/open source software development and several Canadian companies have banded together to develop ISO ice observation standards. However, potential foreign customers for Canadian companies are often buying OOS-related products and services from competitors in the US and Europe.

Conclusions

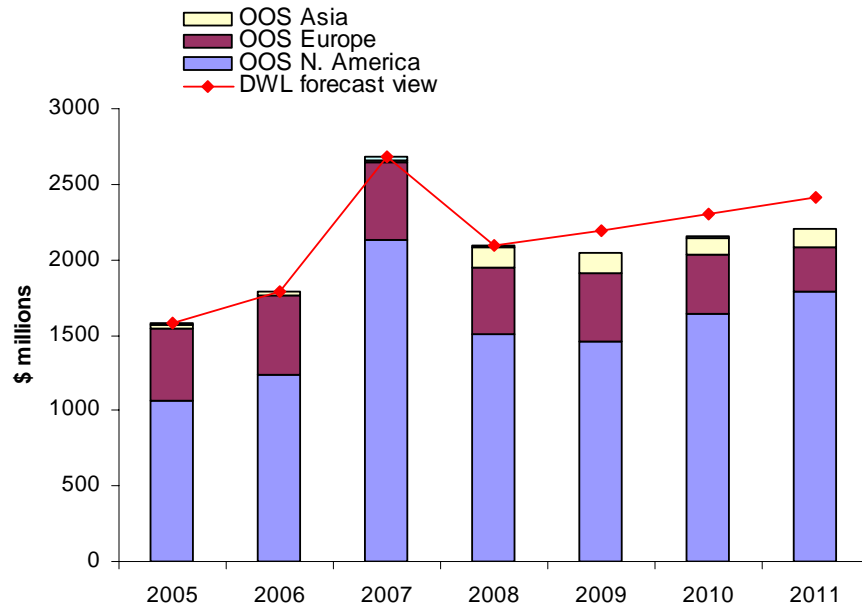


Figure 1: Global OOS Market Forecast 2006-11 (\$ million)

OOS is a major market – based on identified programmes, we value the global market for ocean observation systems at some \$1.8 billion in 2006 and existing programmes will result in growth to \$2.2 billion by 2011. A very high level of activity can be identified in 2007, due to a one off US government expenditure on IOOS of \$700m. With increasing growth and the impact of the market drivers, in particular the response to global warming, we expect total forecast expenditure to grow significantly, perhaps to \$2.4 billion by 2011. This may in time prove to have been too conservative a view.

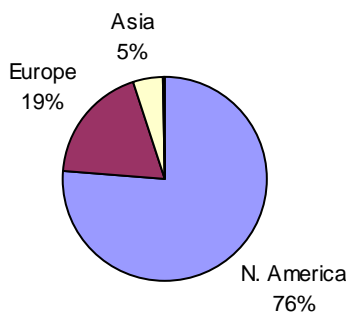


Figure 2: OOS 2007-11 – Global Segmentation

The U.S. is the world’s largest ocean industries player with estimated annual expenditures of \$750 billion in 2002. One-half of these expenditures are generated by the oil & gas industry and one-third is attributed to the Navy.³ US federal expenditures for OOS have been estimated at \$1 billion in 2006.⁴ However, we estimate that total US expenditure is closer to \$1.2 billion.

³ Dr. Andrew Clark, President, Marine Technology Society, in a presentation to the President's Commission on Ocean Policy, Nov. 13/01; and also stated in the Ocean Commission presentation "Technology & Marine Operations: Strategy for Technology Development to Meet the Nation's Needs", Nov. 2002 [www.ocean.commission.gov/documents].

⁴ Mike Hemsley, Dep. Dir., Ocean.US.

Data management and communications (DMAC) is the glue that holds OOS together and accounts for 12% of US annual OOS expenditures. One quarter is committed to the global component and three quarters to coastal management.

Naval involvement is important – much of the global ocean knowledge has been collected as a result of the United States ONR-funded programs, including funding for marine meteorology, small-scale ocean physics, optical oceanography, bioacoustics, coastal geosciences and instrument development.

An essential tool – Ocean Observation Systems are essential for the ocean-user community – in other words all of us – and without doubt are fundamental to increasing the understanding of the oceans and their role in climate change. As this realisation becomes more widespread we believe that OOS will receive more funding from governments worldwide and the commercial opportunities for the supply chain will grow accordingly.

Prospective Further Work

- Develop a strategy to address the opportunities offered by the OOS market – this must acknowledge and address the strengths and weaknesses of Canada in the sector.
 - Address the US market – as the world’s largest OOS market this demands specific study.
 - Work at raising awareness of Canadian ocean technology.
- Focus on identified technology needs:
 - Users require improvements in accuracy, resolution, reliability, lifetime and cost. Low maintenance costs are a key concern and can, for example, be achieved by improved anti-fouling.
 - Select a few sectors – carry out detailed market study on areas such as chemical and biochemical sensors and improvements to satellite-based sensors.
 - Low-cost platforms such as autonomous vehicles
 - Improvements in data transmission and management
- Develop standards – there is a great need for OOS standards. Could Canada take a lead?

1 The OOS ‘Market’

1.1 Introduction

Ocean observation as a market can be viewed on a number of levels:

- Funding agencies – most funding is sourced from governments
- Facilitating organisations – national and trans-national, government & NGO
- Programmes – may comprise of many different projects
- Projects – may comprise use of one or many missions and platforms
- Missions – an activity having specific objectives
- Platforms – range from satellites and aircraft to surface vessels and sub-surface craft
- Sensors – are usually parameter-specific
- Parameters – a great number are measured and are ‘cross-cutting’ (see example in figure below)
- Data gathering & transmission – mainly by cable or radio links
- Data processing and presentation – to generate usable data sets
- Products – one data set may be packaged in many ways so suit different users
- Delivery mechanisms – span all media
- End-user customers – most people, whether they know it or not!
- Modelling – much data is used to model specific situations.

The overall result is a situation of considerable complexity that is not structured for ease of analysis.

	COASTAL ACTIVITY													USER SECTOR
	A	B	C	D	E	F	G	H	I	J	K	L	M	
surface winds														Public
surface temperature														Public
tides / sea level														Public & Private
surface currents														Public & Private
sea state														Public
bathymetry														Public & Private
surface vessels (e.g. ships)														Public & Private
water quality – biological														Public
water quality – chemical														Public
sea ice														Public & Private
water quality – turbidity														Public
sub-surface currents														Public & Private
topography														Public
bottom quality														Public & Private
surface salinity														Public
sub-surface temperature														Public & Private
surface height – mesoscale														Public
internal waves														Public & Private
sub-surface salinity														Public
sub-surface vessels														Public & Private
														Public

Figure 1-1: Cross-cutting Elements – Data and Information Needs

(Source: Canadian Space Agency)

Much of what is measured is done under financing and mandate of governments who aim to monitor activities within their own territories and the areas of the ocean over which they claim authority. This requires the ability to provide indication and warning functions, to monitor, track, analyze and share the maritime picture with agencies responsible for enforcement of national and international laws.

For example, areas over which Canadian Government's departments have a mandate include:

- Security and surveillance
- Ice mapping and monitoring
- Pollution surveillance and monitoring
- Conservation and protection
- Search and rescue
- Science and modelling
- Transport and shipping
- Coastal zone management.

In addition, many of the events that can impact on coastal zones in particular occur in the open ocean in international waters (for example, the formation of a tropical storm or a tsunami-triggering event) so aspects of observation are required on a local, regional and global scale. Also many climate change factors are global in their nature and need of observation.

Within individual countries no single government agency tends to have the full picture on maritime activities, jurisdictions, vulnerabilities or threats and, furthermore, there are overlapping mandates. Taken individually, physical assets used by agencies to monitor and conduct effective ocean observation and surveillance are limited.

It is therefore logical that ocean observation should be organised as large systems covering regions or indeed the whole globe.

We particularly note the following points which apply equally well to satellite and other systems:⁵

- *“Ocean observing requires a network of sensors, platforms, data communication, processing and management architectures and environmental models all operating together in a synergistic manner”*
- (Satellite) systems are extremely costly
- End-users do not operate or pay for the systems and are expecting data to be available for free
- Public and policy makers are not aware or not concerned about (earth observation) from space
- Outreach and awareness activities to public and policy makers are limited
- And the need for the *“community to ... understand the social, economical and environmental benefits....”*

⁵ Crevier, Yves. Co-Chair of Earth Observation Marine Surveillance Coordination Committee, Canadian Space Agency

1.2 Sectors

SECTORS	Services					
	Env. Assessment & Monitoring	Natural Hazard Warning	Search & Rescue	Weather and Sea State Prediction	Marine Research	Marine Education
Markets						
Fisheries & Aquaculture	X	X	X	X	X	X
Oil & Gas	X	X	X	X	X	X
Marine Renewable Energy	X	X	X	X	X	X
Military	X	X	X	X	X	X
Marine Safety & Security	X	X	X	X	X	X
Recreation	X	X	X	X	X	X
Coastal Zone Community	X	X	X	X	X	X
Total Community	X	X			X	

Table 1-1: Study Sectors

In this study we consider the application of OOS to 13 ‘sectors’. In reality seven of these can be regarded as ‘markets’ (in addition there is also the benefit delivered to the entire community). The six others are organisations that use OOS to provide ‘services’ to the markets.

For example, Weather and Sea State Prediction services are at a basic level used by all of the marine players from shipping companies to offshore oil & gas companies and are available free of charge. In addition however, many users purchase custom marine weather services for route planning and operations planning.

So in many cases the raw data from an OOS is input to a model which generates a predicted scenario – e.g. a marine weather forecast.

Some sectors set up their own private OOS – examples include the military for their surveillance operations, or offshore oil & gas companies for weather monitoring around installations in harsh environments. However, in the main, OOS delivers benefits to the population in general either direct or indirect so in the main remains a government-funded activity with relatively little financial input from civil organisations.

1.2.1 Program Expenditure – Regional Examples

The potential market for ocean observing products, services and systems vary widely by geography and industry sector. The industries are pyramid shaped and therefore it is important to recognize the strategic market entry points for securing observing-related equipment sales and service contracts. While some government observing programs look commercially attractive, it is equally important to realize that their requirements are satisfied utilizing in-house resources. In some cases these organizations also represent competition for private sector contracts.

“To hit a home run, you must touch all the bases” applies to successfully securing business. These “bases” in OOS include funding agencies and finance departments, field operations, management, technical departments and procurement offices. The following are examples of potential ocean observing contracts that are financially realistic for Canadian companies to pursue and where Canada has proven expertise.

Africa

There is an emerging thrust in the African Union (AU) associated with the New Partnership for Africa’s Development (NEPAD) that includes a Regional Ocean Observing and Forecasting System (ROOFS) initiative. It is an integrated approach to the management of ocean and coastal environments and natural disasters in Africa.

One of the technical tools to improve the African network of in-situ ocean measurements is a ROOFS-Africa work package that will result in an upgraded in-situ observation and measurement system. Under NEPAD's Environmental Initiative and Development Programs, a five-year budget of \$30 million is allocated for ROOFS-Africa, with \$6 million earmarked for improvements in the African network of in-situ ocean measurements.

Previously funded coastal region projects, such as Large Marine Ecosystem (LME) and Global Environmental Facility of the World Bank, were developed in an era before major advances in the numerical modelling and forecasting. The integration of huge amounts of presently-available ocean and atmospheric data collected by remote sensing from satellites and with information available from in-situ instruments, there is now the potential to assimilate these data into a new generation of forecasting models.

The 5-year, \$6 million work package includes:

1. A series of tide gauges for measuring sea level to monitor coastal zones and the impacts of global change in Africa;
2. A suite of wave buoys to monitor wave conditions;
3. A suite of offshore and met buoys (beyond PIRATA) to improve knowledge of open ocean conditions that eventually affect the coastal seas; and
4. Training, installation and maintenance programs.

The contract components of this work package is broken down as follows:

- Equipment \$2.7 million (incl. installation)
- Maintenance \$2.7 million
- Training \$270 thousand
- Project management \$330 thousand

There are equipment procurement, installation, training and maintenance requirements in each of the five years of the work package.

The funding sources are bilateral and international partners, including Canada. In addition to UNESCO and UNEP, key players in the procurement decision-making process include:

- African Centre for Metrological Applications Development (ACMAD)
- JCOMM, a WMO/OIC integrating and modernizing global ocean data services agency
- IOGOOS, including regional alliances and MedGOOS.

Europe

Under the 'Water Framework Directive and Bathing Water Directive in the European Union (EU), the need for real time ocean monitoring data is required in the Baltic Sea, Black Sea, Mediterranean Sea and Northwest European waters to manage coastal water quality.

Oil spills and algae blooms are areas of special concern. The following market segments (identified by sector activity) require marine information systems to gather, analyze, predict and interpret these water quality parameters:

1. Environmental agencies

2. Meteorological services
3. Harbor authorities
4. Civil protection
5. Research organizations
6. Fisheries departments.

While meteorological agencies need oceanographic data, there is no enforcement legislation in terms of oil spills and algae blooms. Research organizations need better information for understanding algae bloom phenomenon, but it is the enforcement agencies that make the decisions on monitoring programs and subcontractors. Fisheries departments, who are responsible for water quality control and examination of seashells in cultivated areas, have well-developed quality control laboratory programs and in-situ sensors.

Environmental agencies regard better water quality monitoring systems as essential to improve water quality for environmental and security purposes. Harbour authorities need oil spill and algae bloom information because of their economic and social impact in port and near-shore coastal regions. Civil protection groups need real-time information for early detection of oil spills and “polluter-pay” actions.

Harbour authorities represent a market segment that is taking a lead role in developing more accurate monitoring systems by utilizing satellite observing systems. Rotterdam, Hamburg and London are the world’s largest ports and they do have well-developed supplier networks.

Spain is very aware that tourism accounts for 11% of its GDP. It also recognizes that improved water quality management is essential to meeting the EU’s water quality directives and it presently involved in a 5-year service provider networking program that includes the building of a low-orbit observation satellite for environmental monitoring.

Existing potential contracts that get “your-foot-in-the-door” include the delivery of training programs and the provision of technical experts. These are professional service contracts that typically range in value from 100,000 to 300,000 Euros.

There is a Canada-Spain MOU on S&T Collaboration in place that includes participation by the Canadian Space Agency and the National Research Council. The Instituto de Ciencias del Mar is also involved.

Important organizations in the decision-making process include:

- European Sea Ports Organization (ESPO)
- Regional Clean Seas Organization (RECSO)
- European Environmental Agency (EEA)
- Centro Tecnológico del Mar (CETMAR)
- Monitoring and Information Centre (MIC)
- European Institute on Harmful Algal Blooms (EUROHAB)

Spain’s centralized purchasing department in Madrid, Puerto del Estade, is responsible for all the equipment and service requirements of its 27 major ports.

United States

With the large number of offshore blocks being offered in very deep water by the Minerals Management Service (MMS), the US Gulf of Mexico is viewed as an oil and gas frontier province. Seafloor, water column and surface observing service requirements associated with exploration activities include:

1. Seafloor characterization and geophysical surveys: 3-D seismic and low frequency (and therefore, rather low resolution) bathymetric surveys have been conducted over the leased blocks. However, there is a need for high resolution bathymetric and geophysical/geohazards surveys of the seafloor by remote sensing techniques in the support of the engineering and environmental aspects of construction or placement of any structure for exploration or development on the lease, including anchoring, well drilling and pipeline and platform placement.
2. Physical oceanography: the currents vertical structure and their special and temporal variability are quite complex over the slope and continental rise of the Gulf of Mexico. Depending on the exact location of the leased block in the Eastern and Central Gulf, the Loop Current and associated warm core eddies can continuously or sporadically occupy the site, with observed surface currents up to 3 knots, decaying slowly over a substantial portion of the water column. Bottom currents can also be fairly energetic. Numerous long-term regional oceanographic and meteorological studies have been conducted by Scientific Applications International Corporation (SAIC) and Texas A&M under the aegis of MMS and are available to be potential operators. However, a site specific study often needs to be undertaken to ensure that estimates of drag on the riser and forces on the surface and subsurface structures are not underestimated.
3. Environmental sciences: in most cases, MMS leases are accompanied with environmental requesting that the lessee submit a live bottom report containing a bathymetric map (prepared using remote sensing techniques) to determine the presence of live bottom which could be impacted by the activity. If this is the case, the lessee will be required to protect the live bottom area by assessing the impact of the activity on the live bottom through environmental monitoring or relocating its operation. Stipulations also put restrictions on drilling operations (by requiring the disposal of drilling mud through a pipe no more than 10m from the bottom) and sometimes request control of electromagnetic emissions for military purposes.

There is a growing demand for the huge amounts of data to be reduced and packaged in a format that the operator, client and regulatory agency can jointly understand and review on a real-time basis from a shore-based location.

Exxon Mobil remains the industry leader in terms of deepwater exploration and a pioneer in the development of innovative production schemes. BP Amoco Group accounts for more than three million acres under lease, the largest deep water acreage inventory in the Gulf. Royal Dutch Shell Group's operations in the Gulf provide more than 70% of its oil and gas production. About 80% of the leases are in deep water. Chevron Texaco has achieved record gross oil and equivalent production from its first two deep water projects in the Gulf. Marathon is focusing its activities in the Gulf on deep water exploration opportunities and it has been successful on 14 of 16 bids in the Outer Continental Shelf lease sale. Marathon will operate the majority of these blocks.

South America

While South America has a long "wish list" of priority ocean observing projects, the energy sector is actually spending money for observing systems and services. With 9.8 billion barrels of oil and gas equivalent, 996 active offshore wells, 69 fixed and 25 floating platforms and 43 offshore exploratory drilling programs, Brazil is a major player in the offshore oil and gas industry in South America.

Ending the monopoly status of the state-owned oil company, Petrobras, the National Petroleum Agency (ANP) and the National Organization for the Petroleum Industry (ONIP), have created a more favourable business climate for foreign operators and international suppliers to participate in the Brazilian offshore market. The first private company discovery by Texaco and Shell in the Santos Basin is turning it into a petroleum producing region as important as the Campos Basin.

The Petrobras-Devon partnership for the POLVO development project is a case in point. Devon Energy Corporation is a US oil company doing business in Brazil. The POLVO project has the involvement of 100 plus contractors from 15 countries, with 2007 spending estimated at \$250 million.

As part of this change comes the introduction of new environmental legislation that is establishing a whole new set of regulations. These are being developed in co-operation with the domestic and international operators and include observing contracts associated with the following:

1. Well abandonment procedures
2. Oil spill procedure and reporting
3. Criteria to combat oil spillage
4. A national environmental licensing system.

An integrated metocean/seabed stability study associated with well abandonment involves ships, stationary buoys, coastal stations, cores, geophysical lines, lab testing, reports and modelling. While costs vary with market dynamics, a typical 21 day cruise is in the range of \$0.5 to \$0.75 million.

Canada is part of a common bilateral environmental agenda that Brazil has with 10 countries. Some of the key clients for observing-type contracts include Petrobras' management offices in Rio de Janeiro, operations centre in Santa Cruz and procurement office in Houston. Exxon Mobil, BP Amoco, Shell, Chevron Texaco and Statoil are all major players.

Australia

Australia has one of the longest and most beautiful coastlines and one of the largest Exclusive Economic Zones of any nation. Visitors to the Great Barrier Reef generate an estimated \$2 billion in annual revenues. The 75,000 people, who visit Hervey Bay on Queensland's central coast to watch humpback whales, generate an additional \$12 million.

The National Representative System of Marine Protection Areas (NRSMPA) manages the bio-diversity conservation and ecologically sustainable use of the marine resources program throughout the country. A high priority of the Government is to halt the decline in water quality entering the Great Barrier Reef.

An integrated coastal management approach includes the coasts, oceans, estuaries and coastal wetlands areas. The Coasts and Clean Seas Initiative supports coastal space utilization studies, marine waste reception facility projects and coastal monitoring and marine species protection programs.

These projects are funded with an estimated average annual budget of \$18 million and 95% of the funding is managed by the 35 coastal councils.

Asia

The Global Environmental Initiative (GEI) of the World Bank has a program with project contract amounts that are ideal for small-to-medium-sized business (SMEs). Company assists must be less than \$1 million and project funding is a maximum of \$5 million, over a 3-year period.

Through the Global Environmental Facility (GEF) of GEI, ocean observing-related projects are accepted under the Climate Change and International Waters sections. It is a matter of identifying a World Bank member country with an OOS requirement and then jointly submitting a proposal to GEF. For SMEs, project identification and proposal preparation grants of up to \$25,000 are available.

In China's integrated ocean management legislation, its fisheries and ocean planning and zone schemes highlight projects associated with solving freshwater supply, coastal erosion and coastal space utilization problems. Malaysia has clearly identified biodiversity and environmental conservation as priority program areas. The highest levels of importance and implementation for coastal observing projects are related to the discharge of oil and the release of phosphates and nitrates into coastal waters. Indonesia as stressed the importance of empowering local communities to deal with the wide gap that exists between its high technology commercial fisheries and the traditional fishing industry. It plans to conduct monitoring, assessment and modelling evaluations of fishing ecosystem impacts.

Important agencies to contact include UNDP, UNEP and the World Bank. If Asia is the location of a prospective client, then the following organizations are relevant:

1. Global Environmental Affairs
State Ministry of Environment
Jakarta, Indonesia
2. Federal Treasury Department
Kuala Lumpur, Malaysia
3. International department
Ministry of Finance
Beijing, PRC
4. World Bank
Washington, D.C.

1.2.2 Global Marketplace

There have always been ocean observing activities undertaken on a project and/or site specific basis. The integrated, global and systems approach is what differentiates previous programs from what is now known as integrated ocean observation systems. Governments are the pioneers of this new approach and they are also supporting pilot projects to demonstrate the technical and commercial viability and benefits of OOS.

As the scientific community starts to recognize the importance of "knowing customer needs" and commercial entities begin to appreciate the value of better ocean information, OOS becomes a dynamic, growth-orientated marketplace. For those who are accustomed to receiving free data, it will take years for them to recognize the cash value of good information.

The scientific community is the innovator for ocean observing systems. With a desire to improve the understanding and increase the knowledge of oceanography, meteorology and geosciences, the research

and educational markets have taken a lead role in the design, development and implementation of observing systems.

With funding contributions from the IOC and WMO, the Global Ocean Observing System (GOOS) is a permanent global system for observations, modelling and analysis of marine and ocean variables to support operational ocean services worldwide.

The integration of observing systems is achieved through regional programs. The following is a representative list of active regional programs:

Global Sea-Level Observing System (GLOSS) is an operational system designed to provide monitoring of global sea levels. The program aims to establish high quality global and regional sea level networks for the application to climate, oceanographic and coastal sea level research.

The Global Temperature-Salinity Profile Project (GTSP) is a joint IOC/WMO project that manages both real-time and delayed mode observations of global ocean temperature and salinity. The participants are governmental and scientific organizations who support the project through their own budgets, including Canada.

The Tropical Atmosphere Ocean (TAO) array of moored buoys is a program to manage and co-ordinate the development and operation of moored buoys in the tropical ocean regions of the Pacific, Atlantic and Indian Oceans. NOAA's Pacific Marine Environmental Laboratory (PMEL) has taken the lead in the Pacific, JAMSTEC in the Indian Ocean and the Atlantic region is a joint project of France, Brazil and the USA.

The Voluntary Observing Ships (VOS) Program supports atmospheric weather forecasting. VOS is now being combined with the Ship of Opportunity Program under the new IOC/WMO Joint Commission on Oceanography and Marine Meteorology (JCOMM). The VOS founding members included Germany, Hong Kong, India, Japan, Netherlands, UK, the Russian Federation and the USA.

The early adopters are comprised primarily of governmental organizations and led by the IOC and UNESCO. A representative list of programs under development include:

The Black Sea GOOS Program is designed to foster operational oceanography among its regional members, including Bulgaria, Romania, Turkey, Russian Federation, Ukraine and Georgia. The Oceanography Centre of UNAS, Ukraine is the lead organization.

GOOS-Africa is a coordination committee established to promote the development of GOOS in Africa. It plans to form an Africa-wide network of national ocean data centres, upgrade the African network of sea level stations, encourage capacity building in ocean remote sensing and facilitate internet access and data transfer mechanisms. The University of Cape Town has taken a lead role in developing the network.

IOCCARIBE-GOOS is expected to provide information services and products on the coastal areas and seas in the IOCCARIBE region. This includes information on the past, present and future state of the marine and coastal environment, marine ecosystems and biodiversity and weather and climate variability. While the tourism, port, fishing, shipping and offshore oil & gas industries are information users, it is governmental agencies and the scientific research community that will fund the program. In addition to Caribbean countries, it is the governments of the Netherlands, UK and the USA that will be major contributors.

Mediterranean Global Ocean Observing System (MedGOOS) is an informal association founded to facilitate the development of an operational ocean observing and forecasting system at the regional level. Albania, Bosnia, Croatia, Cyprus, Egypt, France, Greece, Crete, Israel and Italy are member countries that have also offered the services of their research institutions.

Pacific Islands GOOS (PIGOOS) will continue to raise public awareness, undertake capacity building workshops and participate in the Argo initiative as the new Pacific regional association. The South Pacific Applied Geoscience Commission (SOPAC), Fiji, is the lead organization.

The Western Indian Ocean Marine Application Project (WIOMAP) plans to improve marine data availability and services through expanded specialized training, an enhanced observing network and the establishment of a number of specialized marine modelling and product centres. The Bureau of Meteorology in Perth is coordinating the project.

A number of pilot projects are in the early adopter category. The USA is the major financial and scientific contributor to programs that include:

Vietnamese Forecasting System (VFS), a forecasting system for storm surges caused by typhoons in the South China Sea.

PhytoNet Program, a network of laboratories that will coordinate observations of harmful algal blooms.

Coastal Observing System for the Eastern South Pacific Ocean (COSESPO) that will provide now-casts and forecasts of the circulation patterns on the shelf and in the bays and harbours of participating countries.

Brazil has taken the lead role in the Quickly Integrated Joint Observing Team (QUIJOTE) program to monitor and predict changes in the coastal zone of the South Western Atlantic.

Italy is leading the Mediterranean Forecasting System Pilot Project (MFSPP), which is aimed at the prediction of the marine ecosystem variability in the coastal areas in time scales of months to days.

The US Navy and NOAA are jointly funding the port security project, Waterborne Chemical Dispersion Modeling. The study is expected to predict the effects of hazardous material releases into the atmosphere and its collateral effects on civilian and military populations.

European and Japanese port authorities have commissioned a study that includes a review of their surveillance system needs associated with unknown vessel monitoring, ship detection and localization and cargo monitoring.

Thailand's Patong Island is the location of a pilot project to link the Island via satellite to the Nonthaburi-based National Warning Centre.

The availability of observing information that enables government agencies and private sector companies to increase profits, improve operational efficiency, or reduce accidents has seen users in the early adopters/mainstream categories being prepared to pay for observing products and services.

According to US studies undertaken by Pugh and Skinner, improvements in open ocean observation has potential benefits to the shipping industry of \$100 million per year, coastal ocean observations has potential benefits to the tug/barge operators of \$10 million per year and search and rescue operations can

reduce costs by tens of millions (\$) per year in lives saved. There is a growing need and demand by maritime industries for surface wind, waves, currents, visibility and water level information.

In the UK, the Met Office and the Centres for Disease Control and Prevention have teamed up for pilot projects that combine improved meteorological forecasts with health data to improve health care support services and facilities decisions.

Ocean.US research suggests that operations and decisions requiring improved weather, climate and ocean information is just now getting to be understood by data providers. The potential customers are involved in oil and gas exploration, development and production; renewable energy operation; electricity generation, transmission and distribution; financial services; and global management.

Medium to long-term environmental management information describes real-time and climatic statistical data in natural marine environments, including ecological and fisheries information, contaminants and pollutants, public health warnings and facility management of estuaries and coastal zones. Recreational activities associated with boating, fishing and beach use can benefit greatly from coastal ocean information. The tendency of those who benefit most from the information is to rely on regulatory and enforcement authorities to provide the data as a public service. It is a lagging market.

There are exceptions and grey areas in all the market categories. The driver is primarily the need for improved environmental information and the leading financial contributors to OOS initiatives are government-orientated organizations. None of the markets have reached maturity.

1.3 Organisations

The considerable complexity of OOS as a subject is added to by the myriad of organisations involved. The chart below shows some of the inputs and linkages for the GODAE (Global Ocean Data Assimilation Experiment).

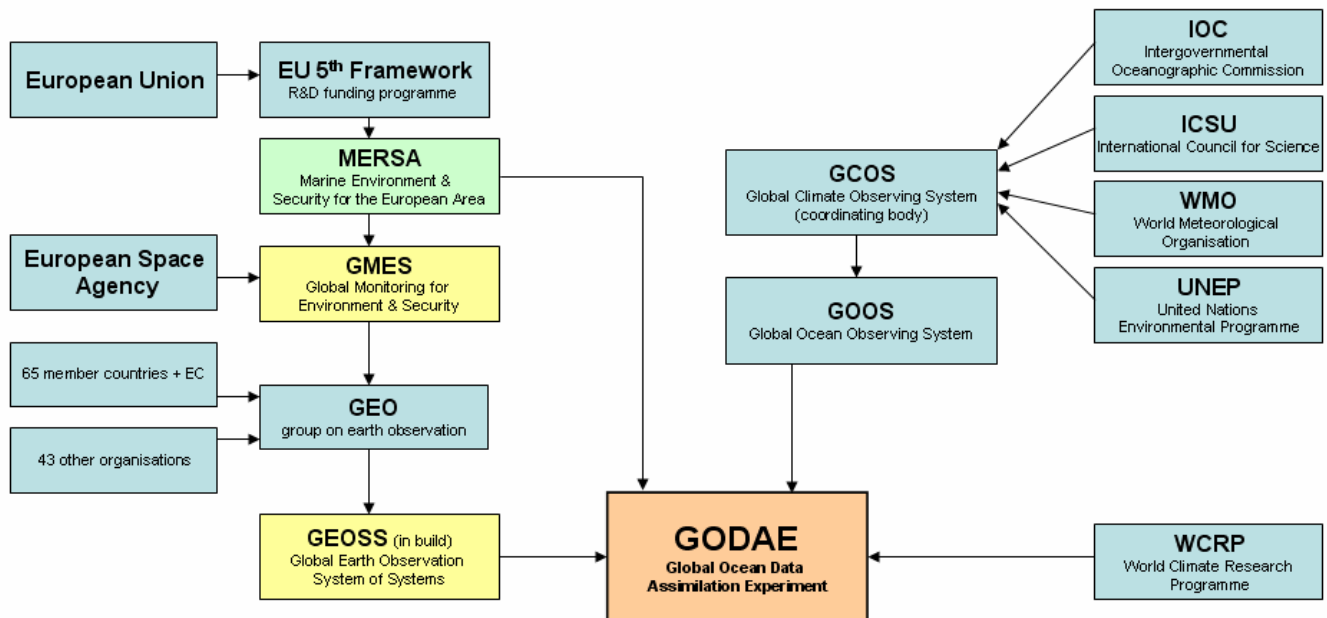


Figure 1-2: GODEA – Inputs and Linkages

The Group on Earth Observations (GEO) includes 64 member countries, the European Commission and 43 other organisations with a vision to construct a Global Earth Observation System of Systems (GEOSS). This is intended to build on and add value to existing (and future) EO systems by co-ordinating efforts, addressing gaps and improving data exchange.

The Global Climate Observing System (GCOS) is a partnership between the Intergovernmental Oceanographic Commission (IOC), World Meteorological Organisation (WMO), the United Nations Environment Programme (UNEP) and the International Council for Science (ICSU). It does not directly make observations itself nor does it generate data products but it supports national requirements framing in the area of climate observations and offers an operational framework for integrating operational systems towards climate issues.

The Global Ocean Observing System (GOOS) is intended to be a permanent global system for observations, modelling and analysis of marine and ocean variables needed to support operational services worldwide. Again, this is a partnership between the IOC, WMO, UNEP and ICSU and is co-ordinated with GCOS.

A further activity of this group is the Global Ocean Data Assimilation Experiment (GODAE), which is designed to demonstrate that it is possible to achieve real-time data assimilation so that a regular complete

depiction of ocean circulation can be created at timescales of a few days at a resolution of a few tens of kilometres. It is a joint GCOS, GOOS and World Climate Research Programme Activity.

1.4 Funding

The funding of OOS programmes is derived from a desire to better understand and manage our ocean resources and its environment. Funding is an area of considerable complexity with frequent changes of budgets. In the overall budget scheme of things, OOS spending has been considered “little science”.

1.4.1 USA

Since 2001, the US Administration’s funding has improved weather forecasting by expanding observations and investing in forecast model improvements. The Ocean and Coastal Observation Act of 2005 directs the National Ocean Research Leadership Council to develop and operate an integrated ocean and coastal observation system. In the President’s Budget for FY ‘07, there is an emphasis on improving weather and climate forecasting to benefit public safety and economic growth.

This is evident in the 2007 Budget, which supports key programs in the National Oceanic and Atmospheric Administration that observe and predict changes in the earth’s environment and manage ocean and coastal resources. The budget includes funding increases for weather forecasting activities, technical assistance to improve tsunami warning capabilities for other nations, increases in the number of advanced technology deep-ocean buoy stations and tsunami inundation mapping, modelling and forecast efforts. A record hurricane season in 2005 and a Southeast Asia’s tsunami in 2004 are major drivers.

Under the President’s Climate Change Research Initiative, the Budget supports continued implementation of the global observing system to improve climate monitoring and forecasts. In the support of the President’s US Ocean Action Plan, the Budget provides for funds to improve management of the US fisheries, with significantly increased funding in the Gulf of Mexico for fisheries research and management programs.

The US ocean and coastal observation system includes the operation and development of an integrated coastal and ocean information system, including ocean monitoring, data analysis, public education and research. The Congressional Budget Office (CBO) estimates that implementation will cost between \$1.8 billion and \$2.2 billion over the 2006-2010 period.

The CBO is quick to point out that “the costs of carrying out the requirements are uncertain because the parameters of the observation system, including public education and research, have not been determined by the National Ocean Research Leadership Council and because it is difficult to predict how many of the necessary programs would be funded and implemented”.

While NOAA is the lead agency, the first baseline budget for an integrated ocean observation system appears in the FY ‘08 budget. The NOAA \$700 million amount for 2007 is a good example of last-minute, single-year funding approval and an indication of the increased awareness in Congress that OOS is important, but most importantly the heightened sensitivity in the US to sea-based aggression.

Historical spending patterns for similar activities suggest the following estimated spending on two levels:

1. Estimated authorized level; and
2. Estimated outlays.

Typically, the authorized spending amounts will be appropriated at the start of a fiscal year, allowing baseline spending projections to closely mirror the authorized amounts. With IOOS still coming of age, much of the funding has started at the regional level and it is just now being rolled up into a larger national IOOS budget item. This is expected to change Congressional representatives perspectives from IOOS being a “little science” to a “big science”.

As IOOS gains recognition and respect from politicians and civil servants, the authorized and outlay spending levels are expected to become more in synch. The following 2006 through 2010 estimated fiscal year projections are shown at both estimated authorized and estimated outlay levels in \$ millions:

2006 – 175/80
 2007 – 325/240
 2008 – 424/390
 2009 – 575/500
 2010 – 675/610

2006-2010 Total \$2.2/1.8 billion

Note: The updated \$38 million in FY ‘07 is because of actual budget slips. OOS is just finding its way into budget jargon and budget functions are moving among defence, science, space & technology, natural resources & environment and transportation. It is a dynamic situation.

The Intergovernmental Oceanographic Commission (IOC) of UNESCO, and the committee for global ocean observing systems, which includes the World Meteorological Organization (WMO), United Nations Environment Programme (UNEP), and the International Council for Science (ICS), provide international co-ordination of OOS funding.

3.4.1 Europe

The IOC also acts as the prime contractor. For the participating EU/EC/EEC donor countries, IOC is the prime for projects such as Argo-GODAE and Pacific-GOOS. It is also the major promoter of new member participation. In Europe, where there are over 430 active floats (or approximately 18% of the global array), the IOC is the lead agency in:

- Providing technical support for data delivered in real time to the Global Telecommunications System of the WMO and to the Internet;
- Establishing regional data centres;
- Securing sustained funding to complete and maintain the array; and
- Co-ordinating research and operational activities related to improving profiling floats.

The International Council for the Exploration of the Sea (ICES) and the IOC have established a steering committee on GOOS (SCGOOS) for the integration of data systems utilized in monitoring North Sea marine ecosystems. There are over 100 participating European environmental and fisheries commissions involved in integrating biological & chemical, fisheries, and physical & chemical data. The annual budget is €3.9 million (\$4.9 million).

The project management and marketing challenges are further exemplified by the roles that member countries' research institutions play in undertaking EU funded OOS projects. The Ferry Box project has equipment on ferries that are operated in the Baltic by the Finnish Institute of Marine Research (FIMR), in the North Sea by the GKSS (grouping of 15 German research organizations), in the Dutch Wadden Sea by

the Netherlands Institute for Sea Research (NIOZ), between Southampton and the Isle of Wight in the Channel, between Oslo and Kiel by the Kiel University and between Oslo and Hirtshals by NIVA (Nordic training centre).

New funding will add ferries in the Mediterranean between Athens and Crete that will be operated by the Hellenic Centre for Marine Research (NCMR), in the Irish Sea by the Proudman Oceanographic Laboratory, in joint co-operation with the Environmental Agency, and in the Gulf of Biscay by the Southampton Oceanographic Centre and the Spanish Institute of Oceanography.

Several EU countries have committed €20 million (\$25 million) to support research, development, and operation of regional early warning systems in the Indian Ocean and Mediterranean Sea. The IOC along with the UN Office for the Co-ordination of Humanitarian Affairs (OCHA), and the UN International Strategy for Disaster Reduction (ISDR), are co-ordinating the program. Approximately 58% of the committed funding is from Germany, Italy, Netherlands, and the UK.

Individual countries also undertake OOS projects that are significant to their nation's economy. With Norway being the world's second largest exporter of fish and fish products, significant contributions to a sustainable management of the marine biological resources are estimated to represent an annual export value of 100-120 billion NOK (\$15-18 billion) by 2020. AMOEBE is a ten year research project of ecosystem observations, which includes the integration of ship, satellite, buoy, aircraft and AUV data. Norway has budgeted 700 million NOK (\$104 million) over the next five years and a total of 1.3 billion NOK (\$193 million) over a ten year period.

While the European Space Agency's (ESA) budget is only 7% of NASA's, environmental research that includes climate change has €1.9 billion (\$2.4 million) earmarked over the next six years. ESA's ocean observing space borne contribution is through the Global Monitoring for Environmental Security (GMES). It is a joint effort of the European Commission and the ESA, with €1,215 million (\$1,526 million) allocated to GMES between 2006 and 2013. Space components represent 55% or €665 million (\$835 million), and services 45% or €550 million (\$690 million) of this total.

1.5 OOS Activity by Application Sector 2001-11

We have identified 110 programmes over the 2001-11 period. In order to assess the significance of each sector, taking the complete ten year period from 2001-11 we have allocated sectors to each 'initiative' we have identified in our research as shown in the table below. (In the case of the major multi-sector programmes, our analysis is based on allocating an equal proportion of expenditure to each sector.)

Table 1-2: Organisations, Programmes & Projects – Number by Sector 2001-11

2001-11	Academic Research	Coastal Zone Utilization	Education	Env. Assessment & Monitoring	Fisheries & Aquaculture	Hazard Warning	Marine Safety & Security	Marine Transportation	Military	Offshore Activities	Recreational	Search & Rescue	Vessel Tracking	Weather & Sea State Prediction	Total applications	Total initiatives	Average no. per initiative
Projects	51	30	32	37	26	21	11	7	5	14	7	11	3	30	285	63	5
Ocean Programs	44	36	34	53	32	29	24	28	12	17	18	25	19	50	421	81	5
Satellite Programs	12	0	2	19	0	6	0	0	1	0	0	0	1	25	66	29	2
Organisations	38	35	33	45	33	35	25	24	15	20	17	21	17	39		66	6
TOTAL	145	101	101	154	91	91	60	59	33	51	42	57	40	144	1169	239	5
Total Programmes																	
OOS N. America	32	19	23	38	18	22	13	18	11	12	17	20	14	40	297	57	5
OOS Europe	14	6	5	20	5	4	8	6	2	4	1	4	5	23	107	36	3
OOS Asia	3	1	1	3	1	3	0	0	0	0	0	0	0	4	16	6	3
OOS Other	7	10	7	11	8	6	3	4	0	1	0	1	1	8	67	11	6
OOS Total	56	36	36	72	32	35	24	28	13	17	18	25	20	75	487	110	4

From this process certain characteristics can be observed:

- most organisations, programmes and projects cover several sectors – typically 5 or 6
- satellite programmes, however, seem to be more sector specific – typically 2
- North American organisations cover many sectors – typically 5
- two sectors dominate – environmental assessment & monitoring and weather & sea state prediction. These are followed by academic (scientific) research.

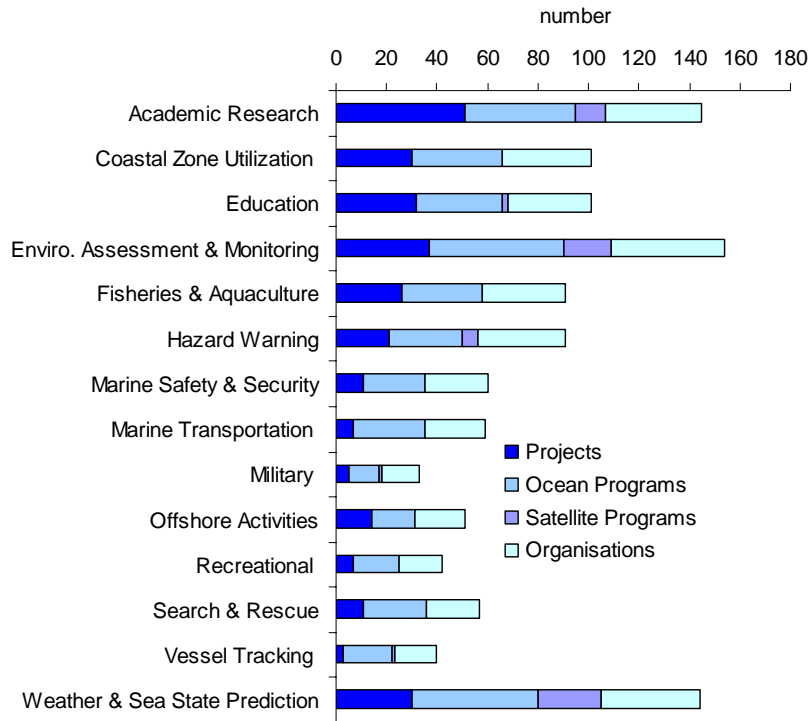
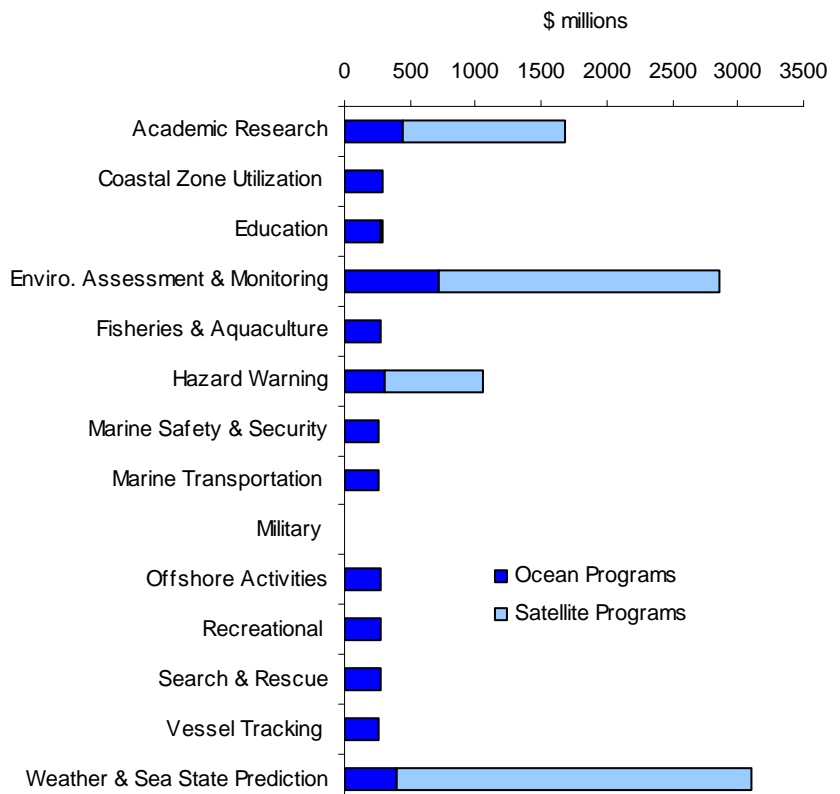


Figure 1-3: OOS Sectors 2001-11 by Activity Number

The chart for the 2001-11 period again shows the relative importance of the academic research, environmental and weather sectors.

Figure 1-4: OOS Sectors 2001-11 by Spend (\$ million)

Satellite-based programmes are the dominant feature of the ‘big four’ sectors. (Projects are excluded from the chart to avoid double counting.)



1.6 Market Size – Identified Programmes

Market by Region

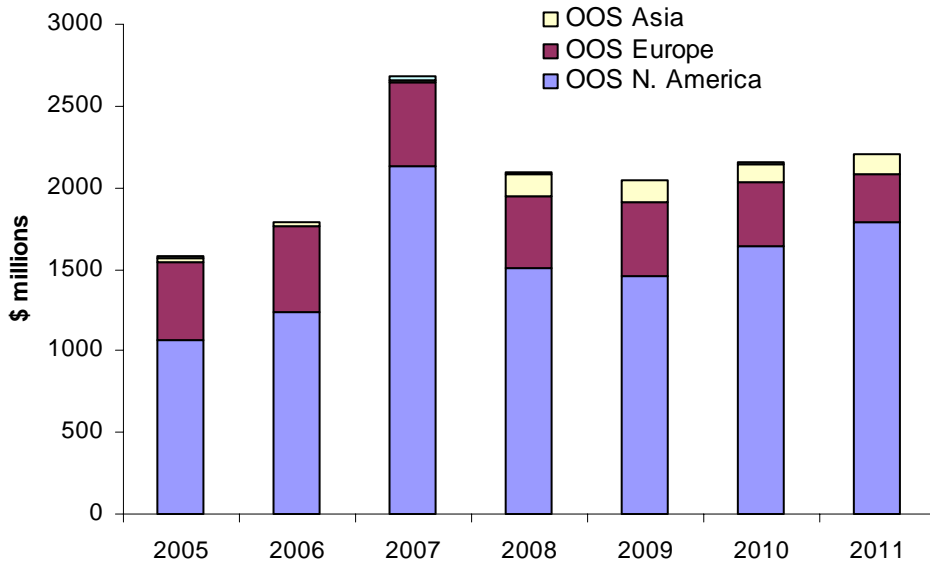


Figure 1-5: OOS Programmes by Region 2005-2011

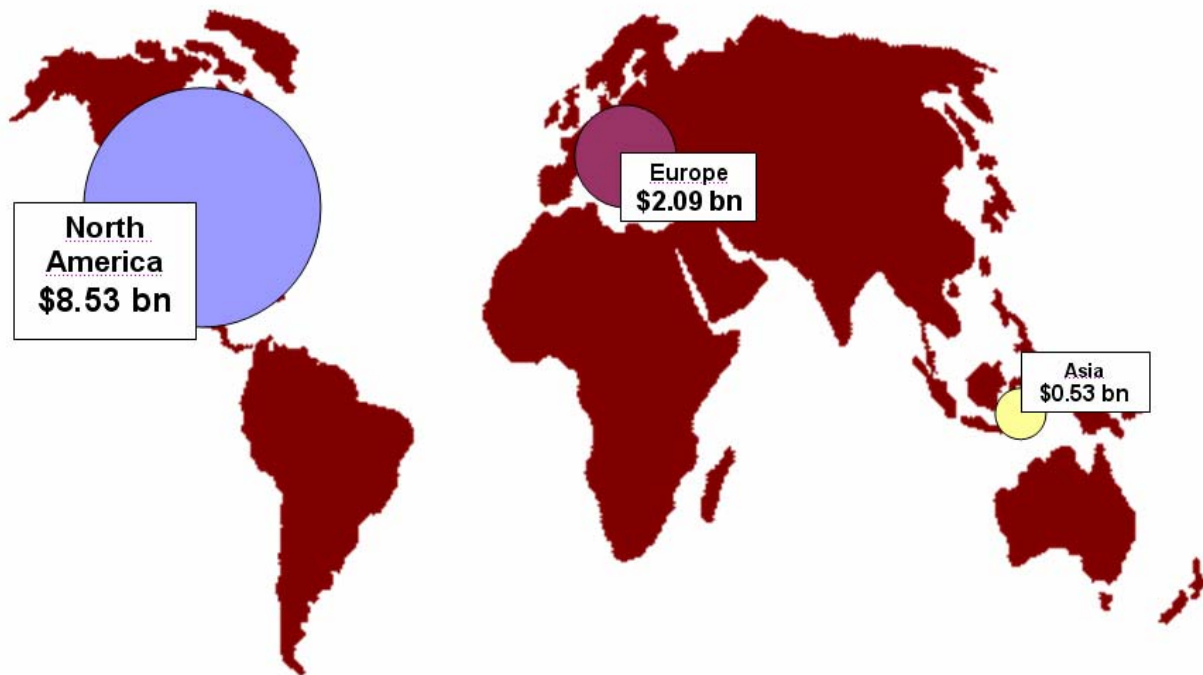


Figure 1-6: OOS Regional Map 2007-11

Table 1-3: OOS Programmes by Region 2005-2011

<i>\$ million</i>	2005	2006	2007	2008	2009	2010	2011	2007-11
N. America	1,063	1,237	2,135	1,501	1,457	1,644	1,788	8,525
Europe	484	527	505	449	449	388	298	2,090
Asia	21	21	21	137	137	117	117	529
Other	13	7	17	0.4	0.4	0.4	0.4	19
Total OOS	1,581	1,792	2,678	2,088	2,044	2,149	2,203	11,162

The market for OOS has been growing strongly. We estimate OOS programmes in 2006 will total some \$1.8 billion, with this *identified* programme spend increasing out to 2011. However, in the light of the strengthening market drivers we would expect actual annual expenditure to grow significantly.

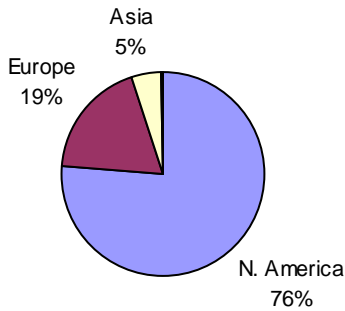


Figure 1-7: OOS Programmes – Regional Segmentation

The US dominates expenditure on identified OOS programmes during the period 2007-2011. Although Europe features in many programmes, its spend is a fraction of that of the US.

It is important that the regional segmentation of projects and programmes relates to the location of the funding body and that significant amounts of the actual spend may be in, or for the benefit of, other regions.

Market by Project Type

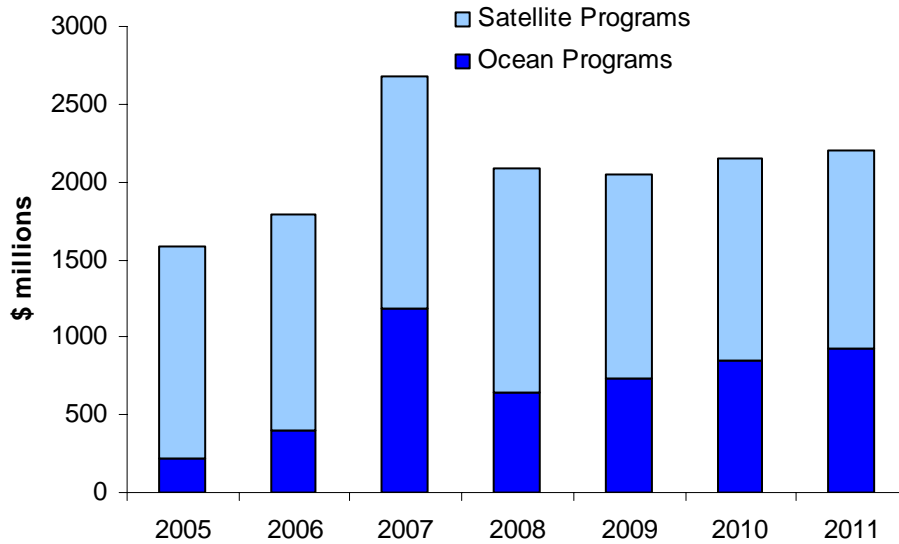


Figure 1-8: OOS Spend by Type 2005-2011

Table 1-4: OOS Spend by Type 2005-2011

<i>\$ million</i>	<i>2005</i>	<i>2006</i>	<i>2007</i>	<i>2008</i>	<i>2009</i>	<i>2010</i>	<i>2011</i>	<i>2007-11</i>
Satellite	1,367	1,390	1,498	1,445	1,311	1,304	1,280	6,839
Ocean	214	402	1,180	643	732	845	924	4,324
Total OOS	1,581	1,792	2,678	2,088	2,044	2,149	2,203	11,162

The market has two main sectors: Ocean-based systems and Satellite-based.

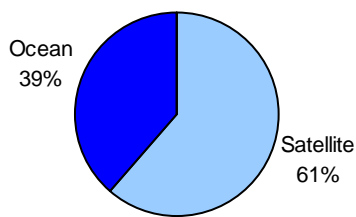


Figure 1-9: OOS Spend by Type

The total expenditure on identified future satellite-based programmes are 50% higher than that of the ocean-based ones.

Note: NOAA spend contains a \$700 million amount for 2007 which is a good example of last-minute, single-year funding approval and an indication of the increased awareness in Congress that OOS is important, but most importantly the heightened sensitivity in the US to sea-based aggression. This can be regarded as a one-time IOOS contribution.

OOS Market by Application Sector 2006

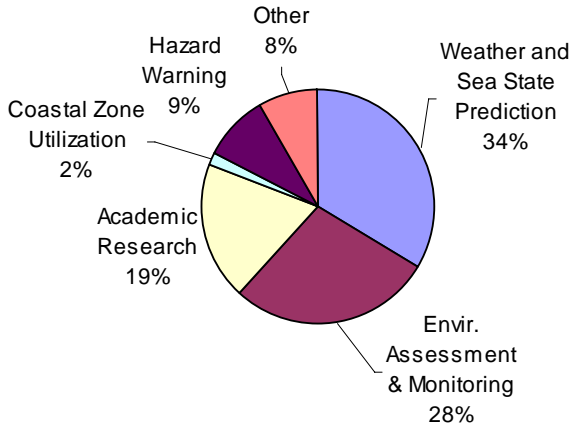


Figure 1-10: 2006 OOS Projects by Application Sector

Our assessment of OOS-related programmes over the period 2001-2011 shows that 90% of expenditure is related to four key activities:

- weather & sea state prediction
- environmental assessment & monitoring
- academic research
- hazard warning.

It is important to note that these four activities are closely interlinked

Table 1-5: 2006 Projects by Application Sector (\$ m)

Application Sector	\$ m 2006	%
Weather and Sea State Prediction	603	34%
Envir. Assessment & Monitoring	502	28%
Academic Research	343	19%
Hazard Warning	164	9%
Coastal Zone Utilization	31	2%
Education	24	1%
Fisheries & Aquaculture	18	1%
Marine Safety & Security	22	1%
Marine Transportation	15	1%
Offshore Activities	22	1%
Recreational	14	1%
Search & Rescue	15	1%
Vessel Tracking	12	1%

Although activity is focused into four main sectors, the other sectors are often direct beneficiaries. For example, all benefit directly from expenditure on activities such as better weather & sea state prediction.

Table 1-6: Organisations, programmes & projects – spend by application sector 2006 (\$ million)

2006	Academic Research	Coastal Zone Utilization	Education	Env. Assessment & Monitoring	Fisheries & Aquaculture	Hazard Warning	Marine Safety & Security	Marine Transportation	Military	Offshore Activities	Recreational	Search & Rescue	Vessel Tracking	Weather & Sea State Prediction	total 2006 (\$ million)
Projects	36	17	13	20	11	8	11	0	54	6	0	5	0	17	198
Ocean Programs	88	31	18	59	18	26	22	15	7	22	14	15	12	55	402
Satellite Programs	255	0	6	442	0	138	0	0	0	0	0	0	0	548	1390
Organisations	762	762	762	777	762	768	777	316	168	322	316	316	316	762	7884
OOS N. America	288	17	17	428	17	155	11	15	7	11	14	15	12	231	1237
OOS Europe	43	13	6	73	0	8	11	0	0	11	0	0	0	362	527
OOS Asia	11	0	0	0	0	0	0	0	0	0	0	0	0	10	21
OOS Other	1	1	1	1	1	1	0	0	0	0	0	0	0	1	7
OOS Total	343	31	24	502	18	164	22	15	7	22	14	15	12	603	1792

OOS Market by Application Sector 2007-11

Table 1-7: Organisations and Programmes 2007-11

	number	\$ million
Total organisations	66	18,778
Total satellite-based programmes	29	6,839
Total ocean-based programmes	81	4,324

Looking over the period 2007-11, we have identified 66 organisations worldwide, involved in funding OOS, spending at total of \$18.8 billion generally. Their specific OOS spending on 110 programmes over the next five years totals over \$11 billion.

The programmes divide into 29 satellite-based, costing \$6.8 billion and 81 ocean-based costing \$4.3 billion.

Table 1-8: Organisations, Programmes & Projects – Spend by Application Sector 2007-11 (\$ million)

2007-11	Academic Research	Coastal Zone Utilization	Education	Env. Assessment & Monitoring	Fisheries & Aquaculture	Hazard Warning	Marine Safety & Security	Marine Transportation	Military	Offshore Activities	Recreational	Search & Rescue	Vessel Tracking	Weather & Sea State Prediction	total 2007-11 (\$ million)
Projects	149	92	32	101	24	16	93	1	174	14	0	13	0	112	821
Ocean Programs	448	295	273	718	273	310	264	255	17	281	269	271	254	395	4,324
Satellite Programs	1227	0	19	2143	0	742	0	0	0	0	0	0	0	2708	6,839
Organisations	1371	1371	1371	1402	1371	1402	1402	1371	828	1402	1371	1371	1371	1371	18,778
OOS N. America	1547	270	270	2481	270	864	253	255	17	271	269	271	254	1233	8,525
OOS Europe	93	22	19	221	0	32	10	0	0	10	0	0	0	1683	2,090
OOS Asia	31	0	0	156	0	156	0	0	0	0	0	0	0	186	529
OOS Other	3	3	3	3	3	1	0	0	0	0	0	0	0	1	19
OOS Total	1674	295	292	2861	273	1052	264	255	17	281	269	271	254	3103	11,162

1.7 Market Forecast

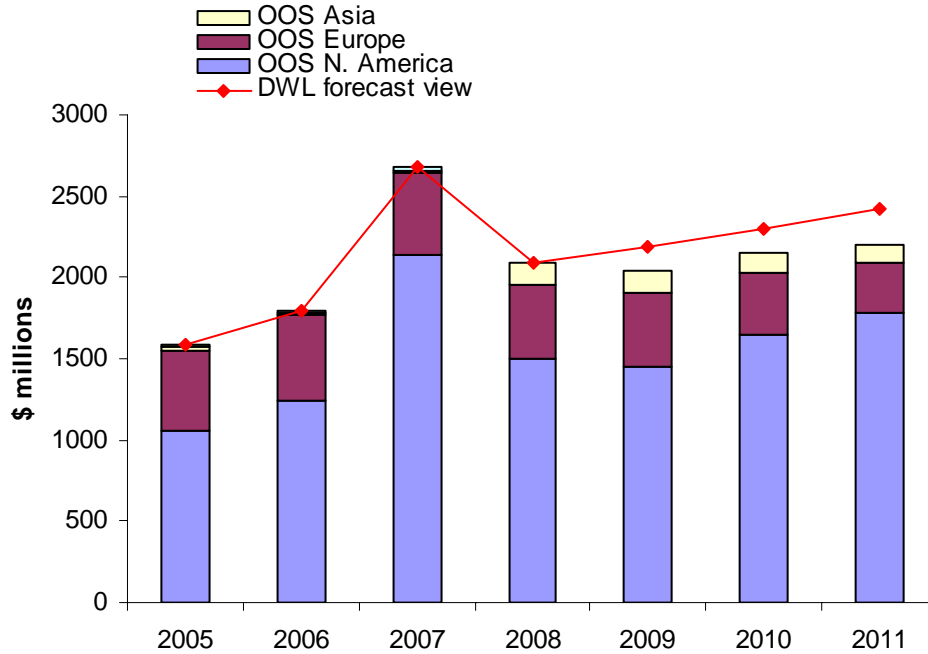


Figure 1-11: Global OOS Market Forecast 2005-11 (\$ million)

Table 1-9: OOS Programmes by Region 2005-2011 (\$ million)

\$ million	2005	2006	2007	2008	2009	2010	2011	2007-11
N. America	1,063	1,237	2,135	1,501	1,457	1,644	1,788	8,525
Europe	484	527	505	449	449	388	298	2,090
Asia	21	21	21	137	137	117	117	529
Other	13	7	17	0.4	0.4	0.4	0.4	19
Total OOS	1,581	1,792	2,678	2,088	2,044	2,149	2,203	11,162
DWL forecast	1,581	1,792	2,678	2,088	2,192	2,302	2,417	11,678

The market has shown good growth and on the basis of currently identified programmes. In 2007, due in part to a one-off US government payment of \$700 million, the market increases substantially and then from 2008 reverts to more predictable levels of spend. As we move beyond 2007 a high level of activity can be identified, but undoubtedly there will be an increasing shortage of information – “data drop”.

However, we are of the view that the market will continue its growth for a number of reasons:

- An increasing international response to global warming resulting in additional investment, particularly in the environmental and metrological sectors
- Requirements for increased expenditure on both operations and maintenance of systems – this later point was also raised by interviewees in our survey.
- Strong growth of the underlying user industries – in particular offshore energy, shipping, coastal zone activity, security, hazard warning, etc.

We have therefore applied an annual 5% increase to the known programmes spend to account for these factors over the period 2008-11. This may in time prove to be too conservative. Therefore, for the above reasons, it is safe to say that the market is not likely to be saturated during the forecast period. Instead, funding is believed to be sustainable during the forecast period and for some considerable time after.

2 Interviews

2.1 Introduction

An original listing was drawn up of 170 potential interviewees. Of these, 56 in-depth interviews were ultimately carried out worldwide over the period May-June 2006, most via the telephone and a few by email. Due to the very wide range of bodies involved in OOS, organisations were chosen to span the many interest and funding groups. These ranged from NOAA to a Marine Warfare Centre, from Marine Laboratories to the Dubai Municipality and from commercial service providers to individual equipment manufacturers.

The individuals interviewed were mainly of senior executive level, with job titles ranging from Chairman and CEO to board members of international ocean-related organisations. At practical working level examples of job titles included Project Manager and Senior Advisor Tsunami Unit (IOC).

2.2 Results

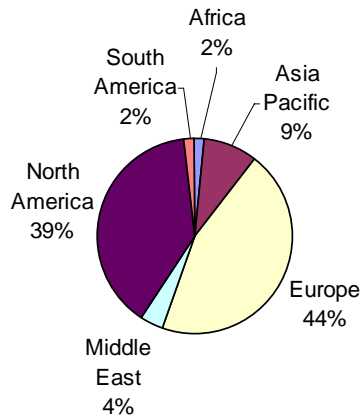


Figure 2-1: Interviewees by Region

The largest proportion of interviews by country were the USA 30% and UK 27%, the rest of Europe accounted for a further 15% followed by Canada at 9%.

The main focus was the two primary markets (funding sources) for systems providers, North America and Europe, then Asia Pacific. Samples were also taken from other regions.

Table 2-1: Interviewees by Country

Country	Region	Interviews	%
Australia	AU	1	2%
Canada	NA	5	9%
Canary Islands	E	1	2%
China	AP	1	2%
Dubai	ME	1	2%
Ecuador	SA	1	2%
Finland	E	1	2%
France	E	3	5%
Germany	E	1	2%
Japan	AP	1	2%
Netherlands	E	2	4%
New Zealand	AU	1	2%
Norway	E	2	4%
Pacific Islands	AP	1	2%
Tanzania	AF	1	2%
Turkey	ME	1	2%
UK	E	15	27%
USA	NA	17	30%
Total		56	100%

<i>Activity</i>	<i>Number</i>	<i>%</i>
Research	28	50%
Equip. & services supplier	20	36%
Forecasting	4	7%
Coastal management	2	4%
Learned society	1	2%
Oil company	1	2%
Total	56	100%

Table 2-2: Interviewee Organisations by Type

The majority of the interviews were concentrated amongst the suppliers of products and services to the OOS community and their customer base – the research organisations. Sample interviews were also held with major users such as forecasters and oil major.

2.3 Responsibilities and Involvement

1. What is your personal involvement with ocean observing systems?

The interviewees spanned the subject area of OOS.

2. What are your current responsibilities relating to ocean observing systems within your organization?

Responsibilities ranged from management of global programmes to coordination of regional OOS programmes, from direction of a number of scientific groups to management of an Antarctic project team.

Interviewees' decision-making status on a self-scored scale of 1-10 (10 being high) averaged 7.5.

3. How would you describe your company/organization's role with regards to ocean observing systems:

50% were engaged in some aspect of research – from inter-agency organisations to scientific and applied research. Their suppliers included both product manufacturers (e.g. oceanographic instrumentation) and service providers.

4. Is your company/organization involved in the maintenance of ocean observing systems? Yes/No

Ten of the organisations interviewed currently maintained an OOS of some type.

5. Is your company/involved in:

<i>Activity</i>	<i>#</i>	<i>%</i>
National initiatives	38	68%
International activities	40	71%
Regional activities	26	46%
National & international partnerships	20	36%
Cooperatives between industry and academia	21	38%

Most organisations were involved in both national and international activities and to a lesser extent regional. There were also significant partnerships and cooperatives between industry and academia.

6. Which application areas would you identify that you are involved with and how:

Many of the organisations had a wide span of activities across the application sectors which is a typical ocean technology profile. As identified earlier, research into specific sectors formed the largest activity and in many instances this covered multiple applications.

7. What are the key parameters measured in the systems you are involved in? e.g. Meteorological, environmental, etc

Most interviewees were interested in gathering a very wide range of data on core variables. There were very few instances of requirements to measure a single parameter.

8. Of the parameters measured – what are the objectives of capturing such data and who are the users?

<i>Objectives / users</i>	<i>Total</i>	
ocean data & models	19	The largest grouping of interviewees was involved in ocean data & models, or the weather / climate area. However, in practice it can be very difficult to separate the areas. A direct output can be hazard warning.
weather & climate	11	
hydrographic	4	The major segmentation is between the above and the specific applications shown alongside, ranging from hydrographic charting to design of structures for the offshore oil & gas and renewable energy sectors.
environmental impact	3	
hazard warning	3	
structure design	3	
fisheries	2	
aggregates extraction	1	The overall picture is of great volumes of data being gathered and being made available either direct or via the results from, say, weather models.
coastal zone management	1	
military	1	
renewable energy	1	
space research	1	The main beneficiary of OOS is society in general who has little knowledge of its existence.
others / not applicable	6	
total	56	

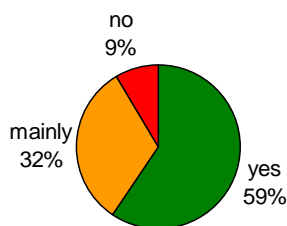
9. Which ocean observing projects or programmes do you have involvement in (now and in the past)?

(Results have been incorporated into the earlier analysis.)

10. For these projects and programmes, what is the annual capital and operational budgets & duration.

(Results have been incorporated into the earlier analysis.)

11. *In current projects you are involved in– do systems perform to specification, or is there room for improvement (in technology, maintenance, etc.)?*



Interviewees stated that in the main, systems had performed to specification. However, many felt that there was considerable room for improvement.

Specific comments from interviewees follow:

- “Systems generally perform to spec in short term; longer term maintenance reliability is yet to be determined and issues will arise.”
- “NEPTUNE will be the world’s 1st regional cabled observatory and as such there are many innovative, developmental aspects, but there is also some deployment of traditional sensors; there will be abundant opportunity for technological, scientific and data management development.”
- “Need systems that cost less to install and maintain.”
- “In general, technology and sensors are extremely expensive. Need to be more work in development of less expensive kit that would allow for multiple sensor deployments at a reasonable cost as opposed to the current scenario where the cost is very limiting.”
- “Huge room for improvement but this is difficult given the remoteness and the training of the people involved in the project.”
- “Building up GOOS in the Black Sea, hoping to deploy more sensors. Better transfer of data from sensor in real time using GSM and satellites.”
- “Improved sensors to measure biogeochemical variables in sustained way. Improved system longevity. Reduced drift. Reduced power consumption.”
- “All oceanographic systems need improvement due to low volume manufacturing.”
- “We do need additional funding for maintenance. Many of the current programs are earmarked and there is no clear indication that systems deployed will actually be maintained in the future.”
- “Always room for improvement in image quality and precision.”
- “Currently perform to spec, but as technology progresses, the specs and instrumentation adapt and improve.”

12. *In previous projects you have been involved in – did systems perform to specification, or was there room for improvement (in technology, maintenance etc)?*

Responses were similar to question 11 above.

13. *Are there future development phases planned for any of the projects/programmes you are involved in?*

(Note: Regional Associations are where the operational funding will flow to, particularly in the US.)

A number of the projects have future phases – these have been taken into account in our market modelling shown earlier. This question also raised some relevant comments:

“Ongoing on several fronts; key aspect is to find better ways of integrating data.” (Shell – Netherlands)

“Our focus is to exploit data, now getting to stage where we have lots of data and now need to model, package and market it.” National Centre for Ocean Forecasting – UK)

“CeNCOOS hopes to become the main data portal for the entire region while providing funds for the development of an operational system. We are in the process of developing a business plan to the criteria of the national IOOS.” (CeNCOOS – US)

“Once GOOS and other projects are put in place, funding is vital for long-term maintenance. Ongoing improvements are incorporated. For weather forecasting, it is important that measurements are taken over the long-term. Expensive projects, e.g. GMES, has around 25 satellites in orbit just for ocean observing. They last about 10 years before sensors decay or propellant runs out.” (Ocean Numerics – UK)

14. *What system infrastructure and technologies are used in these programmes/projects?*

Responses are best summed up by one interviewee’s words – “Lots”.

15. *Who are the principal financing organizations for your ocean observation systems and how easy was it to get funding?*

The predominant funding source is national governments, channelled through various federal and specific agencies. Funding is reported to be very difficult to obtain by interviewees worldwide:

- “Took one and a half years to get funding. Extremely arduous, frustrating exercise” (Canada)
- “The government people need lots of convincing that coastal management is important” (Dubai)
- “Frustrating, but usually forthcoming, particularly when there are issues such as the recent sudden influx of refugees from Africa” (Spain)
- “Highly political issue, challenge is to get long-term sustained funding. In the UK, for example, almost all govt. departments have a say in OOS issues Simpler in the US were federal system is in place and most funding is from NOAA” (UK)
- However, one did note that it was “not too difficult with a well thought out business plan”.

16. *How would you rank your influence in the process of decision making regarding ocean observing solutions within your organization ranking from 1-10 (1= low, 10 = high)*

The average was 7.5

2.4 OOS Technology – now & the future

17. *In your view, what kind of technology will be required and developed in the coming years?*

The many responses we received to this question form a ‘technology users wish list’ and can be grouped into five areas:

- **Costs & Reliability** – low cost, reliable, long-life instrumentation and systems requiring minimum intervention is highest on the users listing of requirements. Some of the problems identified are quite basic, such as the need to dramatically reduce biofouling. Others reflect the relatively low sales of some specialist ocean instruments and their resultant high costs. There is a need to balance the needs for long life and high cost against shorter life and very low cost (e.g. disposable instruments). This cost v reliability theme follows through into buoys and mooring systems.
- **Systems & Platforms** – again cost features highly as a fundamental driver. Autonomous platforms underwater, surface and airborne are seen as the way ahead by many interviewees. They also feature strongly in requirements for arctic data gathering.
- **Sensors** – apart from the general subject of costs and reliability, the greatest individual need is for the development of chemical and biosensors.
- **Data Transmission, Management & Computing** – there is a perceived need for improvements in all aspects of these areas.
- **Space Systems** – further development of sensors is identified as a particular need.

<i>mentions</i>	<i>item</i>
19	Costs & Reliability
9	Reliable, long duration sensors, (downloading, biofouling, memory, power, throw-away?)
3	Cheaper buoys, antifouling, harsh environment
15	Systems & Platforms
3	Arctic data gathering (AUVs, satellites, under-ice systems, photo multipliers)
3	Underwater gliders
2	Need cheaper ship time (or low cost alternative)
1	Remote sensing of seabed resource
1	Airborne systems capable of long flights over ocean
1	Access to ferries to install equipment
1	AUVs and remotely controlled data collection, recording & transmission of data to shore
1	Gridded network of climate observation systems
1	A series of observing instruments need to be strategically placed along the entire coastline
1	More autonomous measurements (currently developing in co-op with NASA)
15	Sensors
7	Chemical and bio sensors
3	Better acoustic telemetry (deepwater, long life batteries)
1	Synthetic aperture systems for radar
1	More robust sensors; buoys capable of withstanding harsh environments
1	Better sources of robust, remote power
1	Most important is HF radar. IOOS interested in implementing along all US coastlines
1	Cheaper longer lasting moorings, more vandal proof, more resources for a world wide array
14	Data transmission, management & computing
5	Near real time data assimilation, data management, computing and modelling
2	Common data handling & dissemination standards
1	Integration of ground and satellite data
1	Better networking of telemetry and communications systems
1	Public hazard warning systems
1	Faster, more powerful computing and data analysis tools
1	Better communications to enable real-time updates
1	Processing power of different real time applications
1	More powerful computing, software development
8	Space Systems
5	Spaceborne sensors: high resolution altimeters, salinity sensors, GPS reflections. move down
1	Improved satellite life expectancy
1	Improved satellite imagery
1	Satellite observations of marine mammals, so that military exercises can take place

18. What factors and situations are driving the development of the industry?

<i>driver</i>	<i>mentions</i>	<i>%</i>	
environmental	30	37%	Interviewees regard environmental issues as the key market driver. This is believed to be associated with the increasing public awareness of the issues of global warming and climate change and the role of the oceans in this subject. The resultant political response is manifesting itself in funding for OOS projects. The other distinct environmental area is pollution monitoring.
commercial	17	21%	
legal / regulatory	11	13%	
tsunami warning	5	6%	
offshore energy	4	5%	
scientific research	3	4%	
funding	2	2%	
military / security	2	2%	
safety	2	2%	
developing world	1	1%	
coastal defence	1	1%	Commercial factors are of course of great importance, from the fundamental need for profits to cost reduction to servicing equity financing.
IOOS	1	1%	
politics	1	1%	
technology	1	1%	Many factors combine to result in increasing regulations that must be met, from corporate safety to environmental law.
	82	100%	

We were surprised that tsunami warning received such a low score but perhaps a public survey would have produced more.

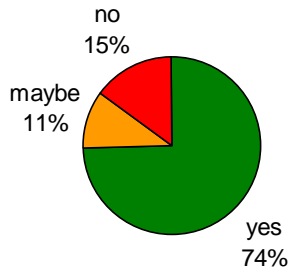
19. What improvements or developments do you feel are required to support the integration of space-based and in-situ observations?

This is acknowledged by many as “A very important point and a core issue at international level. US-based Lockheed Martin has won huge ICT contract from NOAA as one of two companies to proceed with conceptual designs for the Integrated Ocean Observing System (IOOS).”

The subject is complex and respondents note many factors in play, including:

- the need for cooperation between the different agencies and organisations
- more cooperation between the two communities
- funding for research and implementation, including the development of coupled models
- free or cheap access to data
- open sourced data storage and retrieval to better support the concept of ‘collect data once, use many times’
- technical problems, ranging from low data rates to low resolution satellite sensors
- better data transmission
- National standard or a governing body to implement standards and approved methods/technologies for data integration.

20. Are a set of ocean observing system standards needed? Yes/No
If yes, what form would they take and include?



There is very strong support (74% of 47 interviewees who responded) for the establishment of OOS standards. Other views were:

“The oceanographic industry has been slow in developing standards; it’s our “Achilles heel”.

“We adhere to clients’ specifications but it would be useful for industry to have common, baseline standards.”

“Cookie cutter ocean observation model or package would be a mistake. Better information must reflect the

information requirements of each user. Everyone everywhere does not have the same issues or requirements.”

“It is probably too early to do this effectively. In 2-3 years, there may be the basis in experience and a need for this. If and when this occurs, the form of the standards should be based on science and engineering using the ISO approach, or equivalent.”

What form would they take and include?

This second part of the question produced a wide range of comments:

- “Possibly along the line of WMO instrument specifications, but for the ocean.”
- “Internet-based communications (Ethernet connectivity).”
- “Guidelines are needed on issues such as remote sensing, measurement taking and interfacing techniques. Better integration of equipments and data collection also important.”
- “Should be flexible to ensure potential systems are developed and if they do meet the standard, they are supported and encouraged to do so.”
- “Setting standards too high initially is not going to have a positive impact on the development of observation systems.”
- “Environmental standards, equipment specs, HSE, decommissioning of sites.”
- “DMAC certification of the RAs should be attained.”
- “Buoy and in-situ instruments should be standardized in terms of stability, robustness and even the parameters they measure”
- “There is a need for cross-project and intra-national quality assurance of data gathering. Need to get unified calibration of equipment.”
- “Standards were discussed pre-Clivar through the World Ocean Exploration Experiment (WOCE)”.
- “Standards are needed in both taking observations and forecasting.”
- “ISO has some, but lack of integration around the world suggests better, clearer standards are needed.”
- “For ocean colour community we use the NASA inspired SeaWiFS protocols developed in 1997. For water samples, also use JGOF protocols. Also, use round robin EU experiments to standardize chlorophyll readings.”
- “We use GOOS standards for tide work and a range of other internationally recognised standards.”

- “The GOOS standards are good for tide gauges. As a United Nations (UNESCO) group the GOOS standards are international and should be used more frequently.”
- “Standards must keep changing and be kept up to date. Setting standards can prevent the use of new, more sensitive technology which is too advanced to be used. Standards must be appropriate to the prevailing time and measurement accuracy.”
- “NOAA will be the lead. Minimum Wind Speed/direction, Air Temperature, Barometric Pressure Sea Temperature at one meter, Current Speed and Direction via Profiler-Salinity, then expand systems to include optics and water quality monitoring.”
- “Standards for QA/QC. This is being headed by the QARTOD group. Standards should be developed for calibration (methods & frequency). This might be enforced by the notion of an IOOS certification requirement. IT standards for the cyber infrastructure should flow from DMAC. In all areas, attention should be given to international standards.”
- “Data standards (should include), collaborative collection, met data, baseline, coordinated expectations and parameters and user and collection guidelines.”
- “Data for transmission and assimilation. Interoperability standards for moving to multi-use and modularity.”
- “Standard formats for data transfer and archiving.”
- “There are several standards already. If anything, a single standard could be chosen from existing ones.”

21. *In your experience of ocean observing systems, what improvements are required for:*

Again, it is the basics that are still in need of improvement “Improved reliability requires improved corrosion and bio-fouling control and maintaining very long calibration accuracies.”

<i>mentions</i>	<i>item</i>
	<i>a. sensors on surface buoys</i>
6	Better anti-fouling products
4	Better telemetry and data transmission
5	Improved sensors for nutrients and biological characteristics
3	Reliability and robustness must be increased to reduce maintenance costs
2	Corrosion resistance / salt accretion
2	Reliability, reducing meantime between failures
1	Maintaining very long calibration accuracies
1	Easier, less frequent maintenance
1	Better links between different technologies
1	Effective warning to fishermen that a buoy is nearby
1	Lower power
1	Longer battery life
1	For all in-situ sensors, better global sampling.
1	Coastal zone sensors, e.g. acoustic to measure fish and marine mammal properties.
1	Compatibility with other systems
1	Increased quality
1	Lower cost
	<i>b. Meteorological data gathering</i>
1	Better co-operation between different agencies, for example the UK’s Met Office and the EU
1	Real time data
1	Better satellite telemetry
	<i>c. Coastal zone observations</i>
1	Development of cabled ocean observatories will revolutionize the ocean sciences
1	Cheaper, better, more reliable
1	Near real time data acquisition of air-sea interactions
	<i>d. Oceanographic sensors for subsurface moorings</i>
1	Development of cabled ocean observatories will revolutionize the ocean sciences
1	Mechanical profiling platforms for operating sensors need to be made more reliable over long-term operational periods of many years
1	Biological sensors

22. What would you view as the impediments to progress in ocean observing?

“Government awareness, a lot of my time is taken up with making presentations to government to educate them in why we need to invest in coastal management schemes.”

“Political sluggishness is the problem, not the lack of funds. The money is there but with the huge diversity of personal, researcher, politicians and government personnel, etc. having an interest in the sector, it’s difficult to push ahead. It’s in the interest of all to have more transparency and a greater flow of data and information would help.”

The main issues raised are the difficulty in accessing long-term funding (and trained people) which is put down to a lack of government and public awareness of the issues and benefits of OOS. However, some interviewees note the beginnings of improvement following the Asian tsunami.

<i>mentions</i>	<i>item</i>
25	Access to stable long-term funding
13	Lack of government awareness of the significant benefits of observational and operational oceanography.
6	Lack of good personnel. Not enough scientists going through universities to support long-term development of industry.
4	Lack of public appreciation of the issues of climate change and loss of biodiversity.
3	Lack of recognition by the powers of the real cost of working in the ocean environment.
2	Lack of co-ordination between countries and those donating money and expertise.
2	Educating users to know what data and information is/would be available.
2	Lack of research vessels / costs of using very high.
2	Forgetting to update and maintain equipment.
2	Oceanography is a vibrant sector and money is more available now than in the past.
1	Too many demonstration projects, very few operational applications.
1	Vandalism
1	Lack of translation from science to products that benefit society.
1	Government is becoming more interested slowly
1	There is good co-operation between oil companies but not between different parts of the oceanographic sector.
1	Commercial restrictions that prevent companies working together too closely. While market is growing it is currently quite small and very competitive. Better sharing of data and technology.
1	Until UK government admits that there is a problem, the issue will remain one of interest more to academia than the commercial world, who are needed to invest in finding solutions.
1	The Asian Tsunami has raised the profile of the sector.
1	Do not sit comfortably in (UK) government as there is no obvious home for them, different departments are not always working together. The national meteorological programmes is dispersed in different departments.
1	Getting enough equipment onto Royal Naval vessels.
1	Lack of co-ordination between academics in presenting data.
1	Our project is well funded and government has good idea of why we are doing it. The project is used in many graduate and post graduate projects.
1	Government -commercial partnerships and transition from research to commercialization.

23. *What new solutions/technology do you expect the industry to deliver in the future (looking over the next five to ten years)?*

Many items were listed but the ‘top-ten’ were as follows:

<i>mentions</i>	<i>item</i>
5	Chemical & biological sensors - cheaper, better, more reliable
5	Better data communications, underwater, satellite, in situ at lower costs.
5	Data fusion and assimilation in powerful 3D models.
4	Better batteries / power delivery,
3	Autonomous vehicles (surface and underwater)
3	Gliders - already capable of gathering huge amounts of data over a long period of time.
2	Low power-demand sensors,
2	Cheap sensors’ for multiple deployments.
2	Synthetic aperture radar
2	Better anti-fouling technology,

24. *What other developments would you like to see happening in the future?*

Systems

Integration of OOS systems themselves with existing regional environmental monitoring systems, such as satellite-based remote sensing and regional numerical modelling capabilities to provide the basis for an ocean prediction system on tactical time frames of days to weeks.

A network of densely spaced 3D grids to measure parameters such as temperature, salinity.

Address the lack of 3D coverage of ocean from satellites.

Adopt a global approach.

Investment in infrastructure for plug-and-play building blocks to construct decision support tools.

More user friendly technology.

Organisation

Better coordination for lobbying, less fragmentation in the industry and less inter-sectoral turf protection.

More scientific co-operation with developing countries, including sharing data and improving capacities.

Extension for SMART Bay into a large northwest Atlantic initiative.

Increased funding and effort put into education of the next generation of oceanographers. (NOC does this well, needs supporting.)

Real investment in education associated with OOS.

More awareness and education efforts.

NOAA-NASA project co-ordination.

Sensors & Hardware

Better resolution from satellites to be able to see tens of metres below the surface.

Higher frequency radars.

Better quality control of data.

More efficient in-field testing.

Non-toxic antifouling capabilities.

Technologies for monitoring ocean microseisms.

The use of GPS reflections for monitoring the ocean mesoscale.

Inexpensive wireless or fibre optic u/w communications.

Improved u/w acoustic modem technology.

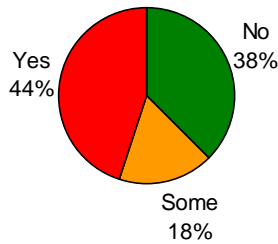
Inexpensive underwater navigation systems.
Smaller sensors used to acquire the same data.
Improvements in telemetry to get data back in real-time and to enable collection of long-term series data.
In situ mooring opportunities limited for AUVs.

Data & computing

Better data communications.
Better archiving – particularly of metadata. Our metadata archive has over 200 fields. We have worked hard to archive this information which can then be used in subsequent studies to ensure historical consistency.
Communications controller that allows GOES/ARGOS/Freewave Inmarsat...
Better software tool kits for building tools for resource managers and emergency responders. The tool kits should too easy to adapt to aggregate various data sets for specific purposes.

2.5 Canadian OOS Industry

25. Do you, or your organization, have experience of Canadian companies in this sector?



region	no	some	yes	total
Africa	1			1
Asia Pacific	3	1	1	5
Europe	7	3	13	23
Middle East	1	1	0	2
USA	3	2	4	9
total	15	7	18	40

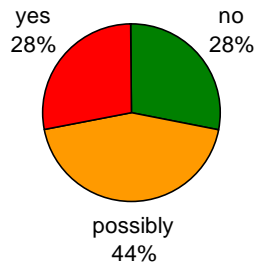
40 of the 56 interviewees were able to respond to this question and their experience was reasonably balanced between those who have experience and those who do not.

The results cannot claim to have a sound statistical basis due to the small sample size and the number of non-responses (senior people or organisations who are not involved in direct contact with commercial companies?).

However, it is interesting to note the comparatively high score of “yes” within Europe, perhaps due to the combination of oceanographic, hydrographic and oil & offshore oil & gas sector activity that has traditionally used some Canadian leading edge products (e.g. submersibles, scanning sonars, etc.) and perhaps also the strong presence of Canadian companies at the ‘Oceanology International’ event held in the UK for many years.

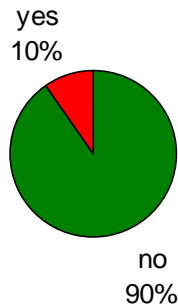
- “Canada is a major player in sector with many scientists active in the field. Lots of commercial companies.” (France)
- “Canadian partners and network contacts in Halifax and Edmonton.” (France)
- “Yes, have worked with ASL on ice observations. Lots of ice experts are Canadian and several have worked on Shell’s Sakhalin development. ISO ice observation standards are being developed a group with several Canadians.” (UK)
- “Use some Canadian instrumentations, optics are particularly good. Have had contact in past with Canadian Space Agency.” (UK)
- “Use some small tri-axis instruments made in Canada.” (UK)
- “Yes, we are currently trialling equipment supplied by British Columbia, Canada-based TRIAXYS, surface wave measurement tool.” (UK)
- “Yes, worked a lot with Canadian software developers, but they were not specialist marine companies. Canada is well represented in spatial information software developers/ open source software development.” (UK)
- “Previously in contact with Canadian Centre for Marine Communications, who has responsibility for networking and promoting Canadian companies, particularly east coast companies.” (UK)
- “Not personally, but Canadian military personnel do attend the Centre.” (UK)
- “Some now, but future looks more encouraging. Now have a Marine Environmental Data Service member on the committee.” (US)

26. Are you able to identify any potential collaborations with, or opportunities for, Canadian industry?



In this case 39 respondents views were fairly evenly balanced (we regard the 17 non-respondents as ‘don’t knows’) between ‘yes’ and ‘no’. Perhaps of greater interest is the market potential to convert the larger number falling within the ‘possibly’ category to ‘yes’.

- “Already work with ocean modelling companies, but always opportunities for more.” (France)
 - “We work with several Canadian companies including Fugro Canada and the military authorities. **Better and more co-operative to work with than the Americans.**” (UK)
 - “Hoskin Scientific is our Canadian distributor.” (UK)
 - “We are already in touch with Canadian suppliers” (UK)
 - “**Would like to work with Canadians.** A colleague is attending a conference in Vancouver to present a paper about the plans of Proudman. We are interested in what the US and Canada are doing with deploying cables to get power to the sensors and to transmit data back. But this is expensive.” (UK)
 - “**Would be very keen to work with Canadian companies.** We have been so busy with the booming oil and gas sector that we have had no time to develop Canadian market.” (UK)
 - “Interested in source of sensors to support ultra-stable water level measurements. **Canada has strong academic programs** in GPS geodesy at U. Calgary, which is important for sea-level studies.” (US)
 - “Work on operational level with government agencies such as Environment Canada.” (UK)
 - “Yes. In particular since Canadian waters are upstream of Alaska’s. Of particular interest to coastal currents and fish/marine mammal migrations.” (US)
 - “Worked with Canadian Hydrographic office, Memorial University of St Johns, University of New Brunswick among others.” (Norway)
 - “Have worked with several companies, but US dominates the North American sector. US government heavily supports its SMEs in this sector – very targeted approach. US has one point of contact the NOAA. This manages scientific R&D and operations. However, NOAA is run by the commercially led Dept of Commerce which has remit to boost business. In Europe, responsibility is split between several, often competing departments.” (UK)
 - “Worked on small projects in Caribbean with Canadian scientists. MES works mostly in UK. Would work with Canadians if offered, but would they want to work with UK companies, not sure that they would.” (UK)
 - “Perhaps, as the Baltic Sea is similar to offshore Canadian environment.” (Germany)
 - “Possibly, we usually work with US or European companies and organisations. Canada seems remote to us.” (Australia)
 - “No / no knowledge of Canada, but always interested in learning more.” (Dubai, Finland, Japan, Norway, Turkey)
 - “Have some Canada-based companies as members including Petro-Canada.” (UK)
 - “Not immediately. We work with NASA and Australian academics on ocean colour research. (UK)
 - “Not immediately – we are focused on the tropics whereas Canada is more focused on colder waters and the Arctic.” (US)
 - “No, but Canada is a major donor to the project.” (France)
27. *Are there any factors that may limit your organization’s ability to work with Canadian companies? (location, policy, etc)*



90% of those able to answer saw no restrictions to working with Canadian companies. In the case of those that did, two related to a lack of knowledge about their organisation’s policy towards purchasing foreign goods & services (see comments below). It is of note that these ‘policy issues’ were raised by US organisations!

2.6 Any Other Comments

28. *Is there any issue that you would like to raise?*

- “Would benefit companies such as ours if there was a way of integrating oceanographic data from around the world in a single place so would be easier and cheaper to access.” (Finland)
- “We are scientists and are often approached by middle men, particularly in Middle East, to do projects. They want too much money and no risk. We would only work with reputable companies. While we do make money, we are also very interested in marine science. Have worked with government agencies in India, Australia, Malaysia and elsewhere.” (UK)
- “Would like copy of report.” (UK)
- “We are working with the military on AUVs which hopefully will find civilian uses.” (UK)

3 Weather and Sea State Prediction

3.1 Introduction

Maritime operations benefit from accurate weather forecasts leading to safer, more efficient operations and potentially enormous cost savings. In addition to state or national meteorological agencies, a number of companies provide marine weather forecasting services. This can range from initial consultation for project planning to real-time forecasting dependant on the end-user requirements. It is also important to note that land weather forecasting is dependant upon observation and modelling of ocean weather systems.

Data sources for weather and sea state prediction may include the following:

- Altimeter data from satellites (indicating high and low pressure)
- Sea surface temperature from satellite or in-situ sensors
- River discharges
- Salinity and temperature profiles (including those from below 1,000m)
- Voluntary observing ships XBT data
- Sea ice observations (thickness and location)
- Bathymetric data for the ocean basin
- Wave data from HF radar and data buoys
- Coastal and onshore meteorological data and model outputs from high-resolution global atmospheric and wave models.

Existing data sources and model outputs are often supplemented by on-site observations to improve accuracy. Areas away from traditional trade routes, such as those in the far north and south Atlantic and Pacific oceans and around the poles, are those that are observation-sparse and require additional efforts to provide forecasting. National meteorological organisations routinely collaborate and share observation and modelled data, via the Global Telecommunications System (GTS) coordinated by the World Meteorological Organisation. This is a network of satellite and physical communication links between regions and countries worldwide. The GTS incorporates data from satellite based sensors and from drifting sensors such as ARGO.

The future is bright for forecasting companies. Considering the US alone, their National Weather Service issues about ten million forecasts every year to hundreds of millions of decision makers. There is a push into remote, harsh and relatively data-sparse marine areas and the need for surface (and subsurface) condition observations and forecasts will increase.

3.2 Market Drivers

Users include all operations at sea, such as:

- Offshore oil and gas
- Military operations
- Marine and coastal construction projects
- Shipping operations
- Recreation
- Fisheries and aquaculture
- Search and Rescue
- Environmental monitors
- Aviation.

All users benefit from forecasting tailored to their requirements in terms of interpretation of data, geographical area and timescale. An hour-by-hour breakdown of wave activity may assist offshore construction, whereas shipping companies may need to forecast a particular route over the next 12 hours, with significant events and changes being highlighted. This would supplement the common “shipping forecast” which gives weather and sea state by sea area.

In virtually every case National Meteorological Services supply data and models to the military. Work done to meet military requirements gives NMS’s capabilities that can feed commercial markets. (Military applications are not covered in more detail here.)

In the US, the Government works on the principle of making most data freely available with the intention of stimulating ‘commercial’ competitive product and service development. A recent NOAA article suggested that the financial benefits of the US Government’s contribution to the GOOS programme were substantial. Whilst reference was made to some specific activities, most of the benefits come from the increased capability to forecast large-scale phenomena like the El Nino-Southern Oscillation (ENSO). Benefits to farmers “could benefit agricultural output by \$300 million per year” and “when crop storage and other worldwide agricultural changes are factored in the increase in output escalates to \$400 - \$550 million per year”. Benefits to the energy industry of having more accurate stream flow forecasts are estimated at “millions of dollars to a single utility”.

A 2001 economic analysis of GOMOOS estimated “that the benefits associated with GOMOOS information could be as high as \$30 million per year, compared with an annual cost of around \$6 million”.

In the UK, the Met Office’s own Marine programme offers ‘Commercial’ services directly to end-users. The kind of services it supplies can be seen as a model for typical services requested from ocean/weather service providers. The Met Office’s Marine Programme commercial revenues are of the order of £2-2.5 (\$3.8-4.6 million) per year. Met Office capabilities include providing a full range of global ocean observations (where available) and ocean models. Contracts include the supply of observations and forecasts of sea surface information, significant wave height, current, salinity and temperature. The majority of services are in support of oil and gas production, ports and harbours, marine transportation and fishing (a significant contract exists with the Maritime and Coastguard Agency for example). Recent customer-driven developments have concentrated on five areas:

- Visualisation – the Met Office has produced a system, known as Optimet, which acts as a visualisation and data portal. It represents the geographical extent of oil company customer operations and displays marine and general weather information including satellite imagery. The upgraded version (Optimet 2) seeks to add more functionality, but as much of the content is freely available to competitors, the Met Office is vulnerable to competition – in 2005 Shell declined to renew its contract for Marine services and changed supplier to Meteoconsult, one of the largest private weather companies in Europe. Other companies such as Fugro-Geos with estimated 2005 revenue £3.5 million (\$6.4 million) are equally active in this data visualisation market but also develop their own expertise in metocean consultancy. This is not really an area of differentiation for the Met Office) or for that mater, other NMSs.
- Route-based forecasting – with the increasing uptake of Liquid Natural Gas (LNG) there is a growing market for ‘route-based’ marine forecasts. The crucial difference between these forecasts and standard ship routing information is that they seek to integrate satellite-positioning information with satellite weather data. This is then combined with other weather data to inform shipping and trading companies about where the optimum berth for LNG cargo is likely to be, based on a combination of expected demand, en-route weather and port weather. At present these

services are in development, but are expected to be taken up with enthusiasm by the marine and energy industries. This, again, is not necessarily an area of differentiation for the Met Office.

- Probabilistic Forecasting and Risk-Based Decision Support – Most weather forecasting has traditionally been ‘deterministic’ which effectively produces a single forecast for weather variables. In recent years there has been an increasing use of ‘ensemble’ data, effectively running the forecast model with a number of different starting conditions based on the uncertainty of the observations. These ensemble forecasts produce a range of possibilities for each parameter, rather than a single forecast. As a result they are much more useful for planning and operational purposes. As an illustration, the Met Office’s marine team in Aberdeen has been supplying probabilistic forecasts to the offshore oil and gas industry for use in planning rig-tow operations. Contractors can now take a risk-based view on whether a tow is likely to be successful.
- Marine Information – a relatively new area for business development has been integrated marine information. Weather forecast information is now being incorporated much more into information systems – expect to see a tie-up between the Lloyds Maritime Intelligence Unit’s SeaSearcher and the Met Office, for example.
- Deepwater Oil Exploration – As the search for oil and gas moves further offshore, ocean current and surface state forecasts are being integrated for delivery to oil & gas companies.

Commercial services are offered by a large number of companies. Those with links to the major National Weather Services have an advantage. In the US, SAIC is a leading service provider, but we understand that 94% of its total \$8 billion sales come from the Government.

An example of how the various organisations come together is the Falklands Offshore Shared Area work in the late 1990s. Here the UK’s Proudman Oceanographic Laboratory provided sub-sea current information, a commercial company (SOS (UK)) provided satellite altimeter wave and scatterometer wind data, Fugro-Geos supplied a year-long metocean survey involving the deployment of a number of drifting buoys and the UK Met Office provided an operational weather forecasting service for:

- The tow route from the UK North Sea to the Falklands
- Marine Forecasts covering the area close to planned drilling
- Marine forecasts covering the area between drilling and the islands
- Aviation forecasts for the islands, rigs and the route in between.

The US Coast Guard (USCG) has estimated that the average total cost of a commercial vessel grounding in one of its five major US ports is between \$386,000 and \$870,000. Poor weather conditions account for most of the groundings. An annual 1% reduction in groundings results in a \$135,000 savings.

3.3 *Developments and Trends*

Satellite-based remote sensing has provided vast amounts of data (via processing centres) to meteorological forecasting models. Advances in computer processing power and information gathering allow modellers to produce five-day forecasts in high resolution for each forecast “cell” area. Models incorporate the bathymetry of the ocean basin and also salinity and temperature data from in-situ remotely sensed observations and models. Outputs from models in some regions of the world are held in the public domain, but in others, meteorological data is the property of the government or military.

Modern forecasting models include the Hybrid Coordinate Ocean Model (HYCOM) which is a critical part of data assimilative systems at the US Naval Research Laboratory and at NOAA’s National Centre for Environmental Prediction. The US Navy tap the velocities, temperature and salinities of the HYCOM prediction system to smaller models that provide even higher resolution for rivers, tides, etc. in real-time for anywhere in the world. NOAA’s new Real-Time Ocean Forecast System will provide mariners with “nowcasts” and five-day forecasts for the entire North Atlantic Ocean. While other ocean models have been developed in the past, HYCOM is unique not only because it provides three-dimensional, global data that is of sufficient resolution to factor in the real-time displacements in currents caused by eddies, but also because of its flexibility in modelling both coastal and deep ocean regions. The HYCOM model will help forecasters and others understand better the ocean’s currents, temperature, salinity and other variables.

The UK Meteorological Office (UKMO) Forecasting Ocean Model (FOAM) is an ocean/sea-ice model and assimilation system that produces real-time daily analyses and forecasts of temperature, salinity, currents and sea-ice in the deep ocean, for up to five days ahead. FOAM is built around nested physically based ocean and sea-ice models. It is driven by six-hourly mean surface fluxes from the UKMO’s operational numerical weather prediction system and assimilates ocean observations (in situ and remotely sensed) that are available in near real-time.

3.4 *Utilisation of OOS*

As a direct feed to forecasters and models, OOS are invaluable. Profiling moored and drifting CTD, surface wind and wave data from meteorological buoys, moorings, HF radar, voluntary observing networks using XBT and remotely sensed data from satellites are all used in producing accurate forecasts. Many OOS already in existence are groups of meteorological buoys deployed in a coastal region or estuary.

Surface condition forecasting companies often provide the OOS sensors to suit the application, as well as undertaking the forecasting. Companies deploy buoys and other in-sea platforms in remote areas of the world to suit the requirements of offshore oil and gas exploration companies.

Weather and Sea State Prediction

Sea State prediction and weather forecasting activities can be broken down into three parts: observations, processing and creation of products and services.

- **Observations** – Observations programmes are usually of global scale and generally cost very large sums. For ocean forecasting the observations come from ships, aircraft, buoys, drifting floats and satellites. In virtually all cases these observing systems are funded and operated by

Government (civil or military) or international bodies. The satellite observation programmes are considered in more detail below. In the case of floats, the primary programme is ARGO. This consists of a multi-nationally funded deployment of initial 3,000 free-drifting, profiling floats followed by more each year to keep the numbers at around 3,000. The funding requirement is \$24 million per year, of which the US contributes roughly half. The UK contribution is around £1 million per year, funded through the Research Councils and the Ministry of Defence and the Department for the Environment, Food and Rural Affairs (Defra). The ARGO programme, despite its success and despite being a contributing part of GCOS and GOOS is under pressure for funding. In the UK all funding parties have said recently (2006) that they see difficulty funding a long-term operational commitment (until now funding has been with a short-term research focus).

- In the US, a major buoy network is the developed and operated by Science Applications International Corporation (SAIC) on behalf of the National Data Buoy Center (NDBC), which is itself part of NOAA. SAIC is also providing support for NOAA's Marine Observation Network and the Deep Ocean Assessment and Reporting of Tsunami Systems at NASA's Stennis Space Center. Data exchange has also hitherto been an issue, but several satellite programmes and international collaborations have been set up to address this.
- **Modelling and Prediction** – In most cases large-scale and regional operational forecasting is conducted by national meteorological services and military organisations. Some research activity is conducted at universities and specialised commercial consultancies. In the US the National Weather Service (NWS), which is part of NOAA, conducts numerical modelling as part of its National Centre for Environmental Prediction (NCEP). NCEP Central Operations then works alongside the Ocean Prediction Centre to provide warnings and forecasts to the Atlantic and Pacific Oceans north of 30 North. Additionally, the US Navy runs a 'Fleet Numerical Meteorology and Oceanography Centre' with a global numerical prediction capability. SAIC supports the Environmental Modelling Centre of NCEP.

In Australia, the Bureau of Meteorology runs a National Meteorological & Oceanographic Centre in Melbourne the produces analyses and forecasts for the Australian, South-East Asia, Southern Hemisphere Regions and Globally.

In the UK, the Met Office runs a global sea-state and ocean wave-forecasting model, a separate Forecasting Ocean Assimilation Model (FOAM), which produces real-time analyses of temperature, salinity and currents for the deep oceans up to five days ahead. Also in the UK, the Proudman Oceanographic Laboratory (part of the National Environment Research Council) provides global marine current modelling, as well as national and international expertise on sea levels and tides.

4 Environmental Assessment & Monitoring

4.1 Introduction

This application area encompasses both the general ongoing monitoring of the overall marine environment for scientific purposes and systems for specific applications.

The latter case relates to the planning and permissions stage of marine or offshore construction activities, where an environmental impact assessment (EA) must be conducted to determine whether or not the project will be detrimental to the location and its surroundings and also for the assessment of local conditions so that the design of any structure can be optimised. A study may take a year or more and use battery powered, self systems of ADCP, CTD and meteorological instruments, tide gauges and TRIAXYS buoys. Remotely sensed data may be bought in, historical data studied and when combined with the year's study results, forecast models made that will give an indication of the conditions on the proposed site, as well as predictions of worse case (50-year wave, 100-year wave) or weather windows (flat calm seas for large operations). Modelling of the likely effect of pollution or spill incidents upon sensitive areas would allow this to be mitigated at the design stage and alternatives chosen.

In the case of modern deep-water oil and gas infrastructure they are so massive that they can suffer from current effects acting in different directions over the full in-water depth of the installation. In the case of an FPSO (floating production, storage and offloading) system for example, mooring chains and seabed-surface mooring connections must be monitored to function within the tolerance of the system.

Some areas, which enjoyed an early development and exploitation of their oil & natural gas resources are now faced with the challenge of maintaining, repairing or replacing an aging network of pipelines that link platforms and bring oil and gas to shore. *Sonda de Campeche* Marine Zone in Mexico is an example of where subsea infrastructure has suffered from neglect. With approximately 120 offshore production platforms, 39 production support and service platforms and a network of over 3,000 km of underwater pipelines, there is increased pressure for Pemex (the national oil company) to adhere to the good engineering practices that are commonly used in areas such as the North Sea. OOS can play an important role in ongoing pipeline leak detection and the monitoring of conditions that effect offshore structure integrity.

4.2 Market Drivers

- Long-term monitoring of environmentally sensitive areas such as reefs
- General pollution monitoring
- Offshore and inshore oil & gas exploration, production and maintenance operations
- Pollution prevention, monitoring and threat assessment
- Dispersal studies for marine outfalls
- Offshore and inshore construction projects
- The positioning and design of marine renewable energy installations.

4.3 Developments and Trends

Remotely sensed and in-situ data are regularly used to produce predictive models to suit the end user requirements, particularly in the offshore energy arena. Instruments for long-term monitoring are mounted on a variety of mobile and static platforms, such as fast coastal ferries, offshore oil & gas installations, in addition to temporary systems such as floating moored buoys, drifting profilers and seabed mounted systems (fitted with acoustically triggered releases so that the units can be recovered). There has been a trend towards adoption of OOS-type infrastructure to support short and long-term monitoring.

4.4 Utilisation of OOS

The installation of a permanent OOS would facilitate EA process as well as subsequent monitoring of projects' effects whilst underway. Cabled systems with a power supply and data connection would support a wide range of sensors such as ADCP, HF Radar, profiling CTD and fluorimeters, but these could also be run off batteries/fuel cells, with communication by acoustic modem and satellite relay. Tidal regimes in a remote area may need monitoring, as would surface weather conditions (and higher if large constructions are planned) and shore based, tower and buoy mounted installations may be required.

Conservationists have been critical of the US Navy, charging that naval weapons and sonar testing have endangered sea creatures. Integrated Systems Solutions (US), has been awarded a \$13.8 million contract to develop innovative environmental technologies and methodologies. This research project involves development of monitoring methodologies to track marine mammals and other endangered species' migration patterns. The idea is to reduce the environmental impact of at-sea testing.

This contract contains options, which if exercised, will bring the estimated value to \$69.8 million. Work will be performed at various locations in continental US and other allied countries as determined by each awarded task order. The work is expected to be completed in February 2011.⁶

4.5 Future Prospects

Permanent installations may be more frequent, especially in deep water areas where the effect of currents on oil & gas structures can be massive. As oil and gas exploration push into harsher areas, design phase assessment of conditions will become more and more stringent. A permanent OOS with sensors that can give data on surface conditions without themselves being at risk (i.e. remote acoustic measurements of wave activity), may survive through the period and give valuable data, as well as being in place to monitor conditions during the construction and operation phase. The installation of a spar column would provide a platform for power generation, for wind and meteorological measurements, wave characteristics from HF radar, as well as an export route for data from in-sea sensors.

The use of commercially available radar and optical earth imaging satellites is allowing oil companies to develop timely oil leakage and spill data as part of the environmental monitoring of offshore exploration and development activities. For the last 5 years, Petrobras, Brazil's state-owned oil company has used the services of Radarsat International to support its environmental monitoring of platforms and oil-

⁶ <http://www.auvsi.org/news/>

transporting pipes. Radarsat can integrate spatial information into its oil spill model and generate critical decision making data in less than four hours.

5 Research

5.1 Introduction

Academic research into the oceans forms a major sector of OOS activity. The scale of the OOS for academic research varies greatly. Shallow water systems such as the Bonne Bay Observatory have a single sensor deployment in 18m of water, 1.4 km offshore. The deep water H₂O system however, lies 2,000 km from land in 5,000m of water using an obsolete submarine telephone cable for power and data transfer.⁷ Current academic OOS projects such as NEPTUNE will cover vast areas of seabed with multiple sensors and projects are under development that will provide a sensor network under the polar ice-sheets. There may be a market for the extension of existing systems, incorporating sensors from other research areas. In South America, seven of the 32 GLOSS CORE Network stations are participating in a pilot project for continuous GPS monitoring at the Tide Gauge sites (TIGA). The project's objective is to separate ocean from vertical crustal movements by fixing tide gauge benchmarks within the International Terrestrial Reference Frame (ITRF).

'Research' can be segmented in a number of ways, such as academic, military and commercial, or by sector of application. Both academic and military tend to share a common funding source of government. Commercial 'marine sector' research activity mainly relates to three main sub-sectors of shipbuilding, oil & gas and other industrial. To some extent, all of the research sectors are investing resources directly or indirectly into work on OOS or are beneficiaries of others work.

Implementation of academic research (for the purposes of this study) often takes the form of funded posts with the researcher often working towards a PhD in the topic area, with funding being drawn down from government (civilian or military sources) regional level or commercial, dependant on the area in which development is needed.

Typical research topics include oceanography, meteorology, hydrography, atmospheric science, geology, biology and fisheries studies. Other areas, including astro and particle physics are now using OOS technology to support neutrino detectors and other non-oceanographic sensors. Researchers in electronics, computing, mathematical modelling and engineering are also involved – the development of new equipment, such as underwater vehicles, sensors and mooring infrastructure is crucial, as are new techniques for processing and disseminating in-situ or remotely sensed observations, or for modelling ocean behaviour.

Research may also be to study a particular physical phenomenon (geothermal vents, seismic activity, upwelling), or a region of interest (confluence zones for fisheries research). The ability to have long-term, multi-parameter observations at multiple locations, all transmitting data in real-time is beneficial to all these research areas, as historically data was sampled with great temporal and spatial separation on scientific cruises.

⁷ <http://www.whoi.edu/oceanus/viewArticle.do?id=2434&archives=true&sortBy=printed>

5.2 Market Drivers

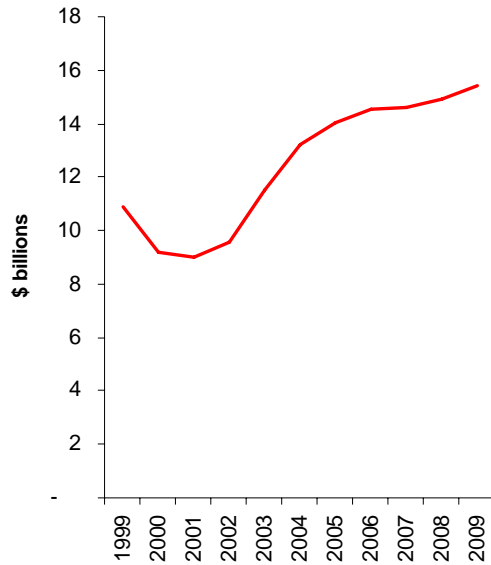


Figure 5-1: R&D – World Market

Source: Douglas-Westwood

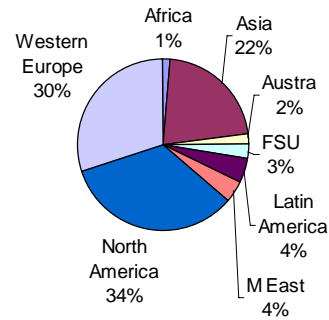


Figure 5-2: R&D – Regional Segmentation 2005-2009

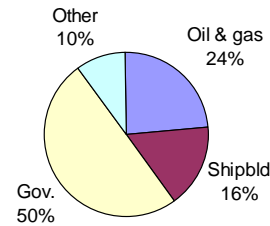


Figure 5-3: Marine R&D by Sector

Source: Douglas-Westwood

The Marine R&D sector was valued at \$12.4 in 2004 and we estimate spend reached \$15bn in 2005. The above estimates exclude the important military naval sector where the US accounts for \$16bn and the world total could be \$32bn. This is important to the civil sector, not only in terms of direct military contracts which can financially underpin both academic research and companies alike, but also the technological spin-off into civil applications. The US Navy budget for development, testing & evaluation has increased from \$14.9bn in 2004 to \$16.3bn in 2005. This includes \$477m for basic research, \$564m for applied research, \$677m for advanced technology development, \$2.8bn for advanced components development and \$8bn for system development and demonstration.⁸ The US has a programme to specifically involve SMEs in military R&D.

In the 2007 budget, the National Science Foundation (NSF) has committed \$38.5 million for two major OOS projects. The Ocean Initiative will provide \$56 million for construction of the Alaska Research Vessel (ARRV) and the Ocean Observatories Initiative will receive \$13.5 million. The latter includes a network of sensors, imaging systems, cable networks and buoys to be deployed along US coastal waters and worldwide deep water sites.

Historically, global activity has been fairly constant with forecast growth estimated at 1.4% annually from 2005 through to 2009. We value shipbuilding R&D at \$2.3bn and its future growth is mainly a function of future growth of revenues, however this sector has little direct involvement with OOS.

⁸ *Sea Technology Buyers Guide/ Directory* 2005

The oil & gas industry is estimated to spend \$3.1bn,⁹ but in future years this must increase in line with the technical challenges that will be faced. Major centres are Brazil, France, Norway, the UK and the US. Other marine industries, we believe, total some \$1.25bn in annual R&D spend.

The long-term drivers for ocean research are well known:

- global warming
- population growth
- demographic change
- the developing economies.

Government is a major spender with over 1,200 ‘research’ vessels operating worldwide. The US leads and we estimate NOAA’s marine budget at \$2.5bn. Other countries probably total \$3.75 billion. The response to global warming is likely to increase this spend.

Western Europe is responsible for a major part of world R&D activity, probably only second to the US. However, the majority of R&D expenditure in Europe comes from industry. Europe’s share of the world market was \$4 billion in 2004, set to grow to \$4.4 billion by 2009. *“Research & Development (R&D) is a driving force behind economic growth, job creation, innovation of new products and increasing quality of products in general, as well as improvements in healthcare and environmental protection. At the Lisbon summit in 2000, The European Council set a clear strategic objective for the current decade: to make Europe the most competitive and dynamic knowledge-based economy in the world.”*¹⁰

Perhaps one long-term concern should be the development of major R&D capabilities in Asia and the growing power of these countries to ‘undercut’ established Western centres in attracting commercial R&D funds. We expect countries such as China, India and Russia to become increasingly competitive due to low labour costs (a graduate with a master’s degree can be employed in India at 25% of the cost of an equivalent person in the US).

A further factor is that offering to undertake R&D in a developing country is often seen as a way to deliver local content which is very important in many commercial sectors such as offshore oil & gas. A challenge for Western governments will therefore increasingly be how to anchor commercial technology development in their own countries against the pressures from developing countries of lower costs and foreign investors needs to meet local content needs.

Despite the major developing economies producing considerable numbers of graduates we note recently expressed concerns that these numbers are insufficient to meet their national needs and graduate quality shows considerable variation.

⁹ Our estimates are based the mid point of figures produced separately by McKinsey and Shell

¹⁰ ‘Eurostat Yearbook’ 2004

5.3 **Developments and Trends**

Installations of OOS for academic research are underway with those in North America making greatest progress. Existing infrastructure is being strengthened and expanded, in addition to new systems being deployed.

Significant technological developments are wide-ranging and include satellite observation and communications, acoustic modems, fibre-optics, computer processing speed, data storage and the spread of broadband internet connections and these are giving researchers access to far more data than ever before. Data storage on magnetic tape, retrieved from a deep-sea mooring on a scientific cruise after six months, has been replaced by user-friendly satellite transmission of data from a surface buoy and presented within seconds or minutes of acquisition on the other side of the world. This has led to the building of academic capability in areas that previously were not able to access the technology and information stream.

Autonomous underwater vehicles (AUV) and autonomous surface vehicles are becoming accepted as part of OOS. Currently they are only deployed on scientific cruises that academic research vessels undertake each year. If provision was made for docking, recharging and downloading of data, the AUV could remain on station, unproductive transit time could be removed from budget considerations and data could be gathered autonomously, with human intervention only required for maintenance or upgrading. Many academic institutions have advanced AUV systems, but these often remain in store until sufficient funding is generated for another research cruise.

Drifting buoys follow surface currents and when equipped with solar panels, GPS and a suite of sensors, can transmit data to support atmosphere/ocean interaction studies or other research. There are a number of projects using drifting sensors that can descend to 2,000m and then return to surface, conducting salinity and temperature measurements to determine the structure of the water column. These projects are now fully deployed but will require continued input from academia in terms of repairs, new deployments and technology developments. Free-drifting sensors give what is known as Lagrangian measurements in comparison to Eulerian measurements which are from one point – giving variation over time rather than space.

Satellite remote sensing has given the academic research community access to unprecedented information in both scope and detail. Measurements of ocean colour (OC) are used as indicators of phytoplankton activity and hence potential food stocks for fisheries. Sea surface temperature (SST) measurements are used by meteorologists and atmospheric scientists. Satellite borne radar altimeters can give indication of high and low pressures over the ocean, based on the “height” of the satellite above the sea surface – the distance will be greater if the sea surface is depressed as would be the case with high atmospheric pressure. These measurements are available from scientific and civilian satellites as well as some data being released from very high resolution military systems. The path of the satellites themselves is affected by fluctuations in the earth’s magnetic field and also its density (the higher the density, the more the attraction due to gravity) and is allowing geological research to support minerals exploration. Differences in radar reflection characteristics of different surfaces can be exploited to provide detection and monitoring of oil spills. In-sea measurements are needed to calibrate and validate satellite based measurements and for providing real data for predictive models to work with.

Towed, undulating recorders (TUORS) are used for gathering biological samples as part of LME studies. Such tools can gather very large datasets at reduced costs over large areas using research vessels.

Power and data nodes (connection points), provide key building blocks of an OOS. The node is attached to a cable down which data and power are transmitted. Redundant copper telephone cables have been successfully used in this way. New installations may take the form of a fibre-optic data cable and a separate power cable.

Remotely operated vehicles (ROV) can then be used to attach extra equipment to the node, by using wet-mateable connectors. Clearly, standardisation of connections and data/power requirements is needed. The node may act as a hub around which sensor arrays are placed, all connected and transmitting data. Different experiments may be supported (dependant upon power requirements and available data capacity) allowing multiple research areas to use the same infrastructure. ROVs are also widely used for high resolution seabed survey and as general underwater observation and work systems.

5.4 *Utilisation of OOS*

Data from an OOS may be utilised by many different end users and careful data management is vital. Information about the data (metadata) must be maintained and access to metadata allows researchers of different disciplines to decide whether or not the dataset is relevant to their needs. Metadata includes such parameters as geographical coordinates giving the extent of the dataset, nature of the data, its format, method of collection, reliability and any quality control measures that may have been in place. Regional data centres hold terabytes of information and metadata is the key to sorting the collections dependant upon the user requirements.

5.5 *Future Prospects*

Academic research using OOS is a large ‘market’ and with concerns over global climate change, sea level rise and natural hazard detection and prediction, funding for large OOS infrastructure projects is being put in place in many parts of the world. Web-based dissemination allows training and capacity building to be undertaken in countries other than those funding infrastructure and allows them to benefit from global initiatives. Developments in sensor and UUV technology, OOS power/data nodes and the development of worldwide standards/protocols for sensor and equipment power/data interfacing requirements will be the result of funded academic research, as will the forecasting/modelling tools that allows decision makers to undertake their tasks.

Time-sharing of OOS between academia, industry and/or other users, may be useful in maximising the use of the systems. Examples include systems placed on merchant vessels, cruise vessel operators offering space for research, industrial deep-water ROVs could be used for investigation of underwater biology, geological sampling or to place new sensor infrastructure while on “standby” from a nearby oil platform or installation.

6 Natural Hazard Warning

6.1 Introduction

Natural hazards in the marine arena include tsunami waves following seismic activity; flooding due to combinations of exceptionally high tides, very low atmospheric pressure and onshore winds and storm surges following extreme weather events.

6.2 Market Drivers

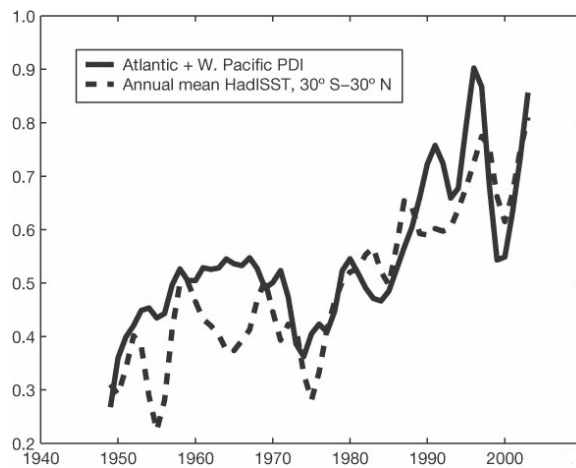


Figure 6-1: Tropical Storms

Source: Emmanuel, MIT

The figure shows smoothed changes in the power dissipated by hurricanes (Power Dissipation Index, PDI) in the western North Pacific and North Atlantic areas, integrated over the lifetime of the storm and over its area, compared to changes in the annual mean SST (Sea Surface Temperature). The units of PDI are those of energy, with units multiplied by an arbitrary factor to match the same units as SST, to facilitate the comparison between the two quantities. The overall result is that the PD appears to have nearly doubled over the past 30 years.

Glaciers are melting and reducing in length by typically 500m in the past 50 years and arctic sea ice is melting with some one million sq km lost in the past 35 years. The overall result has been an average annual rise in sea level of one inch since 1995.¹¹ When driven by major storms, the surges can have devastating effects as demonstrated in New Orleans in 2005.

Major investments are being made in coastal barriers and the size of the fixed barriers (and investment in them) is a function of observation of extreme events within long-term trends. However, a number of these are 'flood gates' spanning river estuaries and the effective operation of these remains a function of the existence of OOS and the associated forecasting models.

Following the 2004 tsunami and the flooding of New Orleans in 2005 funding drivers for hazard warning systems are now in place in the US. The US government's existing Pacific Tsunami Warning System has also identified false alarms: it prevented an evacuation in Hawaii in November 2003 that would have cost the local economy \$68 million. Estimates for upgrading the Indian Ocean Tsunami Warning System are in the order of \$50 million.

The economic analysis of GOMOOS estimates that the benefits associated with GOMOOS information could be as high as \$30 million per year, compared with an annual cost of around \$6 million.¹² If Great

¹¹ Presentation by Bruce Haines, JPL, NASA at the Marine Technology Society meeting, California State Polytechnic University, Pomona, April 12/06

¹² The Economic Benefits of Coastal Observing, Kite-Powell and Colgan, 2001

Lakes coastal forecasts can have the impact of a 1% increase in lives saved, this would represent about five lives saved. At the \$4 million imputed value of human life (Potential Economic of Coastal Ocean Observing Systems; the Gulf of Maine), \$20 million could be saved through avoided loss of life.¹³

It is interesting to note that tsunamis are not a Pacific phenomena. On December 1, 1755 the Lisbon tsunami destroyed the city and affected many other towns and cities on the Iberian Peninsula, across northern Africa and the rest of the European coastline. While this was undoubtedly the worst such event on recent record in the region, there have been others: in Norway in 1905, or more recently Algeria in May 2003. Despite this, there is no effective early warning system for the region.

In November 2005 the first steps towards a tsunami warning system for the North-Eastern Atlantic Ocean, Mediterranean and connected seas were taken at a meeting to be held and organized by UNESCO's Intergovernmental Oceanographic Commission (IOC), which established the tsunami warning system for the Pacific and, over the past year, has coordinated the establishment of the Indian Ocean Tsunami Warning and Mitigation System.

6.3 Developments and Trends

Since 1948 the US Navy have maintained a network of acoustic listening posts in the Pacific with the original intent of detecting submarine activity and the acoustic signatures of nuclear explosions. The array of sensors is connected to the Pacific Warning Centre in Hawaii and information is disseminated from there via the US State Department. The Pacific Warning Centre was built after a relatively small earthquake in the Aleutian Islands triggered a big tsunami that hit Hawaii and killed 159 people in 1946. According to NOAA, About 85% of tsunamis occur in the Pacific. An Alaskan centre was added after a 9.2-magnitude earthquake on March 27, 1964 unleashed a tsunami that killed 122 people across the Pacific.

Concerns have been raised in the press regarding the apparent breakdown in the flow of warning messages that should have been sent out. This could prompt countries at risk to invest in their own warning systems. Local politics may get in the way of an integrated, region wide-system due to the funding required and the decision on which country hosts the warning centres. The IOC is coordinating the development of the systems.

Japan has a sophisticated tsunami warning system (with warnings disseminated through Japan's Meteorological Agency). When 3 metre waves hit the northern Japanese island Hokkaido on Sept. 25, 2003, Japan issued warnings and evacuated coastal areas. However, two fishermen were lost at sea.

In October 2003, Australian and Indonesian researchers received the go-ahead from the UN International Coordination Group, for the Tsunami Warning System in the Pacific to start studying the threat in the Indian Ocean. The researchers worried most about tsunamis originating from earthquakes around the central Indonesian island of Java. It has been argued that the Indian Ocean needs an even better warning system than the Pacific, because the Indian Ocean is smaller and tsunamis can spread disaster much faster. It can take 24 hours for a tsunami to cross the Pacific. The tsunami of Dec. 26 hit Sri Lanka less than two hours after it was unleashed by the earthquake off Sumatra, about 800 miles (1,300 km) away and reached the eastern coast of Africa, 3,500 miles (5,600 km) away, in about nine hours.

¹³ Delta Research Co., Chicago, IL 60603 " Great Lakes Component: Coordinated Regional Benefit Studies of Coastal Ocean Observing Systems", January 13, 2003

After the disaster the German Federal Ministry of Education and Research commissioned the Helmholtz Association of National Research Centres to develop a \$57 million tsunami early warning system for the Indian Ocean, which can later be extended to the Mediterranean and the Atlantic Ocean. The system integrates terrestrial observation networks of seismology and geodesy with marine measuring processes and satellite observation. Germany cooperates with Indonesia, which is the area most heavily threatened by earthquakes in the Indian Ocean because of its proximity to the seismically active Sunda trench.

In November 2005, the German research ship “*Sonne*” began the construction of a tsunami early-warning system in the Indian Ocean similar to the US-backed system that monitors the Pacific Ocean. Germany is providing \$85 million for the system of marine instruments, using seismometers to detect tremors. Code-named ‘Tsunami Early Warning System’ (TEWS), it has been refined to avoid false alarms from quakes that do not cause tsunamis. German and Indonesian scientists were to take two weeks to install the buoys and sensors off Sumatra using 6,000m of mooring cable. The TEWS components consist of 10 buoys, 25 seismographs, 10 GPS stations, 10 GPS tide gauges and 20 ocean bottom pressure sensors. It is set to be complete by mid-2008 and will be part of the DART system expansion proposed by the US.

6.4 Utilisation of OOS

Tsunami waves arise from a movement of a section of seabed following a shift in planetary crust and the seismic event can be detected, pinpointed and assessed within seconds of its occurrence. The seismic event can be detected, as can the wave that follows it.

The US operates six ‘Deep Ocean Assessment and Reporting of Tsunamis’ (DART) buoys in the Pacific. The DART systems have two parts: a sensor, moored on the ocean floor which monitors water pressure and can detect and measure tsunamis and a surface buoy which relays the information to a satellite. The buoys are vulnerable to damage in rough seas as well as vandalism; two of the six were malfunctioning in 2005. The Bush administration plans to add 32 DART buoys as part of a \$37.5 million expansion of the US tsunami warning system.

The education of those at risk as to what to do in the event of a warning and dissemination of information appears to be more complex. Malaysia is reported to be planning to use loudspeakers in mosques, now reserved for the call to prayers, to spread the word when tsunamis strike. Thailand plans to put up 50 towers that will sound a siren when a tsunami approaches. In earthquake and tsunami prone northern Chile, power poles are painted different colours to indicate to passers-by whether they should stay put or head to high ground after a tremor – red means move to higher ground. In Hawaii, public telephone books contain maps showing tsunami danger zones and shelters.

6.5 Future Prospects

OOS to detect tsunamis are to be upgraded, expanded and a number of new systems will be installed complete with warning centres and information dissemination equipment. The emphasis is on the use of proven and reliable technology, robust and durable instruments and systems that feature inter-operability. UN-led efforts to coordinate developments may be delayed by local politics but funding is appearing.

There are considered to be three essential components that are required to effectively lessen the impact of tsunamis: hazard assessment, mitigation and warning guidance. Future project proposals submitted to IOC reflect these priorities, including “Tsunami: Reduction of Impacts through Three key Actions” (TROIKA). Activities proposed under the project include:

- hazard assessment – production of inundation maps for local and distant tsunamis based on numerical simulations
- mitigation – development of emergency response plans, posting evacuation route signs and development of educational programs
- warning guidance – development of a global network of tsunami detection buoys.

The emerging technological needs of tsunami monitoring and detection include:

1. Better estimates of the magnitude of earthquakes by increasing seismic surface wave periods to 450 seconds
2. The use of geodetic data to detect large crustal deformations (like Sumatra 2004) of up to 10 cm/s
3. The detection of the size and location of the rupture zone is being provided by arrays of stations (seismic arrays, infrasound arrays and hydro-acoustic arrays) with automated processing
4. Space borne radar altimetry with broader warning system coverage to detect tsunamis of more than 10 cm of amplitude; and
5. Remote sensing of leading waves and inundation zones in near real time of less than 12 hours.

7 Coastal Zone Utilization

7.1 Introduction

In both developed and developing countries the coastal zone is undergoing the most profound change. Already more than 60 percent of the world's population lives within 60 kilometres of the coast.¹⁴ By the turn of the century two-thirds of the population (3.7 billion) in developing countries is expected to occupy the coastal area. Consequently, unless careful environmental management and planning are instituted, severe conflicts over coastal space and resource utilization are likely and the degradation of natural resources will seriously limit development options.

There is continuing pressure on the coastal and marine environment from activities including mariculture, agriculture, urbanisation, industrial developments and tourism. Although there have been many attempts to protect coastal areas and to encourage sustainable forms of coastal development, few have been successful. The main reason is that they have largely been sectorial and there is fierce competition for coastal resources in many areas.¹⁵

The high and growing coastal population density means that long-term sea level rise and storm surges have been of growing concern with major investments made and further needed in both understanding the extent of the problems and protecting coastal communities worldwide.

In February 1953 the Netherlands and South Eastern UK faced disaster when flood defences were breached by the joint onslaught of a hurricane-force wind and exceptionally high spring tides. In the UK, 307 were drowned, plus over 200 at sea, but in the Netherlands the flood killed 1,835 people. Almost 200,000 hectares of land was swamped, 3,000 homes and 300 farms destroyed and 47,000 cattle drowned. It was The Netherlands' worst disaster for 300 years. The resulting massive programme of dyke reinforcement and movable storm barrier installation was completed in 1997 at a cost of \$15 billion.

In the UK, a major tidal barrier to protect the city of London was installed across the River Thames at a cost of £500 million (\$875 million approximately) and seems money well spent. Since completion in 1982 the barrier has had to be closed 92 times.¹⁶

Following events such as the 2004 Tsunami, Hurricane Katrina and the overwhelming of the New Orleans sea defences it is evident that considerably more needs to be done in many countries. (Total economic losses from Hurricane Katrina alone are estimated to exceed \$125 billion.¹⁷ The US government has committed about \$3.1 billion to strengthen the New Orleans levees.) In Italy, construction of the \$3 bn Mose Barrier is underway to protect the City of Venice.

Planners need to be able to determine what areas are likely to be at risk under certain weather conditions, or as part of their response to longer term sea level rise and to deliver informed decisions in the face of land-hungry commercial pressure.

Other issues include sediment and nutrient transport changes due to human activity and the effect upon fisheries, sensitive ecosystems and coastline (erosion and deposition of waterborne material such as sand).

¹⁴ <http://www.unesco-ihe.org/education/ilearning.htm>

¹⁵ UNEP

¹⁶ <http://www.publications.parliament.uk/pa/cm200506/cmhansrd/cm050616/text/50616w12.htm>

¹⁷ <http://www.house.gov/transportation/water/10-20-05/10-20-05memo.html>

7.2 Market Drivers

Data from ocean observation is invaluable to coastal zone planners in terms of property developments, identification of areas at risk from flooding (storm surges & sea level rise) and also to determine the effects of coastal development on along-coast sediment transport and the supply of sand to beaches, or on erosion of sensitive areas.

Biological indicators of fisheries stocks and aquatic health may be of interest to coastal zone planners as well – the creation of lagoons may provide extra water-side frontage but may cause oxygen levels to diminish.

Examples of potential government markets include:

UK Environment Agency (Anglian Region), at present collect / use the following coastal zone information:

- Beach profiles at 1 km centres (taken twice yearly)
- Bathymetric profiles (which map the seabed profile) at 1 km centres on a rolling programme, each section of the coast covered once in a five year period
- Aerial survey, 1:5000 scale photography, available digitally since 2003
- Purchase of selected Proudman Oceanographic Laboratory Class A tide gauge data
- Sediment sampling and analysis, during bathymetric data collection
- Bathymetric surveys of selected estuaries
- Nearshore wave and tide monitoring on a five year rolling programme.

In Korea, where 42% of fisheries are expected to be aquaculture-based by 2010, the concepts of “fish ranching” and “fisherinas” will revitalize fishing communities based upon an integrated tourism, aquaculture and culture management approach. Korea’s Marine Policy Bureau of the Ministry of Maritime Affairs and Fisheries has also placed a major emphasis on integrated coastal management, marine protected area management and integrated ecosystem approaches.

With China’s desire to build an economy that has 5% of its GDP generated by marine activities by 2010, it is committed to promoting a co-operative regional Southeast Asia Sea approach to marine and coastal management. Japan also recognizes the importance of participating in an integrated management approach to ocean space utilization in the Southeast Asia Sea and in Indonesia, the Ministry of Marine Affairs and Fisheries see regional co-operation as the only way to expand and improve its port operations, transportation, fisheries management and aquaculture industries.

In the US, the Great Lakes region alone consists of 68 commercial harbours, 734 miles of navigation channels, 150 miles of breakwater, 25 lock chambers, 44 dredged material confined disposal facilities and the movement of over 1,200 commercial carriers annually. Improved understanding of wave motions and coastal currents can greatly assist coastal engineers in building structures that mitigate the effects coastal erosion, flooding and storm surges place on coastal property.

With the Great Lakes fisheries having an annual economic impact of over \$1 billion, the current, temperature and plankton forecasts supplied by the Marine Instrumentation Laboratory (MIL) of the Great Lakes Environmental Research Laboratory are invaluable for restocking the Lakes with trout and salmon.

The health of coral reefs has a direct impact on tourism-dependent economies. As part of the Caribbean Coastal Marine Productivity (CARICOMP), the 18 countries who are involved in monitoring the long-term variation in ecosystem structure and function of coral reefs are planning to expand the network.

The US, through NOAA, is participating in coastal monitoring, forecasting and education aspects of the initiative.

7.3 *Developments and Trends*

Tidal monitoring has extended from pure marine navigation applications towards being part of the coastal zone sensing infrastructure. Global initiatives such as GLOSS (Global Sea Level Observing System) recognise that some countries and regions need external support for tide gauge networks in terms of installation and maintenance.

GLOSS presently has 15 near-real-time high frequency sampling network of tide gauges in coastal Indian Ocean waters. These gauges transmit data every hour through Geostationary satellites that in turn re-transmit the data over the WMO Global Telecommunications System. There are an additional 31 tide gauges that do not operate in real-time.

Many countries' 'mean sea level' or similar vertical survey datum also needs observing to ensure that discrepancies between historical and present sea levels are accounted for when planning marine or coastal construction projects. An error in the positioning of sea defences can be disastrous.

Tide gauges and other marine sensors were historically either self recording, or needed observations at discrete time intervals. Modern systems can be mounted on a harbour wall, looking down at the sea surface from above, or mounted on the seabed measuring the pressure of water above them; all transmitting data as independent units. Mass installations such as in the US by NOAA, under its NWLON project (national water level monitoring network), relay data via satellite every three hours to a control centre from 180 tidal stations.

The UK also has 46 stations relaying data as part of the Permanent Service for Mean Sea Level (PSMSL).

7.4 *Utilisation of OOS*

An OOS consisting of tide gauges would give data for long-term studies (if sited at required density along a coast), as well as providing tidal data for marine navigation. If the OOS had wave buoys and meteorological sensors as well, it could form part of a storm surge warning system as well as providing relevant data for efforts to model local conditions. Adding other sensors (ADCP, CTD, dissolved oxygen, fluorimeters, chlorophyll-a and sediment) would increase the potential 'market' for the data. The OOS data could be presented "raw" for larger clients to analyse themselves, or processed and output in a way that would allow easy integration with Geographical Information Systems (GIS) or for web-based applications (search for areas at risk of flooding by post/zip code). The OOS could be integrated with flow sensors at locations in the watershed feeding the estuary or coastal rivers to enhance flood warning capabilities.

OOS could provide suitable infrastructure and support for bathymetric mapping exercises using swath sonars mounted on autonomous vehicles. These would be able to provide mapping into areas that surface

vessels may not be able to access. Bathymetry from aircraft, using laser ranging (LIDAR) is in use worldwide as a mapping tool for coastal zones where the optical characteristics of the water allow its use. Large areas of shallow water can be mapped in a short space of time with all these systems compared to single-beam echo-sounders. LIDAR systems may be integrated with digital imaging to provide rapid 3D measurement and visualisation of areas.¹⁸

Marine habitat mapping in the coastal zone would also benefit from OOS infrastructure – swath bathymetry techniques not only give depth data, but also classification of seabed material based on the characteristics of the acoustic return.¹⁹

7.5 Future Prospects

This application area of OOS is developing and likely to expand due to global concerns about sea level rise and flooding. Integrated coastal zone OOSs would give flood/storm surge warnings in addition to long-term studies that would enable predictive models to be generated. Environmental and meteorological sensors would also provide added value to the OOS infrastructure via more potential end-users, particularly in an area where water based recreation and commerce are commonplace.

¹⁸ http://www.eonline.com/Common/Archives/2000sep/00sep_corbley2.html

¹⁹ e.g. systems such as those from CODA Octopus

8 Fisheries & Aquaculture

8.1 Introduction

Fishing is an important industry that is seeing growing demand, but the world catch tonnage is falling as a result of serious resource problems and quota restrictions. The industry faces a future of continuing global decline worldwide until a point of sustainability can be reached.

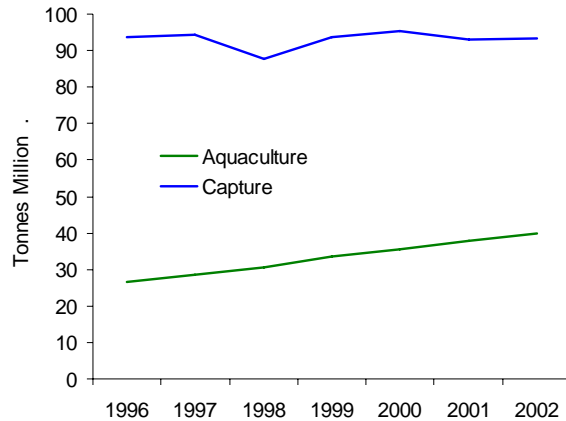


Figure 8-1: Fishing and Aquaculture Production

Source: FAO and Eurostat

Since 1996 capture fishing tonnage has been at best flat and has shown recent decline. The increasing world demand for fish and other seafood is being met by aquaculture where tonnage growth over the period 1996 to 2002 averaged 7% and \$ value averaged annual growth of 4%.

OOS are applied to the monitoring of fisheries both in terms of factors impacting on fish populations, (nutrient levels, oceanographic factors, etc) and monitoring of fishing activity.

Upwelling is a process whereby the wind-driven movement of water results in more nutrient rich deeper water being drawn up nearer the surface. Upwelling processes can be interrupted, causing massive effects on fisheries and climate and the El Niño event is the most commonly known. NOAA (and others) monitor sea temperature using buoys and remote sensing and attempt to predict the Southern Oscillation effect (the relative difference in atmospheric pressures prevalent over the East and West Pacific) that gives rise to El Niño. Fisheries monitoring vessels regularly conduct CTD sampling to determine the temperature regime of local waters and relate changes in fish catches to changes in the ocean.

In the case of vessel monitoring, good fishing grounds are high-value assets and nations invest considerable sums in their policing of fishing vessels and in some instances they have probably contributed to sustainable fisheries such as Iceland.

Since 1 January 2001 all vessels exceeding 24m l.o.a. operating in EU waters have been subject to the VMS (vessel monitoring system) with automatic position reports being made to the fisheries monitoring centres of both the flag and coastal states. In 2000 a collaborative project began to investigate the potential of space-borne synthetic aperture radar to detect and identify non-compliant vessels. This has the advantage of showing all vessels in a region rather than those using VMS. RADARSAT (Canada) was chosen as the principal instrument. The more advanced IMPAST system was started in 2002.²⁰

The DECLMIS system which focuses on satellite imagery for maritime vessel identification has 17 partners including Canada and China started in 2002.

²⁰ http://pta.jrc.cec.eu.int/entity.gx/_entity.object/SEC-----000000000016E12/_entity.name/fao_jrc.pdf

8.2 Market Drivers

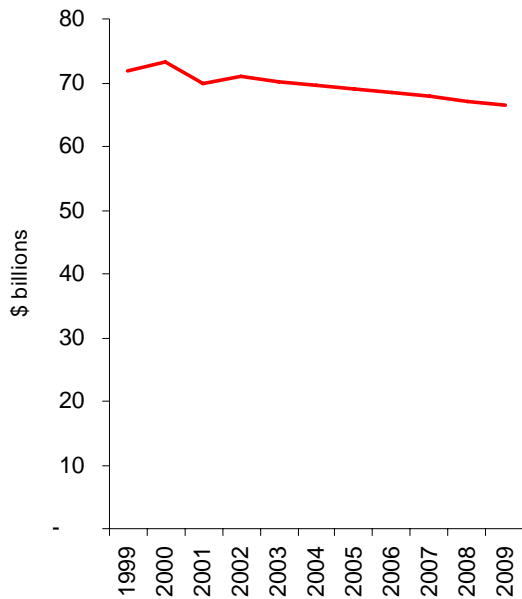


Figure 8-2: Fishing – World Market

Source: Douglas-Westwood

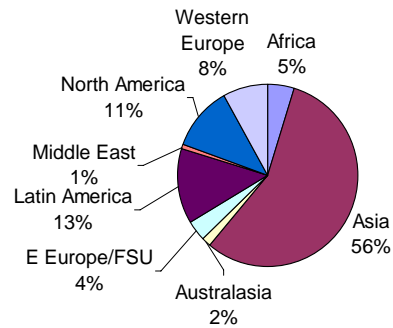


Figure 8-3: Fishing – Regional Segmentation 2005-2009

Our five-year forecasts assume the value of the catch will stay constant from 2002 prices onwards. This assumption has been made on the basis of increasing production of fish (including shellfish) from aquaculture, keeping prices steady.

Whilst the global capture fishing industry is in decline, in the last 50 years fish consumption per person has doubled. Japan, the US and the EU are major seafood markets that depend on imports for approximately half of their consumption.²¹ World fish consumption has been increasing since the 1960s, due to population increase and lifestyle factors, such as increased awareness of health benefits and fishing technology has advanced to increase catches. As a result of this over-fishing (and pollution) the ocean population of edible fish has decreased by 90% during the last 50 years. The only way to bridge the gap between reduced capture fisheries output and increased world demand has been through aquaculture.

Historically, production value was \$66 billion in 1999 and is forecast to fall to \$53 billion by 2009. The world catch tonnage is falling as a result of serious resource problems and quota restrictions. There are some opportunities offered by new species. However, the industry faces a future of continuing global decline worldwide until a point of sustainability can be reached. This decline is forecast at a rate of 0.99% in US Dollars, based on historic trends.

OOS systems are used by:

- researchers to assist in the understanding of fisheries productivity
- fisheries protection departments to monitoring of fishing fleets and location of catches and detection of “rogue” fishing vessels.

The fish data collection activities of NOAA’s National Marine Fisheries Service has annual expenditures of approximately \$45 million for ship time surveys, recreational monitoring and observer programs. There is additional funding at the state and industry levels.

²¹ FAO, ‘Projection of World Fishery Production in 2010’

8.3 **Developments and Trends**

Fisheries Science

An OOS would likely be studying a confluence zone (where ocean currents mix), or an upwelling (where nutrient rich deep water is brought up into the reach of fisheries). Plankton growth and behaviour, sediment studies, water temperature structure and optical characteristics are examples of the potential study areas. Data would be used to determine the health of the fishery ground and to detect indicators of any changes (both immediate and long-term). Profiling sensors would give data in the vertical dimension and AUV nodes could support data collection in the horizontal.

Pollutant monitoring may also be a crucial use of OOS. Persistent organic pollutants of concern include organochlorine pesticides – such as HCH, industrial chemicals – such as PCBs and combustion products – such as chlorinated dioxins/furans and polycyclic aromatic hydrocarbons, radio-nuclides and heavy metals.

Successful aquaculture (fish farming) relies on having good water quality. Sensors have been developed for this market to measure dissolved oxygen, pH, total dissolved gas, ORP, conductivity and salinity, all in one sensor unit. OOS incorporating these sensors provides real-time monitoring and warning functionality to operators.

If the OOS included HF radar, fishing (and other vessels) can be monitored and their locations recorded for fishing quota and restricted area purposes in addition to providing useful information for search and rescue operations. HF radars can be installed either on towers along the coast, or on spar buoys out at sea, with a potential range of between 200 and 400 km. In 2005, fishing fleets belonging to Iceland and Russia agreed to their vessels being tracked by satellite.

The Scotian Shelf (Gulf of St. Lawrence and Grand Banks) has a long-established and highly-developed living marine resource monitoring program. While Continuous Plankton Recorders (CPRs) gather seasonal and decadal data on phytoplankton colour index and plankton species abundances, there is a need for much more plankton information. The additional requirement is for more synoptic coverage of zooplankton diversity and production and seasonal/annual estimates of primary productivity based on the analysis of satellite imagery.

Currently, monitoring of fish stocks and the state of the ocean environment is by research vessels. Potentially, AUVs could also provide CTD and other sensor samples. Profiling sensors on buoyed moorings would provide real-time data on temperature and pollutant levels, as well as operational surface weather condition information. This would reduce vessel time, as well as increase temporal and physical data density. Other prospects include the further use of towed undulating recorders (TUOR) from behind manned or unmanned surface vessels.

Illegal Fishing

Fishing fleet tracking and surveillance could form part of a wider marine intelligence OOS, or be part of the search and rescue capability. Present methods are mainly based around the use of aircraft. For example, NAS company Surveillance Australia won the 12 year, AU\$1bn Australian Coastwatch contract. The aircraft are used to detect illegal fishing (together with illegal immigration, quarantine and environmental hazards, drug smuggling and missing vessels. Surveillance Australia has been the sole fixed wing aerial surveillance provider for Coastwatch since 1995, operating fifteen aircraft plus support systems and infrastructure under a performance based service contract.

9 Marine Safety & Security and Vessel Tracking

9.1 Introduction

There are more than 90,000 ships registered in over 150 countries and perhaps 50,000 merchant ships trading internationally. In total commercial and privately owned vessels represent massive investment and may be the target for acts of opportunistic or organised vandalism, damage, theft, piracy or terrorism.

To consider one specific case, tracking for ships and boats for purposes of fleet management is becoming a necessity for the US Coast Guard which has more than 4,000 boats and 60 cutters in its fleet.

Vessels are potentially at threat when at sea, moored or in harbour. Insurance and legislation may soon demand vessel tracking and security systems for those potentially at risk. Ports, harbours and marine operators may also benefit from vessel tracking and management systems (VTS), alongside waterborne intruder detection capability. Major VTS are common in large ports and key waterways worldwide.

In addition to concerns regarding safety & security of individual vessels, a growing volume of potentially hazardous cargoes are carried, ranging from crude oil to chemicals and the chances of deliberate or accidental damage to vessels grows by the day. The resultant impact on coastal communities is well documented.

9.2 Market Drivers

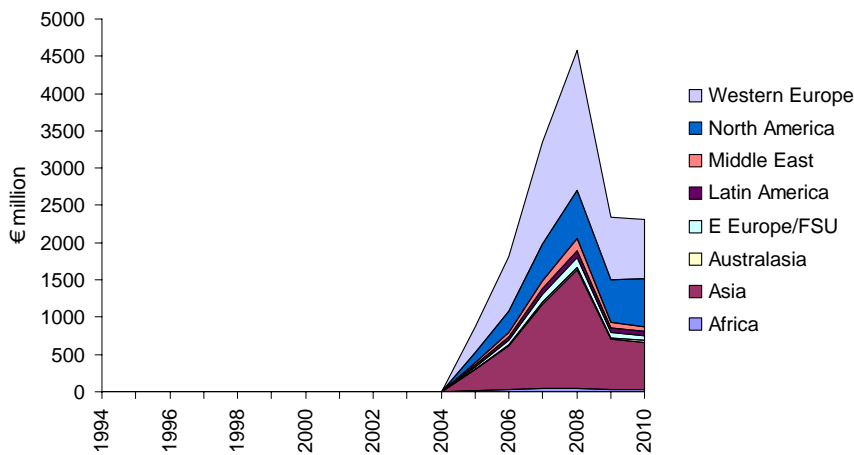


Figure 9-1: Marine Security Expenditure

Although much of the cost of post-9/11 marine security activity will fall on European and Asian ship-owners in meeting new standards and operators as container security handling fees, the large expenditure on port security is only just beginning and will be spread over many years.

We define this sector as having several drivers including:

- Vessel safety – tracking and traffic management
- Prevention of piracy – a real threat in SE Asia
- The response to global terrorism – a high growth activity.

However, following the events of September 11, 2001, this latter factor now dominates. In 2003 the OECD published a report on the risk factors and economic impact of security in maritime transport.²²

The IMO responded by developing new requirements under the International Convention for Safety of Life at Sea (SOLAS) and these entered use on 1 July 2004. This is supplemented by the International Ship and Port Facility Security Code. The effect was to generate costs for the shipping industries and new business opportunities for suppliers to the sector.

The ISPS Code will require company, ship and port facility security plans, to be approved by the flag administration. The timetable for installation of the Automatic Identification System (AIS) will be advanced. Ship identification numbers must be permanently marked in a visible place on the hull or superstructure. Ships will be issued a Continuous Synopsis Record (CSR), intended to provide an on-board record of the history of the ship, containing such information as all names used by the ship, nations with which it has been registered, identification numbers and registered owners.

The MCA's UK AIS Network is now fully operational with Kongsberg Norcontrol IT having delivered AIS hardware and software for 18 Maritime Rescue Coordination Centres (MRCC), one training centre, 51 remote physical shore stations and one AIS Service Management (ASM) site and a new Graphical User Interface called the C-Scope User Interface.

The main driver of the shipping industry is the tonnage of seaborne trade (import & export), the volume and geographic distribution of which changes as a function of nations' GDP. Seaborne transport is estimated to be responsible for up to 90% of world trade by volume and in the case of some countries such as Brazil and Peru (95%). Over the last four decades seaborne trade has nearly quadrupled and the volume of shipping business continues to rise. The OECD estimates world trade growth at 7.3% for 2005 and 9.1% for 2006.²³

Every vessel is potentially at risk, though some classes of vessel may be more desirable targets for terrorism. These include oil and gas tankers, especially those carrying Liquefied Natural Gas (LNG) and the shore-side infrastructure such as refineries, LNG plants and terminals. Over 190 seaports in the USA handle goods valued at more than \$700 billion annually and nearly half of the goods, including hydrocarbons, contain hazardous materials.

The safety concerns surrounding LNG installations pose difficulties for energy companies attempting to build new terminals. No such terminals have been built in the US for two decades, but applications to construct 30 more have been made in recent years. However, only half a dozen are likely to materialize in the next decade. Exxon has announced plans to build a \$600 million plant on the Texas coast and wants to build three more in other states. Chevron has announced plans for construction off the coast of Baja, California. Royal Dutch/Shell and BP are among other companies driving to build new terminals in California, Texas, Alabama, Florida, Mexico, Nova Scotia and other locations.²⁴

Offshore oil and gas installations worldwide may also be threatened. 65% of the world's proven oil reserves are in the Middle East. Over half of Saudi Arabia's oil reserves are contained in just eight fields, among them Safaniya, the world's largest offshore oilfield. About two-thirds of Saudi Arabia's crude oil is processed at Abqaiq a single enormous facility, 25 miles (40 km) inland from the Gulf of Bahrain. On the Persian Gulf, Saudi Arabia has just two primary oil export terminals: Ras Tanura – the world's largest offshore oil loading facility, through which a tenth of global oil supply flows daily – and Ras al-Ju'aymah.

²² *Security in Maritime Transport: Risk Factors and Economic Impacts*, OECD, 2003

²³ OECD Economic Outlook No.78, *December 2005*

²⁴ <http://www.iags.org/n0121041.htm>

On the Red Sea, the Yanbu terminal is connected to Abqaiq via the 750-mile East–West pipeline. A single attack causing severe damage at any of these plants could take up to 50% of Saudi oil off the market for at least six months.

9.3 **Developments and Trends**

Maritime security, like safety, is of paramount importance to the operations of a vessel. The International Maritime Organisation (IMO) International Ship and Port Facility Security Code (ISPS Code) came into force on 1st July 2004 and is applicable to all vessels (and the ports receiving them) that operate on international trades and that are over 500grt. In summary the ISPS Code:

- enables the detection and deterrence of security threats within an international framework
- establishes roles and responsibilities
- enables collection and exchange of security information
- provides a methodology for assessing security
- ensures that adequate security measures are in place.

It requires ship and port facility staff to:

- gather and assess information
- maintain communication protocols
- restrict access; prevent the introduction of unauthorised weapons, etc.
- provide the means to raise alarms
- put in place vessel and port security plans; and ensure training and drills are conducted.

Since the constellation of low earth orbiting communications satellites has been established, GPS-equipped security systems can transmit a vessel's ID and location to a control centre from anywhere in the world. The data can also include panic alerts, break-in indicators, fire-alarms, etc., so that shore-side authorities can be warned of events.

There are increasingly signs of collaboration between terrorism and piracy. According to International Maritime Bureau (IMB), pirate attacks on ships have tripled in the last decade. Each year 350-400 piracy attacks take place worldwide. In the first six months of 2003 alone, 234 attacks were reported, in which 281 seafarers were killed, assaulted, or kidnapped. The majority of the attacks take place in the Philippines, Indonesia, Bangladesh and Nigeria. The waters off Somalia, a collapsed state and a sanctuary for terrorists, are among the most dangerous in the world. The IMB reported *"The risk of attack to vessels staying close to the coastline from Somali armed militias has now increased from one of possibility to certainty."* Maritime security experts have repeatedly warned about the collusion between piracy and terror, voicing concerns that Islamist groups operating in these regions could capitalize on the disorder and target strategic chokepoints by placing a bomb on a supertanker or ramming a ship into one.²⁵

9.4 **Utilisation of OOS**

Vessel Tracking – HF radar can be used in a vessel tracking mode in addition to giving information on surface current and wave activity and if vessels are equipped with active radar transponders (that generate an ID signal when interrogated by other radar), vessel tracking in waterways and coastal regions would

²⁵ <http://www.iags.org/n0111041.htm>

greatly benefit. Global satellite communications and GPS equipment allow position and status messages to be sent regularly from a vessel anywhere in the world to a control centre.

Another major application of vessel tracking is the fisheries vessel systems described earlier.

In-water security – current military developments such as the US Navy’s ADS (advanced deployable system) would provide an in-water acoustic sensor network designed to detect swimmers, RIB and submersibles approaching a vessel of other perimeter. Also, accurate bottom surveys are necessary to establish a baseline for mine countermeasure ships as they search for mine-like objects buried in the sediment.

9.5 Future Prospects

Port and harbour security could be enhanced by systems such as ‘Cerberus’ – a portable, standalone, all-integrated tower developed jointly with the US Army and IXCT Technologies.²⁶ Cerberus combines ground surveillance radar with thermal/day cameras and other sensors mounted in the towers with unattended sensors located elsewhere, to extend the eyes and ears of field and base forces. Cerberus can also monitor and activate fuel levels in power generators, battery levels, backup solar panels and camera orientations. Two-way wireless links dispatch sensor commands and coordinate data flow among the towers and a central command centre, providing complete multi-sensor perimeter coverage. Motion detected by ground surveillance radar, for example, will immediately trigger a pop-up window at the command and control centre and train a cue-to-slew camera to provide additional assessment of the target. In one current deployment, seven towers are networked to provide perimeter security around a critical military asset. Similar systems are already in use around US military bases and some civilian, waterside locations.

Aerial reconnaissance and patrolling is another option to detect intruders – the Inventus UAV (unmanned aerial vehicle) is a state-of-the-art reconnaissance system²⁷ packaged in a highly efficient, stable flying wing form. Outfitted with cameras, the Inventus flies and covers a large ocean area and relays a real-time data link back to the ground station. This link provides real-time aerial surveillance and early warning of suspect or unauthorised craft movements to the coastal or law enforcement authority. Inventus is fully autonomous and can be launched and recovered even from a seagoing or patrol vessel.

²⁶ http://www.icxt.com/companies/view.cfm?content_id=7D8583BC-F9ED-95B8-A994D7599315FA35

²⁷ <http://www.inventus-uav.com/home.html>

10 Military

10.1 Introduction

Military OOS projects are wide ranging and include ocean-wide submarine detection systems initiated during the cold war to use of AUVs in surveillance of shallow waters, ports & harbours. The “offensive” use of OOS and related technology is not covered here. The “defensive” and “information gathering” roles are more related to conventional OOS applications – current projects from the US include rapidly deployable sensor networks to detect underwater intruders, data transmission via high-speed acoustic modem networks, upgrading and extending submarine detection systems and providing testing grounds for underwater weapons, vessels and detection systems.

10.2 Market Drivers

Since the end of the cold war the emphasis of the defence community has moved from the deepwater nuclear submarine threat to the shallow-water littoral zone, from submarine-launched nuclear attack to global terrorism. The US alone has 95,000 miles of tidal shoreline that are vulnerable to asymmetric attack.

Intelligence sources have reportedly raised concerns about Al Qaeda links with a Dutch scuba diving school and recent incidents have highlighted the vulnerabilities of ships and coastal sites to attacks of this nature. In March 2004 Hamas frogmen attacked an Israeli beachfront guard-post from the sea and in April 2004 oil rigs off the Iraqi coast were targeted by a number of small boats. The US Navy suffered the loss of 17 sailors when the *USS Cole* was attacked off Yemen in October 2000. The Sri Lankan Navy lost a number of vessels in 1995 when Tamil Tigers used suicide divers to attack ships.

The US and NATO countries are therefore developing solutions to perceived threats from the water. Their goal is to convert ocean observations into information and knowledge to support the war fighting needs of friendly nations.

The US military is by far the world’s largest prospective client for OOS. For example, in February 2006 the US Navy awarded Lockheed Martin \$144 million for continued development of the Advanced Deployable System (ADS), a rapidly deployable undersea surveillance system. The work is being performed under an option to a \$21 million contract awarded in 2004. Lockheed Martin will provide system engineering, detailed design and program management required to conduct a Detailed Design Review and build a system that will be deployed from a Littoral Combat Ship (LCS) for technical and operational evaluation. ADS uses distributed passive acoustic bottom-mounted arrays wirelessly linked to an analysis and reporting system to provide continuous acoustic coverage over large areas of the ocean. It is designed to detect and track modern diesel electric and nuclear submarines, as well as provide capability for tracking surface ships and detecting sea mine-laying activities. The ADS consists of four major sub-systems: analysis and reporting system; sensor; tactical interface; and installation support. This variant of the ADS will be designed to be embarked on the LCS and deployed from its deck. If all options of the ADS contract are exercised, the cumulative value will be \$243 million.

10.3 Developments and Trends

The US Office of Naval Research, in conjunction with the Naval Oceanography Program and the National Oceanographic Partnership Program (NOPP), has taken the lead in a number of OOS-related programmes including those mentioned above, as well as groups interested in technology miniaturisation and super-fast computing solutions. Miniaturisation of AUVs (and subsequently lower unit cost) would enable “swarms” of AUVs to be released as part of a sensor/detection network. Onboard computing would allow a reduction in the amount of information to be fed back by the acoustic modem system. The US Department of Homeland Security funds research into maritime security via the US Coastguard Research & Development Centre.

NATO’s ‘Defence Against Terrorism Programme’ includes a project relating to harbours and ships in order to protect against explosive-packed speedboats and divers using sensor-nets, electro-optical detectors, rapid reaction capabilities and unmanned underwater vehicles. Italy is leading this effort with the support of the NATO Underwater Research Centre (NURC). An example of a sonar system is the Coda Octopus Echoscope, which provides diver detection to protect ports and harbours has been undergoing trials at NURC with the UK defence science group QinetiQ.

Magnetic intruder systems are also in use – for example the Nautronix MariPro system utilises cables laid on the seabed to form elongated loop pairs. The transit of a ship over the loop distorts the earth’s magnetic field that produces a voltage at the loop terminals. This system is simple, low cost and very effective in areas where the threat to the cable loops by fishing activity can be mitigated. In general, radar is used to identify surface targets which have been detected. Detections without a radar contact are potential underwater threats. Operator interface can be as simple as a strip chart displaying the unique signature for each type of vessel transiting the loops.

Hydro-acoustic sensor systems have been developed with hydrophones positioned near the sound channel axis. Omni-directional low frequency units are cabled to shore where the signals are authenticated and passed over a satellite link to a processing site.

Certain types of surveillance systems require autonomous deployment. Cable-packing technologies facilitate completely autonomous deployment for remote, self-powered array systems, from a small vessel or AUV.

10.4 Utilisation of OOS

Underwater intrusion – protection of vessels in ports and harbours. This may take the form of a permanent installation using networked powered sensors, or a deployable solution consisting of buoy-mounted sensors, AUV and unmanned surface vehicles towing acoustic arrays.

Rapid environmental assessment – using AUV to map the approach to a shore landing site with regard to bathymetry, oceanic acoustic and temperature structure, minefield detection (and potentially finding a way through). Data is acoustically transmitted back to shore and the capability of launching an unmanned reconnaissance drone from the AUV has also been developed.

Sensor networks for testing the performance of military technology – a number of long-established ‘ranges’ exist worldwide.

Long-range acoustic monitoring of submarine activity – was referred to earlier.

10.5 Future Prospects

Global terrorism threats will keep the military complex focused on protecting the security of its assets (fixed and static). There is a clear drive for underwater intrusion detection systems of either a permanent or deployable nature. Military research has also occurred in acoustic modem development and the ability to control multiple underwater vehicles.

Unmanned surveillance vehicles and installations are being developed by the US in many shapes and forms, both airborne, surface and sub-surface. For example, Northrop Grumman recently demonstrated the RQ-4 Global Hawk's ability to support high-altitude maritime surveillance missions using a new integrated sensor suite. Recent tests showed that the system can track a vessel from 20,000m altitude. Global Hawk flies autonomously, well above inclement weather and prevailing winds, for more than 35 hours. During a single mission, it can travel more than 10,000 nautical miles from its take-off location and it provides detailed image-based intelligence on 40,000 square miles.²⁸

Recently, the US Navy has successfully tested an unmanned undersea vehicle (UUV) as a long-term mines reconnaissance system (LMRS). Operating from a submerged nuclear attack submarine (SSN), the system can operate for 40 hours at a cruising speed of approximately 7 km and at depths of between ten and 200 feet below the surface. The US Navy plans to purchase 12 systems at a unit cost of over \$100 million.

Airborne systems may integrate with in-water components of an OOS. An AUV or surfacing AUV may even provide launch and recovery platforms. The 13 inch diameter Micro Air Vehicle (MAV) could potentially be launched from a pod towed behind an AUV such as REMUS, as it has vertical take-off and landing capabilities. Called a ducted fan air vehicle, the MAV flies like a helicopter, using a specially designed fan enclosed in a duct that is driven by a gasoline engine. The fan draws air in through the top of the duct and expels it out of the bottom to provide thrust. The thrust produced by the duct and fan combination is powerful enough to enable the MAV to hover, as well as fly at speeds up to 50 mph (80 km ph).

Electro-optical scanning systems are also being developed for asset protection scenarios. For example, General Dynamics SPIDER and CEDAR²⁹ long-range intruder detection systems operate unattended and provide full, panoramic scanning. Using infrared and daylight imagery for automatic motion detection, the systems provide remote operators with real-time, high-resolution imagery and an audible alarm that indicates whether single or multiple objects have been spotted within their long-range scanning radius. CEDAR is designed for fixed installations, while SPIDER can operate as a stand-alone unit or be mounted on vehicles. Both systems are in full-rate production and in field use in military and homeland security applications. These systems may be integrated with HF radar installations as part of coastal defences.

The potential for such systems is considerable, but technology now exists (or is in development) whereby a vessel can come alongside or anchor in a foreign harbour and rapidly deploy an in-water sensor network. Complete with some offensive capability, alongside unmanned aerial surveillance that conduct patrols, or can be launched from roving AUV in response to a detected or perceived threat. Video and infra-red thermal images can be sent to a secure command post along with data from explosive and chemical agent “sniffers”. An electrified fence can be deployed to prevent boarders from the water and unmanned

²⁸ <http://www.auvsi.org/news/>

²⁹ http://www.export.gov.il/Eng/_Articles/Article.asp?CategoryID=710&ArticleID=2939

surveillance towers equipped with HF radar, video and thermal imaging equipment, can be deployed around the perimeter of and approaches to, the location.

The US Navy's partnerships with regional OOS agencies (GCOOS, NGLI, GOMOOS and ICON) has generated a tremendous amount of shared data that now requires a support structure of data management and modelling. With the existing knowledge of tidal currents and coastal circulation, the prediction and management of waterborne contaminants can now be packaged for a number of different user groups, with benefits ranging from improving homeland defence to increasing the number of recreational beach days.

11 Oil & Gas

11.1 Introduction

Global energy consumption has more than doubled over the past four decades, mostly being driven by demand from the developing economies such as China. It is likely that the era of cheap energy has ended – a situation which has profound implications for global economies and the marine industries.

Hydrocarbons (oil & natural gas) are currently the world's most important energy source providing 62% of global energy demand.³⁰ Oil is of particular importance as it is the fuel of transportation for which there is no short-term substitute. Oil demand is currently some 85 million barrels per day (b/d) and the IEA forecasts this demand will grow to 118 million b/d by 2025. However, many believe it is unlikely that this demand can be satisfied and that onshore oil production is close to its peak.

11.2 Market Drivers

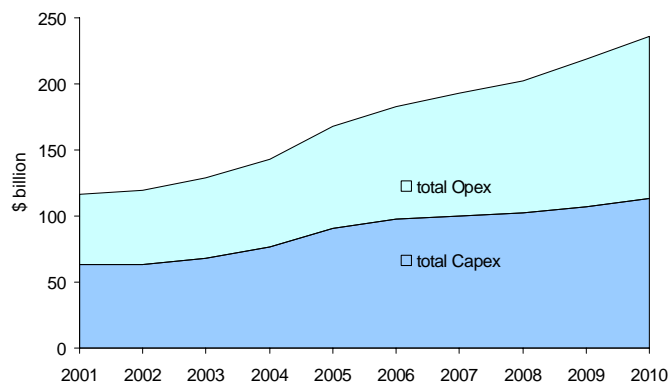


Figure 11-1: Offshore Oil & Gas Expenditure Forecast

Source: The World Offshore Oil & Gas Forecast (Douglas-Westwood)

Growing expenditure – high oil & gas prices mean that unprecedented amounts of money will be spent developing and operating offshore oil & gas fields. DWL forecast global offshore capital expenditure will grow from \$98 billion in 2006 to \$113bn in 2010.

Global operational expenditure is forecast to continue increasing from \$85 billion in 2006 to \$122 billion in 2010 as total production grows.

Environmental – the industry is subject to considerable pressures to show that it is not polluting the oceans and that in the event of an oil spill that this is tracked and quickly dealt with.

Security – offshore oil & gas installations are potentially important targets for terrorist attacks and local political dissidents, with major implications for national and international security of energy supplies.

“These days there is more willingness to spend on researching weather, currents etc. before a project starts as the use of asset managers to look after a project for longer periods means that the individual has greater interest in long-term viability of the asset. For deep water, data is now often acquired early to analyse deep currents which avoids over design of infrastructure. More projects are fast tracked these days which means we have to get metocean data much earlier in the project’s lifecycle.”

Metocean Manager, oil major, Europe.

³⁰ ‘BP Statistical Review of World Energy 2005’

11.3 **Developments & Trends**

We expect to see a continuing growth in world offshore oil and gas production. Our forecasts are that after 2010 all offshore oil production growth will come from deep waters, compensating for declining output from shallow waters. From providing around 34% of total global oil production in 2004, offshore oil is forecast to be providing 39% by 2015. From providing around 28% of total global marketed natural gas production in 2004, offshore gas is forecast to be providing 34% by 2015.

This, however, hides an underling problem. Production from shallow water regions is in decline (although many small fields remain). This has caused the major oil and gas companies to move to deepwater areas. As numbers of new shallow water fixed platform installations fall there is an increase in deepwater floating production systems and subsea production. Studies conducted by Louisiana State University's Centre for Energy Studies indicate that in the US Gulf of Mexico, an average of over 140 structures will be installed each year and that over 180 will be removed each year over the next two decades.

Attractive exploration prospects are decreasing as more of the world's offshore basins are explored. Most of the 'easy' offshore oil has probably been found and as a result increasing activity will be focused in remote deepwater and arctic areas which are subject to the full force of the ocean environment and the impact of changing weather patterns. A good case in point, West Africa, is emerging as the world's fastest expanding exploration and production regions with ultra-deep waters proving particularly prospective.

11.4 **Applications of OOS**

The major existing and potential applications of OOS in the offshore oil & gas sector include:

- environmental information for structural design
- improved information for removal of exploration and development platforms
- weather warnings
- iceberg watch
- security.

Environmental information – as installations are planned for more extreme environments there is a requirement to deploy systems to measure wind, wave and currents for input to the design of the offshore (increasingly floating) platforms. These systems may be retained on site throughout the life of an offshore facility and therefore in effect become a true ocean observation system. (More information is available in the environmental assessment and monitoring section of this report.)

Weather warnings – the 2005 hurricane season in the Gulf of Mexico demonstrated the impact of weather on the offshore oil & gas industry and the relevance of OOS. Hurricanes Rita and Katrina destroyed 111 offshore platforms, set adrift 19 rigs and damaged 44 pipelines shutting in 1.4 million bpd (barrels per day) of oil production and 8.8 trillion cubic feet of gas. From August 26, 2005 to February 22 2006, cumulative shut-in oil output was 130 million barrels, equivalent to 23.7% of the yearly Gulf of Mexico production. The cumulative shut-in natural gas production was 653 billion cubic feet, equivalent to 17.9% of the yearly Gulf of Mexico output.

Iceberg watch – in arctic waters, the emphasis moves to iceberg watch. This is a factor for installations off the east coast of Canada. (It will also be of importance to the developing operations in the Barents Sea

off northern Norway and Russia.) Currently, the International Ice Patrol (IIP³¹ – part of the US Coastguard) monitors iceberg danger in the vicinity of the Grand Banks of Newfoundland and broadcasts the southwards limits of all known ice. Because of frequent fog and poor visibility over the Grand Banks, IIP relies heavily on radar onboard aircraft for iceberg reconnaissance. Side-Looking Airborne Radar (SLAR) is the primary system used for this purpose. The IIP operates an aircraft on missions for seven days every other week. It takes approximately four flight days to investigate a 120 nautical mile swath along the entire area. Daily patrols are conducted using a parallel search pattern with 30 nautical miles track spacing and the SLAR range set at 27 nautical miles. An OOS for ice-berg watch purposes would have to include both underwater and above-water technology. Unmanned aerial drones such as those developed for the US military could provide an alternative to manned missions. Underwater, in-situ sensors such as (upward looking sonar, radar and satellite based remote sensing would form the basis of an iceberg-watch OOS.

Security – although offshore facilities are more secure than onshore ones, concerns over security are long-founded particularly in the North Sea, offshore Nigeria and the Middle East. Current developments include potential crossover from the US Navy’s ADS project (Advanced Deployable System) which includes a rapidly deployable combined acoustic sensor array and installation AUV for both security and monitoring purposes. Security patrols are well within the capability of such systems, especially when deployed with autonomous docking, downloading and recharging infrastructure that could be part of the OOS. HF Radar mounted on towers around an installation could be used to monitor surface current and wave activity, but would also provide surface vessel tracking/detection capability. The towers could also be equipped with infra-red thermal detection systems and video monitoring.

Future Prospects – as oil & gas exploration and development moves into deeper waters, new territories and remote areas, historical observations on meteorological and oceanographic conditions, as well as navigation information to allow safe passage, may need significant updating. Heavy equipment may need to be transported through relatively uncharted waters and hydrographic surveys may need to be carried out using surface vessels, or perhaps AUVs.

Currents can have massive effects on marine structures and, deep installations may need measurements to be taken over the full water depth. Acoustic Doppler Current Profilers (ADCP) will continue to develop and give higher resolution at greater ranges. Acoustic modem technology and developments in batteries and fuel cells allow sensors to be deployed at depth and remain in place until released by an acoustic command. Then communicate their data through the water without cables to a surface buoy equipped as a relay station. As part of a permanent OOS, data would be available in real-time from multiple powered sensors and the use of profiling sensors that travel up and down a mooring cable would be supported.

An OOS around an oil installation could not only provide data/power infrastructure for sensor data, it could also support AUV equipped with ROV capable of moving from a docking station to a remote location. Then perform maintenance or inspection tasks using the AUV as a “mother ship” for the ROV, before returning to its “home” node to recharge. Positioning of AUV and other in-sea equipment could be catered for by adoption of an underwater GPS style set of acoustic beacons, such as those developed by Nautronix – the NASNET system.³² The same technology would provide precise positioning for FPSO and other dynamically positioned vessels.

³¹ http://www.uscg.mil/lantarea/iip/FAQ/ReconnOp_10.shtml

³² <http://www.nautronix.com/>

12 Marine Renewable Energy

12.1 Introduction

The marine energy sector is dominated by oil and gas, but growth is beginning in offshore renewable energy and the competitive economics of this will greatly benefit from the increasing costs of fossil fuel (conventionally) generated power. This tiny new industry has the largest growth of any sector, with offshore wind having the greatest short-term growth prospects. There is also a wave and tidal power sector which is at an embryonic state of its development but has a number of advantages over other renewable energies. Although wave generated power is in its infancy, orders for installations are being agreed upon.

12.2 Market Drivers

Windpower – there is presently over 700 MW of offshore wind capacity installed worldwide across 20 offshore wind farms in the waters of seven countries. 96% of all existing installed capacity is in the countries surrounding the southern North Sea (Denmark, Germany, The Netherlands and the UK).

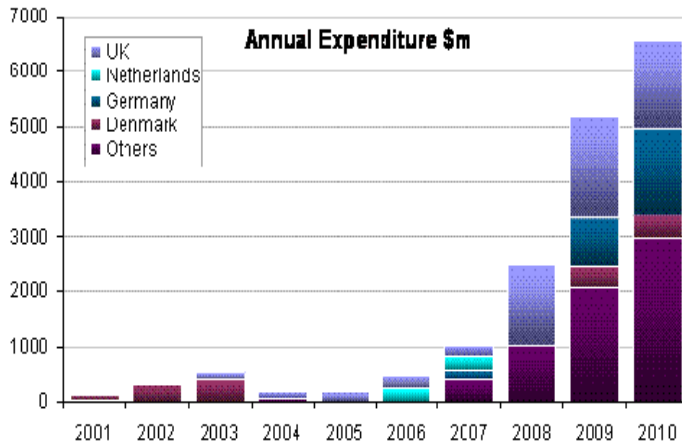


Figure 12-1: Offshore Windpower Capital Expenditure

Source: The World Offshore Wind Database (Douglas-Westwood)

The total global offshore wind capacity forecast for installation between 2006 and 2010 stands at 7.8 GW. The four southern North Sea countries make up 4.6 GW of this; over half the world market.

Wave & Tidal (WT) Power – 10 kW prototype current turbines are already operating and the concept of vertical axis turbines in a tidal fence is being pursued in Canada, with plans to install a 30 MW demonstration system in the Philippines. The global resource is very large, it is in close proximity to coastlines and many areas with high population densities.

OTEC – Ocean Thermal Energy Conversion systems use the ocean’s natural thermal gradient—the fact that the ocean’s layers of water have different temperatures—to drive a power-producing cycle. These systems are therefore restricted to tropical regions.

12.3 Developments & Trends

As the decade progresses we expect major investments offshore N E Canada and the US and China. Total annual expenditure will quickly grow at the end of the period reaching in excess of \$2.5 bn. At present European technology leads the world and their manufacturers are working on the challenge of reducing costs by the use of large 5 MW turbines involving increased distances from the shore and greater water depths.

12.4 Utilisation of OOS

Observation systems tend to be installed on a proposed site to evaluate the resource (e.g. wind, waves, tides and currents) for a year or so prior to the decision to go ahead with the construction project. In many instances these systems remain in situ after the project goes on line in order to measure output against the available resource, e.g. power output against wind.

Typical observation hardware for tidal power systems could consist of battery powered single or multiple ADCP mounted on an anchored mooring, with a surface buoy that has metrological sensors and radio/satellite capability. A number of such installations may surround the proposed site and could be connected to existing infrastructure to provide permanent power and data transmission. This is becoming more commonplace. HF radar can be used for wave and current studies in addition to in-water sensors.

The effect of scour on the foundations of wind-turbines (typically mono-pile) can be severe and ADCP monitoring of current activity could be backed up by inspection of the foundation area by a swath-bathymetry and video-capable AUV.

OTEC locations will need monitoring of oceanic temperature structure as part of site location and operation monitoring. OOS could provide the infrastructure to support acoustic control of inspection and maintenance AUV / ROV that may have docking nodes around the area.

12.5 Future Prospects

Present offshore windfarms typically consist of 30 turbines with a combined output of up to 90 MW. Future plans are for 200 turbine windfarms of 1GW. OOS may have an application for wind, wave and tidal monitoring and perhaps maintaining a large vessel exclusion zone around these installations.

As the wave & tidal renewables sector develops, projects will need OOS in place to support research into the effects of installations on tides, biology and sediment transport. In 2005, a prospective wave power generation site off Cornwall, UK, had a sensor package installed at a cost of \$120 thousand, in advance of final site selection. This is the first phase of “Wave Hub” which is due to be a UK testbed for wave energy generation.³³

³³ http://news.bbc.co.uk/2/hi/uk_news/england/cornwall/4214557.stm

13 Recreation

13.1 Introduction

Recreational water and coastal environment users will benefit from access to weather prediction and surface condition information from an OOS. However, in common with some other OOS applications this is a sector where the end-user expects the ‘product’ to be made available free-of-charge.

13.2 Market Drivers

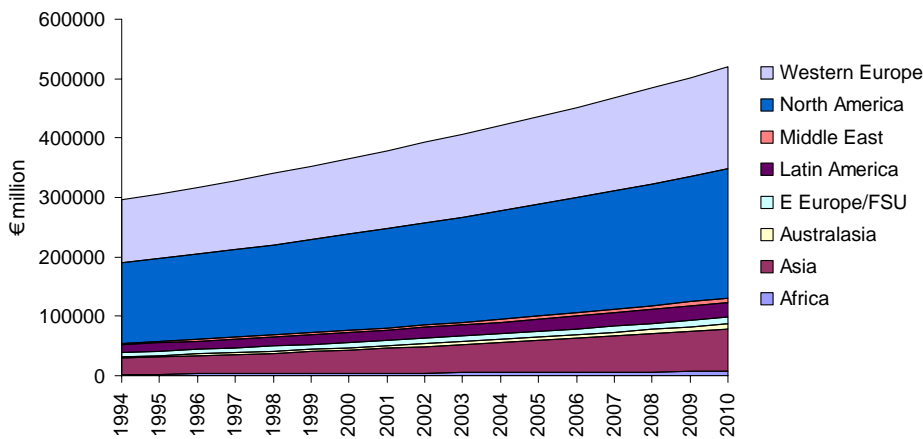


Figure 13-1: Marine Tourism – World Market

Source: Douglas-Westwood

Marine Tourism is one of the world’s largest marine markets and is likely to show high growth in future years. However, the sector is a difficult one on which to gain precise information as there are no international statistics that chart its value. Therefore, we take a view working from the global tourism industry as a whole and calculating a percentage for marine tourism. This approach has its limitations and at best can only deliver an approximation.

We estimate the world marine tourism market was \$235bn in 2005, 10.5% of all tourism expenditure. This is a very large value and how much of it should be ascribed to ‘marine tourism’ is a subject of much controversy as each sub-sector and associated agency has its own view.

The cruise industry is a sub-set of Marine Tourism. It offers large growth potential with major investments being made in cruise terminals worldwide. The world market is of the order of \$16bn; however, the total economic benefit is at least twice that value.

It is important to note that the total marine tourism figure does not take into account travel to and spending in, coastal areas, which if included would form a broad definition of the sector. Trying to narrow down the sector definition to include only such activities as cruise holidays, leisure boating, other water sports such as scuba diving, recreational fishing, etc., is more problematic as there is no internationally comparable information in this area that is readily available.

The market for information services is a by-product of OOS. Access to up-to-date, detailed weather and condition forecasts is valuable to those involved in: diving, power boating and personal watercraft, marine sight-seeing, wildlife-spotting, yachting, dinghy-sailing, swimming, canoeing and surfing. Beach and waterfront managers would also benefit from OOS-derived information in terms of water quality, or determining acceptable conditions for vessel rentals or events.

The largest and most affluent recreational boating market in the world is the United States, with over 77 million Americans engaged in boating activities. The global demand for recreational boats is estimated to reach \$23.7 billion by 2010, with the US contributing \$16 billion. The number of recreational boat registrations in the US has surpassed the 15 million mark, with annual growth expected to be approximately 2% over the next decade. By comparison, the 2nd and 3rd largest geographic markets are Italy and the UK, with boat registrations of less than one million each.

13.3 *Developments and Trends*

Weather prediction for specific activities has become more commonplace, verbal forecasts are often accessible through telephone services and the internet provides a wide range of forecasting services. Visitors can research most aspects of their holiday plans via the internet and this includes information on local weather conditions, pollution information and also views of beaches and surf conditions from webcams.

13.4 *Utilisation of OOS*

Some coastal regions already incorporate OOS in recreational information provision but formats vary. Many users may be unable or unwilling to interpret time series plots or plot their own based on data downloads, while some create their own forecast based on real-time data. Key data could include:

- Wave height and period
- Sea temperature
- Air temperature
- Wind speed and direction
- Sunshine
- Rainfall
- Tidal height.

These would be sourced from a combination of moored buoy and meteorological tower, perhaps with HF radar and satellite observations of sea surface temperature. Other data could include pollen count (for hay fever sufferers), or pollution indices. Delivery of forecasts and data would be through existing media (internet, TV, radio stations, newspapers).

13.5 Future Prospects

Water and coastal based recreation is a massive industry and the number of personally owned water-craft appears to be steadily increasing. Tourism has fluctuations like most industries and visitor figures to coastal resorts in the Pacific and Indian Ocean are expected to fully recover from post-tsunami levels, especially if OOS-based warning systems are brought on-line.

Laboratories-on-chips technology for automated monitoring and detection of e-coli and other contaminants could contribute to improved management of recreational beaches and also lead to an increased number of beach days.

Delivery of data and forecasts could be part of vessel management schemes – vessels transmit their identification and other details, which are logged by a monitoring centre. They then receive the latest navigation information, forecast and relevant shipping activity news, through an internet enabled electronic chart system connected to shore via radio or GSM (Global System for Mobile communications) data service (mobile phone technology).

14 Search & Rescue

14.1 Introduction

The Search & Rescue (SAR) application of OOS relates to location of survivors in the water, the management of personnel and resources, the detection and early warning of severe weather incidents and as part of long-term predictions. Real-time data can help the logistical support and effectiveness of long-range search and recovery missions.

14.2 Market Drivers

The US Coastguard budget for 2007 is in excess of \$7 billion. Japan's coastguard plans to spend in excess of \$2 billion in 2007.

Improved coastal forecasts can greatly reduce SAR costs. For example, the Great Lakes District of the USCG responds to more than 7,000 incidents a year, saving on average of 475 lives, along a 6,700 mile shoreline. The impact of a 1% increase in lives saved, translates into \$20 million saved through avoided loss of life. The USA has a 95,000-mile coastline.

14.3 Developments and Trends

Information Management – integrated information systems allow communication between geographically separated land control centres that may be dealing with different aspects of a marine rescue – for example, one centre may have radio contact with the survivors, but another is co-ordinating the response. SAR control centres in different countries often have to work with each others' personnel and SAR aircraft.

Drift Forecasting – during the time between call-out and arrival in the last reported position, survivors can be carried away from the area at speeds that vary depending on surface wind, wave and current activity. Models help determine this drift.

GMDSS – the Global Maritime Distress and Safety System (GMDSS) promises to bring major improvements to maritime safety and communications. GMDSS is an automated ship to shore distress alerting system that relies on satellite and advanced terrestrial communications links. The system also provides some limited ship to ship communications capabilities. Every ship subject to communications or the safety conventions must comply with GMDSS. These vessels include all passenger ships regardless of size and cargo ships of 300 gross tons and upward. GMDSS uses both satellite and terrestrial radio systems.

Distress Beacons – these emit a signal that can be detected by aircraft and satellites within the COSPAS-SARSAT system. The latest digital distress beacons reduce that radius of error down to just 5 km. In the US in 2005, the SARSAT system aided the rescue of 222 people in 93 incidents. Worldwide, the system has been responsible for 18,500 rescues since 1982.³⁴

³⁴ <http://www.sarsat.noaa.gov/>

Satellites – the European Galileo will provide a global Search and Rescue (SAR) function, based on the operational Cospas-Sarsat system. To do so, each satellite will be equipped with a transponder, which is able to transfer the distress signals from the user transmitters to the Rescue Co-ordination Centre, which will then initiate the rescue operation. At the same time, the system will provide a signal to the user, informing him that his situation has been detected and that help is under way. This latter feature is new and is considered a major upgrade compared to the existing system, which does not provide a feedback to the user.

14.4 Utilisation of OOS

OOS-derived data is crucial in developing models of predicted drift and expected location based on actual conditions. A combination of HF radar, current data and meteorological observations would greatly improve the success of such a system.

Existing SAR provision is sometimes not sufficient to cope with freak-waves or flash-floods. OOS data would be useful in determining the likelihood of severe weather events as a predictive modelling tool, or in the management of scarce personnel and resources.

The OOS could provide vessel tracking capability which has obvious benefits for SAR as well as for coastal security and management.

14.5 Future Prospects

Vessel tracking and monitoring via a combination of HF radar, GPS-based position reporting and video surveillance will enhance the capabilities of SAR organisations. OOS data on surface conditions will be available to shore-based co-ordination stations, SAR aircraft and surface vessels via satellite communications that can also transmit the result of drift forecasts.

The behaviour of vessels appearing on the radar screens of coastal navigation control centres may also become automatically analysed and the alert raised if the vessel is moving erratically or possibly without power. This may require the use of coastal video surveillance in addition to the OOS data on wind, wave and currents.

In the event of an oil spill or an accident at sea, GPS equipped, positioning reporting buoys can be deployed by low flying aircraft. These could act as targets for surface vessels to home in on, in addition to providing drift monitoring via the GPS and satellite communication function. Future units may be equipped with an acoustic array, or even have their own infra-red sensors that could help pinpoint survivors.

15 Education

15.1 Introduction

‘Education’ in its broadest sense ranges from kindergarten to graduate school and through to general public awareness as involvement in marine and coastal science is no longer restricted to graduates and researchers. Interest in the marine world, technology, exploration and marine life has been stimulated over the last two decades by Hollywood with films like “The Abyss” and “Titanic”, as well as projects funded by the Discovery Channel and National Geographic (amongst others). These projects have used ROVs or manned submersibles to provide video footage of dramatic undersea features such as geothermal vents, or to explore the remains of historic vessels. With the advent of internet enabled OOS, data (including video) can be sent from the ocean into the classroom and the daily lives of ocean scientists on or below the sea has become less of a distant experience.

15.2 Market Drivers

At the further education level, our research has identified 241 higher education establishments offering marine courses worldwide. However, it is difficult to estimate all the associated expenditure in this area as total operating costs of universities often greatly exceed fees charged. In addition, it is difficult to clearly separate the education element of universities’ activities from their research.

From a commercial point of view, all education and training has a strategic role in ‘marketing’ the supplier country and its technology to foreign students.

Potential markets, with education as an OOS application, include the creation of a dedicated OOS, probably in shallow water and covering a small area, but rich in terms of interactive function and content. For example, the “classroom under the sea” approach of the Rutgers Marine & Coastal Laboratory (US) is aimed at stimulating interest in the marine environment and has downloadable data, interactive activities and teacher’s resources. The data is presented as a by-product of academic research but having the education aspect may assist in funding applications for an OOS.

Ocean.US has been mandated by the National Ocean Research Leadership Council to take a leadership role in promoting education and awareness of ocean observing systems.

15.3 Developments and Trends

The expansion of broadband internet allows rapid access to data and satellite based remote sensing image products for many schools and educators. This facility is important in capacity building – planned and future OOS will only reach their potential if there is the scientific capacity within a community to interpret the results and to change the direction of a research programme if required. UN OOS programmes around the world all involve this capacity building stage.

15.4 Utilisation of OOS

Long-term involvement by local schools and colleges with an OOS would develop a sense of ownership and be useful for promoting environmental awareness. Primary education (ages 5-11) may find the interactive elements of use – perhaps a seabed crawler or ROV could be in the classes’ control (via the internet) for an hour or so. This could develop into examining the reasons for the OOS, how sensors work, problem solving, as well as looking at weather and wave activity.

15.5 Future Prospects

Education based on the data from and involvement with an OOS should have a good future, possibly with the education aspect being a useful by-product rather than a funding driver for the OOS. Providing the access necessary for community involvement is always beneficial in gaining acceptance for a project.

16 Future Prospects

16.1 Technology – Land and Sea

There have been no real ground-breaking changes over the last few years and the situation can be described as one of continuing evolution. Developments on the horizon are in the application of AUVs and fuel cells for powering them, adoption of HF Radar and the consolidation and growth of OOS infrastructure, including interfacing equipment to communication and power nodes at depth and improved computer processing power for modelling.

Response to the December 2004 tsunami should provide an increase in orders for sensors such as ADCP, HF Radar and tide gauges, the latter being also driven by the global rise in sea level, especially to replace existing obsolete technology (two thirds of the tide gauges in IOC projects in Africa are reported as not operational). Further miniaturisation of technology and the increase of data processing and analysis that can be completed in the instrument, with only the results being transmitted will assist researchers in many OOS areas, especially those involved in climate change, CO₂ exchange and fisheries.

Results from our interview programme show that many old established problems remain – the most desired improvements for ocean instrumentation is reduction in fouling from marine organism build-up.

Acoustic Doppler Current Profilers (ADCP)

Over the past decade, current profilers have greatly expanded the ability to make detailed current measurements in challenging field applications. ADCP measure the velocity of water using Doppler shift from the reflection of acoustic energy from particles in the water column. ADCP can be mounted vertically or horizontally and give water current motion at intervals out from the unit. ADCP can be mounted on the seabed, mooring, vessel or an AUV (where they can act as a means of measuring of travel speed and direction – then known as a Doppler Velocity Log – DVL). Highly accurate, single point ADCP also exists.

Autonomous Underwater Vehicles (AUV)

AUVs potentially allow access to all ocean depths and fuel-cell technology provides a capacity for great operational endurance, as does integration to OOS infrastructure for recharging and docking. AUVs are normally used to provide a mobile sensor platform, but some designs incorporate hovering capability, or the ability to ferry equipment to site and perform tasks with a manipulator arm or mini-ROV. AUV miniaturisation for expendable ‘swarm’ applications (particularly military) is ongoing, as is their development in assisting the deployment of sensor arrays. There is great potential for extending the cost-effectiveness of shipboard measurement campaigns via AUV-assisted operations.

Conductivity, Temperature and Depth (CTD)

CTD measurements are used to provide measures of temperature, salinity (via the variation of conductivity of water with salinity) and of the speed of sound through the water column. Knowledge of the speed of sound is crucial for acoustics-based measurement as found in the majority of hydrographic surveying equipment, or in acoustic detection applications (military and civilian). Salinity and temperature measurements are used to identify distinct water masses and are used to monitor the effects of climate change and upwelling events.

Current Meter - Mechanical

Mechanical current meters are used on moorings and give highly accurate current speed and direction measurements that can either be logged internally or sent via telemetry. They have a significantly lower unit cost than ADCP (\$5,000 vs. \$40,000) and they are often included on mixed ADCP/current meter moorings, or in academic research where ADCP may not be available. They can be deployed over the side of any size vessel and can be operated with no external power supply.

Current Meter – Electromagnetic

Electromagnetic Current Meters measure the voltage resulting from the velocity of water flow through a magnetic field, according to Faraday's law of electromagnetic induction. By using two sensor coils and a compass, the vector and hence the direction and speed of water travel can be obtained. These are used as single point sensors in locations where mechanical current meters would be inappropriate; in wave zones, low current regimes, very high flow regimes (where low drag and lack of moving parts permit practical deployment without concern for fragility) and for long deployments where memory capacity and user programmability are needed.

Drifters

Drifters consist of a surface float carrying GPS, satellite telemetry equipment and a large drogue (a canvas chute, or sail design) to insure that the drifter tracks the water movement rather than being blown by wind. The drifter also measures sea-surface temperature. Location and temperature are relayed over the Internet to scientists' computers in near real time. These simple and low cost units have been crucial in mapping the ocean surface currents and are still being deployed as part of hurricane model validation.

Expendable Bathythermograph (XBT)

XBT have been used by oceanographers for many years to obtain information on the temperature structure of the ocean to depths of up to 2,000m. The use of XBT has significantly increased over the past decade, especially from voluntary observing vessels (VOS). The XBT probe is designed to fall at a known rate, so that the depth of the probe can be inferred from the time since it was launched. By plotting temperature as a function of depth, a temperature profile can be rapidly obtained whilst the vessel is underway.

Floats

Subsurface floats are used to measure ocean circulation, as they sink to a predetermined depth and then tracked via an acoustic transponder. Development has led to floats that surface at regular intervals to update their position (via satellite), using bladders to control buoyancy. CTD sensors can be carried and their data transmitted autonomously such as in the ARGO float program. Floats are used to provide data for ocean circulation, ocean/air interaction and climate change research. A principal advantage of neutrally buoyant floats is their low cost, facilitating an extremely large geographic distribution with reasonable sampling density.

Fuel Cells

Fuel cells produce electricity through reverse electrolysis; an electrochemical reaction. This combines hydrogen and oxygen to form water vapour, heat and electricity. These by-products can be re-utilised by the fuel cell system. Water vapour may be captured and used as re-supply for additional hydrogen. The electricity is directed to an external circuit, where it is used as needed. Fuel Cells could be a way to power AUVs in a way that should reduce the bulk and weight associated with existing battery technology. Various types exist including Aluminium-Air, Lithium-Ion and Nickel Hydrogen.

Gliders

In-sea gliders are designed for substantial observational endurance and resolution on a vertical scale. They are distinct in providing a capacity for observations of parameter gradients along defined horizontal sections. Gliders migrate vertically (0-1,000m) through the ocean by changing ballast and they can be steered horizontally by gliding on wings at about a 35 degree angle. They generally broach the surface six

times a day to contact Mission Control via satellite and transmit their data. Speed is generally about 0.5 knots. Along their trajectory they may gather CTD or other data. Depth averaged and surface currents can be estimated from GPS fixes at the surface. Two-way communication via satellite provides an opportunity to adapt the sampling strategy in response to the data acquired in real-time.

High Frequency (HF) Radar

The rough surface of the ocean will reflect HF radar energy. By using two or more radar stations, the direction, speed, height and period (time between successive wave crests) can be obtained. HF radar uses the 3-50MHz band. Rain or fog does not affect HF signals. These systems are being installed as part of coastal OOS in the US and have applications in surface condition monitoring and current mapping. Developments include the use of HF radar for tracking vessels in addition to waves and currents. To improve the range of detection for smaller vessels, new super-directive compact antennas are being constructed and tested.

Moorings

For long-term observations, oceanic moorings are used as a structure on which to mount sensors. Typically, they consist of a surface float (with GPS and satellite telemetry) connected via a steel cable to an acoustic release unit and then an expendable weight. Sensors are mounted at intervals along the cable – (CTD, ADCP, fluorimeters, plankton sensors, etc.) and these are normally battery powered. In an OOS where real-time data is desired, sensors could relay data to the satellite telemetry unit via wire or acoustic modem for onward transmission. The mooring could have power/data communication directly from the OOS if available. Instrumented moorings are well suited for long-term observations.

Remotely Operated Vehicles (ROV)

ROV are the underwater workhorses of industry and academia. Normally they are deployed from a surface vessel and are controlled/powered via a multi-cored umbilical cable. They range in size and complexity from the “eyeball”, a beach ball-sized observation ROV, to 6,000m rated 3 tonne “workclass” ROVs used mainly by the offshore oil & gas industry. There have been moves to allow academics to time-share the use of industrial ROVs when they are not scheduled for work projects. A development that could be very pertinent to OOS is the ability of an AUV to “piggyback” an ROV to a remote power/data node within an OOS and then act as a base for the ROV to undertake a maintenance or installation task, before being brought back by the AUV to a central point.

Tide Gauge

Traditionally, global sea level change has been estimated from tide gauge measurements collected over the last century. Tide gauges, usually placed on piers, measure the sea level relative to a nearby geodetic benchmark. The most commonly used tide gauge measurement system is a float operating in a stilling well. Modern systems are often quartz or silicon pressure sensor based, are highly portable and easily deployed. They are either self logging or have a radio telemetry output.

Towed Undulating Recorders (TUOR)

TUOR constitute an important platform for integrating chemical and physical measurements with biological measurements, as they can carry sensors such as plankton samplers alongside CTD and nutrient analysers. They can be programmed to profile to depths of 500m, or with a shallower profile range at speeds up to 25 knots. Future TUOR may be able to be towed by automated surface craft. The ability to sample from a range of depths while underway is a major benefit for vessel operators.

Volunteer Observing Ships (VOS)

Observations from a variety of merchant, fishing, military and research vessels have been provided through the WMO Voluntary Observing Ships (VOS) program for over two hundred years. With the

availability in recent years of more reliable satellite data, the importance of VOS data for numerical weather prediction (NWP) has declined. However, the VOS data remain critical for climate studies and are a mainstay of a number of key international global climate datasets. For example, in recent years European National Meteorological Services have cooperated to develop the EUMETNET Composite Observing System (EUCOS) and its surface marine program E-SURFMAR. This has resulted in a decrease in observing activity with a reduction in the number of VOS but in an increase in the use of automatic weather measurement systems (AWS on VOS). One such type of observing system is AVOST (Automatic Volunteer Observing Ship System) developed by AXYS Technologies Inc. of Canada. The AVOST system collects meteorological or oceanographic sensor data automatically, allows for user observed data input and transmits the data via INMARSAT (or other forms of telemetry) as required. The data are collected and transmitted following MANMAR and WMO FM 13 formats.

16.2 Satellites

Satellite Based Remote Sensing

Committee on Earth Observation Satellites (CEOS) agencies are operating or planning around 170 satellites with an Earth observation mission over the next 15 years. At the start of 2005, 68 earth observation satellites were operating. We believe that there are at least 38 satellites (operating, approved or planned) involved in ocean measurements. Over 20 of these satellites in current operation that may be said to have either partial or complete dedication to ocean observation. There are at least 25 further missions planned that have at least some ocean observing capability. Observations obtained via satellite include ocean colour (from which chlorophyll concentration is obtained), sea surface height, wind field, temperature, dust and aerosol optical thickness. Satellite observations constitute the most potent capability for integrating global observations of the upper ocean. Although they generally provide little information on the ocean interior, the global extent of coverage greatly outweighs this limitation. The global coverage that is unique to satellite-borne sensors provides a powerful capability for integrating and constraining other observations and model results.

The Group on Earth Observations (GEO) is to build the Global Earth Observation System of Systems (GEOSS) with a ten-year implementation plan. GEOSS aspires to encompass all areas of the world and to cover in situ, airborne and space-based observations.

At a European level, several collaborative activities make use of ocean satellite data or at least are intended to facilitate its use. Global Monitoring for Environment and Security (GMES) is a joint initiative of the EU and European Space Agency. In much the same way as GCOS, it exists to bring data and information providers together with users so that information can reach the people that need it and it is intended to be the European part of GEO. An example of its activity is the Marine Environment and Security for the European Area (MERSEA) project. This is an EU 6th Framework funded programme intended to develop a system for operational monitoring and forecasting of ocean physics, biogeochemistry and ecosystems on a global and regional basis. The latest funding is €14 million for three years (2004-7). As well as being a European input to GMES it is also the European contribution to GODAE. This project does not fund satellite operations but exists to facilitate the distribution of output. In 2004 FP6 funding for satellite communications and GMES projects was €60 million.

Continuity and improvements in many ocean measurements have been assured with the launch of missions such as Envisat and Aqua. SMOS (2007) and SAC-D/Aquarius (2008) which are worthy of special note since they will provide new capabilities for measurements of ocean salinity. Ocean surface wind and topography measurements – pioneered by the Topex-Poseidon and ERS missions – will be continued operationally by sensors on the METOP and NPOESS series.³⁵

Ocean Observing Satellites

Background

Satellite technology has revolutionised the ability of scientists, governments and business to observe the oceans and atmosphere and their interaction (the latter being the key process driving our weather and climate). Because scientists have made great progress in developing numerical modelling techniques to describe the nature and interactions of the ocean and atmosphere, the increased amount of data available

³⁵ http://www.eohandbook.com/eohb05/ceos/part3_3.html

has transformed forecasting. As the main source of inaccuracy is now believed to be uncertainty about the initial state of the model (i.e. a lack of good observations), satellite data is a key way of reducing this uncertainty and improving weather forecasting capability. Another significant improvement in modern satellites is the speed with which data are transmitted to users, as, alongside data availability and quality, speed of access to data is the critical factor in making effective use of satellite data in forecasting. Current missions such as Envisat provide near real-time access to data.

Organisation/Companies Spending the Money

The large capital expenditure requirements for satellite launch mean that Government organisations fund rocket construction and launch activities with Government, research and commercial organisations providing the satellite and instrumentation. Europe and the US have launched the majority of weather/earth observing satellites with others being launched by Russia, India, Korea, Taiwan and Japan. In the US, the primary funding is by Government through NASA, NOAA, the National Science Foundation (NSF) and the DOD. The sheer number of different missions and funding bodies in the US has led to repeated calls for the satellite programme to be rationalised (most recently during a US National Research Council enquiry into NASA's budget – see below).

NOAA has collected an inventory of all its observing systems and created the NOAA Observing System Architecture to document and identify ways to evolve them in an integrated manner. So far, NOAA has identified 102 separate observing systems that measure 521 different environmental parameters. NOAA plans to use this document to help integrate its systems with other agencies and international programs.

In Europe, the main organisation spending money is EUMETSAT, a collaborative grouping of 18 nations based in Darmstadt, Germany and the European Space Agency (ESA). In all countries there is a wide variety of organisations involved in the subsequent supply chain.

Satellites may occasionally be on a single mission for a single customer (e.g. Geosat was primarily for the US Navy), but increasingly they are launched as part of a wider framework. These frameworks can be simply as part of a collaboration at a technical level (e.g. the European Metop mission will be specifically intended to link to the NOAA Polar Operational Environmental Satellites (POES) or as part of a wider collaborative effort to integrate multiple observing, data, processing, modelling and dissemination capabilities (as discussed above).

International collaboration agreements include both construction of satellites and instruments as well as ground controlling, signalling and data exchange. As an example, the Indian Space Research Organisation recently concluded an agreement with the Indonesian National Institute for Aeronautics and Space (LAPAN) for satellite tracking and communication.

In an ideal situation a mixture of geo-stationary and polar orbiting satellites should be used for environmental observing, especially when used for operational weather forecasting. NOAA's operational network of satellites is described as GOES (Geostationary Operational Environmental Satellites and POES (Polar Operational Environmental Satellites). Hitherto European weather/earth observing satellites have tended to be placed in geostationary orbits but Eumetsat has agreed to share polar-orbiting meteorological satellite duties with the U.S. government. The Metop mission will place a satellite into a polar orbit in conjunction with the NOAA POES satellite. Together they will provide complementary orbits ('morning' and 'afternoon') and will provide maximum coverage – this further illustrates the trend toward collaboration.

Satellite instrumentation is also increasingly international, with, for example, the latest Metop satellite having five new European instruments, five US (NOAA) instruments of existing design, one instrument

of French design, French Search and Rescue (SAR) processing and Canadian SAR communications equipment.

Capex (Current and Future)

The NASA budget for earth science for 2004 was \$5.5 billion and was expected to grow to \$7 billion in 2008. Latest indications (June 2006) indicate that the budget is under pressure, with cuts expected that will reduce expenditure to \$5.38 billion in 2008. This has had the effect of putting pressure on the US earth science satellite programme. Missions cancelled include 'Hydros' (\$200 million soil moisture measurement) and Deep Space Climate Observatory (\$100 million energy balance observation). Missions delayed include the Global Precipitation Measurement (GPM) and GIFTS (Severe storm data gathering). In addition, at a recent (June 2006) meeting to discuss the US National Polar Orbiting Environmental Satellite System (NPOESS), the budget of \$11.5 billion was put under pressure and the project is most likely to be delayed. Also, the next round of proposals for earth-centred missions will now not be considered until 2008. Perhaps most worrying for earth science, a proposed cut of 20% in earth-science R&D will hit smaller scale projects, many of which analyse the data from satellites and also companies adding value to this data in the commercial market.

As a comparison, the NOAA budget for the same year (2004) was \$3.336 billion. Of this, \$837 million was for satellite programmes, of which \$391 million was for polar orbiting satellites (\$124 million for existing satellites) and \$277 million for geo-stationary satellites, of which \$104 million was for new developments.

In 2006, NOAA budgeted \$321 million for NPOESS (an amount matched by the Department of Defence) and \$240 million for GOES – R.

According to Retired Navy Vice Adm. and now the Undersecretary of Commerce for Oceans and Atmosphere, Conrad C. Lautenbacher, there is \$95 million in net increases to support requirements for NOAA's role in building an integrated earth observing system. Included in this is a net increase of \$52.6 million for the Geostationary Operational Environmental Satellites to maintain continuity for this critical observing technology and \$16.1 million for the NPOESS to ensure the first satellite is available for launch in 2010.

A satellite programme that illustrates the collaborative nature of modern weather and climate missions is COSMIC. Designed to monitor hurricanes, typhoons and storms over the oceans, as well as a number of other weather phenomena, COSMIC is a \$100 million project for the establishment of six satellites. It is a joint project between the US NSF (£20 million) and Taiwan's National Science Council and National Space Organisation (\$80 million) and involves NASA, NOAA, the US Air Force, the Office of Naval Research and the US DOD Rocket Launch Program.

EUMETSAT has a budget for its MSG Programme of €1673 (at 2003 prices) for its activity up to 2015.

The UK National Met Service (Met Office) has a turnover of £160 million. Of this, all except around £20 million is funded through the sale of services to UK Government departments. The Met Office CAPEX for contributions to EUMETSAT in 2004/05 was £18 million (directly attributed to Meteosat Second Generation, MSG), with £2.2 million towards non-satellite costs of EUMETSAT. Total Met Office investment in the satellite programme has been £175 million (currently 'booked' at a value of £61 million). This is the UK contribution.

It must also be borne in mind that satellite missions are vulnerable to funding cuts, technical problems and accidents. Instruments fail, rockets explode and funds are withdrawn. As examples, in June 2003 the onboard tape-recorder for the altimeter on ERS 2 failed, but fortunately ENVISAT was able to take over;

in 2005 TOPEX/Poseidon failed (although well after its expected life); the first three satellites of the Indian SROSS programme all failed in the late 1980s and early '90s. CRYOSAT 1 was destroyed on launch in 2005 (at a cost of \$170 million).

Future Direction

As mentioned above, the pattern for the future sees increased collaboration between nations and within nations. In the US both NOAA and NASA operate their own civilian, space-based EO programmes that include an ocean-observing remit. NOAA concentrates on sustained, operational measurement and prediction of environmental parameters for weather and climate. NASA concentrates on research and sensor development and does not plan for the operational observing needs beyond the life of the mission. The table below shows some related launches under the current system but in its recent report the US Commission on Ocean Policy recommended to the US Congress that NASA's EO satellite programme be transferred to NOAA for operational control, with R&D and engineering retained by NASA.

Whilst NASA operates the current fleet of three EO spacecraft (Terra, Aqua and Aura) and many of the smaller, instrument-specific missions, it is not intending to replace the main three. As discussed above, the main polar-orbiting programme (NPOESS) will be a joint effort by NOAA, NASA and the Department of Defence (DOD). Increasingly NOAA will take the lead as the GOES – R programme begins.

Commercial Exploitation

The commercial exploitation of EO satellite data in Europe and Canada was surveyed in 2004 by ESA.³⁶ The estimated total revenue from these services was €285 million (\$317 million) 2002, with an additional €25 – 30 million (\$32-38 million) from image sales. 78% of sales were marketed to Government and other public sector clients.

Global Satellite Navigation Systems

There are complementary and/or alternative systems to GPS existing and under development including the Russian Glonass and European **Galileo** programme.

- **Global Positioning System.** The US GPS system was completed in 1993 with a full constellation of 24 satellites. These all transmit a signal that contains the position of the satellite and an atomically accurate time-stamp. By observing multiple satellites, the receiver can deduce its position in 3-D. Various ways of using GPS data exist to improve the accuracy of positioning, but basic positioning is normally all that is required for OOS applications (not navigation).
- **Glonass**, the Russian system, became fully operational in 1993 and in July 2006 13 satellites were operating. In 2004, India reached an agreement with Russia to jointly develop the Glonass global navigation satellite system. Under the agreement, India will become the sole partner of Russia on Glonass development, replenishment and future use and the Glonass satellites can be launched from India or Russia using either Indian or Russian launch vehicles. The Glonass system is expected to be fully operational by 2007 (meaning that at least 18 satellites will be in orbit) and would then be available for use by civilian and military users in both India and Russia.
- **Galileo** will be Europe's own global navigation satellite system, providing a highly accurate, guaranteed global positioning service under civilian control. It will be inter-operable with GPS and Glonass, the two other global satellite navigation systems. A user will be able to take a position with the same receiver from any of the satellites in any combination. By offering dual frequencies as standard, however, Galileo will deliver real-time positioning accuracy down to the

³⁶ The State and Health of the European and Canadian EO Service Industry – ESA, VEGA, Booz, Allen and Hamilton – August 2004.

metre range, which is unprecedented for a publicly available system. The fully deployed Galileo system will consist of 30 satellites (27 operational + 3 active spares). According to various published reports, the European Galileo satellite navigation system will cost between 3.5 to 4 billion euros (\$4.5–5.2 billion.) There are good reasons to believe that this cost estimate is way too low.

17 Conclusions

OOS is a major market – based on identified programmes, we value the global market for ocean observation systems at some \$1.8 billion in 2006 and existing programmes will result in growth to \$2.2 billion by 2011. With increasing growth and the impact of the market drivers, in particular the response to global warming, we expect total forecast expenditure to grow significantly, perhaps to \$2.4 billion by 2011. This may in time prove to have been too conservative a view.

The U.S. is the world's largest ocean industries player with estimated annual expenditures of \$750 billion in 2002. One-half of these expenditures are generated by the oil & gas industry and one-third is attributed to the Navy.³⁷ US federal expenditures for OOS have been estimated at \$1 billion in 2006.³⁸ However, we estimate that total US expenditure is closer to \$1.2 billion.

An essential tool – Ocean Observation Systems are essential for the ocean-user community – in other words all of us – and without doubt are fundamental to increasing the understanding of the oceans and their role in climate change. As this realisation becomes more widespread we believe that OOS will receive more funding from governments worldwide and the commercial opportunities for the supply chain will grow accordingly.

It is also useful to think about prospective further work:

- Develop a strategy to address the opportunities offered by the OOS market – this must acknowledge and address the strengths and weaknesses of Canada in the sector.
- Focus on identified technology needs
- Develop standards – there is a great need for OOS standards. Could Canada take a lead?

³⁷ Dr. Andrew Clark, President, Marine Technology Society, in a presentation to the President's Commission on Ocean Policy, Nov. 13/01; and also stated in the Ocean Commission presentation "Technology & Marine Operations: Strategy for Technology Development to Meet the Nation's Needs", Nov. 2002 [www.ocean.commission.gov/documents].

³⁸ Mike Hemsley, Dep. Dir., Ocean.US.

18 Appendices

18.1 Sector Definitions

Application	Real-time	Multi-parameter	Comment
Academic Research	Y	Y	Multi-discipline scientific user base
Coastal Zone Utilization	?	?	Planning & management - long-term sea level changes, sediment transport (viewed using CODAR radar systems)
Education	Y	Y	Seabed networks "bringing the ocean into the classroom" via the internet.
Environmental Assessment & Monitoring	Y	Y	Oil spills, pollution tracking / prediction
Fisheries & Aquaculture	Y	Y	Coastal upwelling leads to plankton growth. Interruption to upwelling (El Nino) causes chaos
Hazard Warning	Y	Y	Tsunami & hurricane warning systems
Marine Safety & Security	Y	Y	In port and underway - underwater sensors, satellite tracking
Marine Transportation	Y	Y	Best route from A to B based on predicted weather, etc
Military	Y	Y	Offensive - beach landing mapping, mine detection and clearance. (Not generally included in this study.). Defensive - intruder detection, underwater or surface.
Offshore Activities	Y	Y	Oil & gas, renewables, construction - may have own observation network around key infrastructure. Or buy-in satellite imagery for ice movements
Recreational	?	?	Beach, yachts, fishing, etc. Use prediction, routing services
Search & Rescue	Y	Y	Satellite beacons, forecast of drifting based on the conditions
Vessel Tracking	Y	Y	Using satellite imagery (and radar and AIS?) as part of integrated systems
Weather and Sea State Prediction	Y	Y	Metrological agencies / weather services (e.g. impact of successful weather prediction on agricultural economics)

Notes:

The above are applications, not systems which can be multi-application.

18.2 Interviewees

Company/Organisation	Country
2wcom GmbH	Germany
AOOS	USA
ASL Environmental Sciences	Canada
AW-Energy	Finland
Canadian Centre for Marine Communications (CCMC)	Canada
Canadian Space Agency	Canada
Channel Coastal Observatory	UK
CLIVAR	UK
CLS (Collecte Localisation Satellites)	France
Coda/ Octopus	UK
DFO	Canada
Dubai Municipality	Dubai
Ecuador Navy	Ecuador
EMU Survey	UK
Fugro Oceanor	Norway
Geodata Institute, Southampton University	UK
Gill Instruments	UK
Ice Cube project, University of Wisconsin-Madison (UWM)	USA
IGOC (a UNESCO department)	France
Institute. of Marine Sciences	Tanzania
Instituto Canario de Ciencias Marinas	Canary Island, Spain
Japan Meteorological Agency	Japan
Kongsberg	Norway
L - 3 Communications	USA
Liverpool Bay Coastal Observatory	UK
Marine Ecological Surveys	UK
Maritime Warfare Centre (MWC)	UK
Middle East Technical University	Turkey
Monterey Bay Aquarium Research Institute	USA
NASA/JPL	USA
National Marine Environment Forecasting Center	China
NAVOCEANO - Stennis Space Ctr.	USA
NCOF (National Centre for Ocean Forecasting)	UK
NIWA	New Zealand
NOAA	USA
Ocean Numerics	UK
Ocean. US	USA
Oceanographic Commission IOC, part of UNESCO	France
Pacific Gyre Inc.	USA
PacIOOS	Pacific Islands
Plymouth Marine Laboratory (PML)	UK
SCRIPPS	USA
Shell (Metocean)	Netherlands
Sonardyne	UK

Company/Organisation	Country
Southern California Coastal Water Research Project (SCCWRP)	USA
Stema Survey	Netherlands
SUT	UK
Texas A&M University	USA
Tropical Atmosphere Ocean project	USA
University of North Carolina	USA
University of Victoria	Canada
University of Wales, Bangor	UK
Western Australia GOOS (WAGOOS)	Australia

18.3 OOS Programmes, Projects, Organisations & Acronyms

Table 18-1: OOS Satellite Programmes

Satellite Programmes	Acronym/Web Link
Constellation Observing System for Meteorology	COSMIC/FORMOSAT-3
Cryosat	CRYOSAT
Cryosat	CRYOSAT2
Earth Clouds Aerosols and Radiation explorer	EarthCARE
Earth Explorer Atmospheric Dynamics Mission	ADM-Aeolus
Environmental Satellite	ENVISAT
GEOdetic SATellite	GEOSAT
Geostationary Satellite Server	GOES-R
Geostationary Satellite Server	GOES-N
Geostationary Satellite Server	GOES I-M
Geosynchronous Imaging Fourier Transform Spectrometer	GIFTS
Global Precipitation Measurement	GPM
Gravity Field and Steady-State Ocean Circulation Explorer	GOCE
Indian Remote Sensing Satellite	IRS-P3
Jason	JASON
Jason	JASON 2
Magnetic Field Mission	SWARM
Megha-Tropiques	Megha-Tropiques
Meteorological Operational satellite programme	METOP
Meteosat 1st Generation	MeteoSat
Meteosat 2nd Generation	MSG
Meteosat 3rd Generation	MeteoSat
National Polar-orbiting Operational Environmental Satellite	NPOESS
Ocean Surface Topography Mission	OSTM
OCEANSAT 3	OCEANSAT3
Sea Surface Salinity	ESSP/Aquarius
Soil Moisture and Ocean Salinity	SMOS
Topex/Poseidon	Topex/Poseidon
Tropical Rainfall Measuring Mission	TRMM

Table 18-2: OOS Ocean Programmes

Ocean Programmes	Acronym/Web Link
Alaskan OOS	AOOS
Astronomy with a Neutrino Telescope and Abyss environmental RESearch	ANTARES
Atlantic Network of Interdisciplinary Moorings and Time-series for Europe	ANIMATE
Atlantic Zone Monitoring Program	AZMP
Australian OOS	AOOS
Autonomous Ocean Sampling Network	AOSN
AVISO	AVISO
Baltic Operational Oceanography System,	BOOS
Black Sea GOOS	BLACKSEAGOOS
Cabled Regional Observatory Workshop	CROW
Carolina Reef Ocean Observing and Prediction-USC	Caro-COOPS
Center for Integrative Coastal Observation, Research and Education	CI-CORE
Central and Northern California Ocean Observing System	CeNCOOS
Central Gulf of Mexico Observing System	CenGOOS
Channel Coastal Observatory 2003	CCO
Chesapeake Bay Observing System	CBOS
Coastal Ocean Currents Monitoring Program	COCMP
Coastal Ocean Monitoring Network for West Florida	COMPS - West Florida
Coastal Ocean Observing System	C-GOOS
Coastal Ocean Research and Monitoring Program (UNCW)	CORMP
College of Marine Sciences	College of Marine Sciences
Cook Inlet Coastal Monitoring and Habitat Program	Unknown
Coral Reef Targeted Research and Capacity Building for Management - Coral Reef Early Warning System	CREWS
Current and future scenarios the carbon balance in Europe	CARBONDATA
Current and future scenarios the carbon balance in Europe	CARBONEUROFLUX
Developing Arctic Modelling and Observing Capabilities for Long-term Environmental Studies	DAMOCLES
Dubai Coastal Zone Monitoring Programme	Dubai Coastal Zone Monitoring Programme
Early Tsunami Warning System	Unknown
Economic and Social Science Research	Economic and Social Science Research
Estimating the Climate and Circulation of the Ocean	ECCO
European Directory of the Ocean Observation System	EDIOS
European Environment Information and Observation Network	EIONET
European Space Agency (Earth Observation Program)	ESA (Earth Observation Program)
Forecasting Ocean Assimilation Model	FOAM
Geostationary Satellite Server	GOES
Global Ocean Data Assimilation Experiment	GODAE
Global Terrestrial Network for Permafrost	GTN-P
Great Lakes Ocean Observing System	GLOS
Gulf of Maine Ocean Observing System	GOMOOS

Ocean Programmes	Acronym/Web Link
Gulf of Mexico Coastal Ocean Observation System	GCOOS
Gulf of Mexico Coastal Ocean Observation System Regional Association	GCOOS-RA
Indian Ocean Tsunami Monitoring and Warning System	IOTWS
Indian Ocean Tsunami Monitoring and Warning System	IOTWS
Integrated Ocean Observing System	IOOS
International Nusantara Stratification and Transport	INSTANT
IOC Sub-Commission for the Caribbean & Adjacent Region	IOCARIBE
Japanese Tsunami Warning Centre	Japan Tsunami Centre
Joint Australian Facility for Ocean Observing Systems	JAFOOS
Joint Institute for Marine Observations	JIMO
Long Island Sound Coastal Observing System	Long Island Sound Coastal Observing System
MarCOAST	MarCOAST
Mediterranean GOOS	MEDGOOS
National Buoy Data Centre	NBDC
National Oceanographic Partnership Program	NOPP
National Undersea Research Program	NURP
National Water Level Observation Network	NOAA NWLON
Network for the Detection of Stratospheric Experiment on Ozone	NDSC
North Carolina Coastal Ocean Observing System	NCCOOS
North West Shelf	NOOS
Northern Gulf of Mexico Littoral Initiative	NGLI
Ocean Observations Initiative	OOI
Ocean Research Interactive Observatory Networks	ORION
OCEAN Sustained Interdisciplinary Timeseries Environment observation System	OceanSITES
OPTIMET	OPTIMET
Pacific Island OOS	PacGOOS
Partnerships for global ocean observation	POGO
Peruvian Programme for El Niño	NAYLAMP
Physical Oceanographic Real-Time System	PORTS
Polar Operational Environmental Satellites	POES
Regional Ocean Observing and Forecasting System Africa	ROOFS-AFRICA
SeaSearcher	SeaSearcher
Ship of Opportunity Programme	SOOP
South Atlantic Bight Synoptic Offshore Observation Network	SABSOON
South East Asia GOOS	SEAGOOS
Southeastern Atlantic Coastal Ocean Observing System	SEACOOS
Southern African Data Centre for Oceanography SADCO	SADCO
Study of Environmental Arctic Change	SEARCH
SURA Coastal Ocean Observation program	SCOOP
The Automated Shipboard Aerological Programme	ASAP
The West Indian Ocean Marine Applications Programme	WIOMAP
Tsunami Early Warning System	Unknown

Ocean Programmes	Acronym/Web Link
US Navy SOund SURveillance System	SOSUS
US Tsunami Warning Program	US Tsunami Warning Program
Wallops Ocean Observation Project	WaCOOL
Water Quality Monitoring - Cook Islands	Unknown

Table 18-3: OOS Projects

Projects	Acronym/Web Link
A Regional Capacity Building and Networking Programme to Upgrade Monitoring and Forecasting Activity in the Black Sea Basin	ARENA
Advanced Deployable System	ADS
Aloha Mooring	ALOHA
Antarctic Muon and Neutrino Detector Array at the South Pole	AMANDA
ARGO Home	ARGO
Astronomy with a Neutrino Telescope and Abyss environmental RESearch	ANTARES
Baikal Neutrino Detector	BAIKAL
BlueLINK	BLUELINK
Bodega Ocean Observing Node	BOON
Bonne Bay Observatory	BBO
Coastal Bethic Observatories	COBO
Cooperative Ocean Observing Experiment	COOE
Data Buoy Cooperation Panel	DBCP
Deep Ocean Assessment & Reporting of Tsunami	DART
Deep Underwater Muon and Neutrino Detection	DUMAND
Detection and classification of marine traffic from Space	DECLIMS
Geophysical and Oceanographic Station for Abyssal Research	GEOSTAR
Hawaii-2	H2O
ICECUBE	ICECUBE
Improving Fisheries Monitoring by Integrating Passive and Active Satellite Technologies	IMPAST
Indian Ocean Moored Array Project	I-MAP
Indian Ocean Tsunami Warning System	IOTWS
Irish Weather Buoy Network	IWNB
Kuwait EPA	KEPA
Laboratory in the Abyss of Europe with Real time data Transfer to shore for Interdisciplinary Studies	LAERTIS
Landsat Data Continuity Mission	LDCM
Malaysia Tsunami Warning System	MTWS
Marine Environment and Security for the European Area	MERSEA
MENAI Database	MENAI
Mercator Ocean	MERCATOR
MERIS	MERIS
MetNet	MetNet
MFSTEP - Mediterranean Forecasting System for Environmental Predictions	MFSTEP
Minerals Management Service (drifters)	MMS
MODIS	MODIS
Monterey Accelerated Research System	MARS
Neptune	NEPTUNE-CANADA
Neptune	NEPTUNE - USA
Network for Marine Surveillance, Control and Observation in the Canaries	RED ACOMAR

Projects	Acronym/Web Link
Neutrino Extended Submarine Telescope with Oceanographic Research	NESTOR
Neutrino Mediterranean Observatory	NEMO-Mediterranean
New Jersey Shelf Observation System	NJSOS
New Millenium Observatory	NEMO
North-East Asia OOS	NEARGOOS
Operational Oceanographic System	FERRYBOX
Pilot Research Moored Array in the Tropical Atlantic	PIRATA
Posiedon	POSIEDON
Prince William Sound Observing System Pilot Project	PWSSC
Real-Time Deep Sea Floor Observatory	Hatsushima
Red de Alerta Y Observación	RAYO
Sea Air Land Modelling Network	SALMON
Sea-viewing Wide Field-of-view Sensor	SeaWifs
Seawatch South Africa	SSA
SIMORC	SIMORC
SMART Bay Project	SMART
St Lawrence Global Observatory	SLGO
Submarine earthquake detection system	Muroto
Texas Automated Buoy System	TABS
Triangle Trans-Ocean Buoy Network	TRITON
Tropical Atmosphere Ocean	TAO
UNESCO-BILKO	BILKO
Versatile eco-monitoring network by undersea cable system	VENUS - Jamstec
Victoria Experimental Network Under the Sea	VENUS

Table 18-4: OOS Related Organisations

Organisations	Web Link
Advanced Real-Time Earth monitoring Network in the Area	ARENA - Jamstec
Advisory Committee on the Protection of the Sea	ACOPS
Alliance for Coastal Technology	ACT
Arctic Research Consortium of the US	ARCUS
Canada Group on Earth Observations	CGEO
Centre for Environment, Fisheries & Aquaculture Science	CEFAS
Centre for Integrated Marine Technology	CIMT
Climate of the Arctic and its Role for Europe	IPY-CARE
Coastal-GTOS (C-GTOS)	C-GTOS
Committee on Earth Observation Satellites	CEOS
Commonwealth Scientific and Research Organization	CSIRO
CSIRO Marine and Atmospheric Research department	CMAR
Deep-ocean Environmental Long-term Observatory System	DELOS
Defence Science & Technology Organisation	DSTO
Department for Environment, Food and Rural Affairs (UK government)	DEFRA
European Global Ocean Observation System	EUROGOOS
European Meteorological Network	EUMETNET
European Organization for Exploitation of Meteorological Satellites	EUMETSAT
European Sea Level Service	ESEAS
European Space Agency	ESA
Front Revolving Observational Network with Telemetry	FRONT/SEAWEB
Global Monitoring of Environment and Security	GMES
Global Ocean Observation System	GOOS
Global Sea Level Observation System	GLOSS
Global Terrestrial Observing Network	GT-NET
Global Terrestrial Observing System	GTOS
Group on Earth Observations	GEOSS
Indian National Centre for Ocean Information Services	INCOIS
Indian Ocean OOS	IOGOOS
Indian Space Research Organisation	ISRO
Institute for Aeronautics and Space	LAPAN
Integrated Arctic Ocean Observation System	iAOOS
Integrated Global Observing Strategy	IGOS
Intergovernmental Oceanographic Commission	IOC
International Strategy for Disaster Reduction	ISDR
IOC Sub-commission for the Western Pacific	IOC/WESTPAC
IOC Sub-commission for the Western Pacific (93-94)	WESTPAC
IOOS Data Management & Communications	DMAC
Japanese Agency for Marine-Earth Science & Technology	JAMSTEC
Joint Technical Commission for Oceanography and Marine Meteorology	JCOMM

Organisations	Web Link
National Institute of Water and atmospheric Research	NIWA - Australia
National Institute of Water and atmospheric Research	NIWA - New Zealand
National Institute of Water and atmospheric Research India	NIOT
National Oceanographic and Atmospheric Administration (2005)	NOAA
National Oceanographic Research Institute OOS	NORIOOS
National Office for Integrated and Sustained Ocean Observations	OCEAN US
National Science Foundation	NSF
Natural Environmental Research Council	NERC
Navy Oceanographic Office	NAVOCEANO
Navy's Directorate of Oceanography and Meteorology	METOC
NOAA Centre for Operational Oceanographic Products and Services	NOAA COOPS
NOAA Coastal observation systems	NOAA COOS
NOAA Hazardous Materials Response Division	NOAA HAZMAT
Ocean Observatories Initiative	OOI
Office of Naval Research	ONR
Partnership for Interdisciplinary Studies of Coastal Oceans	PISCO
Southern California Coastal Ocean Observing System	SCCOOS
Southern California Coastal Water Research Project Authority	SCCWRP
The Ocean Data and Information Network for Africa	ODINAFRICA
US Coast Guard	USCG
US Commission on Ocean Policy	USCOP
US Group on Earth Observations	USGEO
Western Australian GOOS	WAGOOS
Woods Hole Oceanographic Institution	WHOI
World Climate Research Program	WCRP
World Meteorological Organisation	WMO