United Nations
Educational, Scientific and
Cultural Organization

Intergovernmental
Oceanographic
Commission

The Global Ocean Observing System

A summary for policy makers

The Need for Sustained Observations of the Oceans and Coastal Seas

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What is oceanography and what is a sustained long-term ocean observing system?

Oceanography is the science and understanding of the marine world. Oceanography has been conducted by scientists for over 150 years, building a highly developed understanding of the oceans and their contributions to the world's climate and ecosystems. Modern oceanography uses satellite observation, research ships, robotic instruments and large computer models to obtain and analyze data.

The output of decades of oceanography is written in books, published in academic papers or maps, stored as records in computers, or provided as images and information on the internet. The knowledge gained is the basis for ocean services that are used to improve human use of the sea, its exploitation, management, and conservation.

Users of oceanographic science now request that the outputs be distilled into information products using integrative models which portray the state of the entire ocean today, next week or next decade. Such information is increasingly needed by nations to manage national ocean areas and accessible understanding of the oceans in this way can lead to more efficient shipping, mitigate storm damage and flooding of coastal cities, sustain healthy fisheries, protect coral reefs from degradation and improve climate forecasting. However the ocean changes continuously and must be continuously observed in order to deliver accurate ocean services.

Although our scientific understanding of the ocean has improved greatly in recent years, the complex processes at work in the ocean do not permit a complete view of the ocean without an adequate description of the state of the whole global ocean based on comprehensive observations delivered in a timely manner. The accuracy of ocean forecasts depend upon the present state knowledge to extrapolate models into the future. Models may forecast ocean currents or temperature for 2-3 days ahead very accurately, but will degrade and become less accurate.

To describe the ocean more accurately and deliver useful management products and tools, more observational data are needed on weekly/monthly basis, to improve the estimates of present ocean state, constrain model calculations and extend forward the duration of forecasts. With this approach trends, changes, anomalies, and emergencies can be detected.

This sequence of making observations, feeding the data into computer integrating models that are based on scientific laws or verified scientific knowledge, and then using the ocean state and forecasts for socio-economic benefit on a routine basis is called operational oceanography. Operational oceanography provides necessary ocean services which must be based on sustained and repeated observation of the ocean.

The Global Ocean Observing System (GOOS) is the international observational system that ensures long term sustained ocean observations. Since 1990, IOC has been tasked by the international community to co-ordinate the planning, implementation, and on-going development of GOOS.

How the Global Ocean Observing System has been developed

Much of current knowledge about the ocean has been the fortuitous result of curiosity. Because people do not live at sea, and because its depths are opaque to light or electromagnetic radiation, the ocean below the surface remained largely unknown for most of human history. Only in 1770 did Benjamin Franklin first chart one of its largest currents, the Gulf Stream, which despite carrying in excess of a billion kilograms of water past Cape Hatteras every second, was largely unknown to mankind. Aboard the HMS Beagle in 1831-1836, Charles Darwin observed, and provided the first explanation for how coral atolls are formed. In 1893 Fridtjof Nansen first proved the circulatory, trans-Arctic pattern of ice drift by freezing his boat into the ice, off the coast of the New Siberian Islands (Russia), and drifting for three years before reappearing in the vicinity of the island Svalbard (Norway). In the 1950's and 60's the new big factory fishing fleets of Russia and Japan started to use modern oceanographic methods to predict the migration of major fish stocks.

In the 1950's, Rachel Carson, a founder of the American environmental movement, could only vaguely hypothesize that the massive shoals of fish being commercially harvested in the North Atlantic must spawn somewhere, and that if we could ever discover these places, we ought to protect them. More recently explorers such as Jacques Cousteau and Bob Ballard have excited public interest by new discoveries beneath the sea surface and promoting films and popular books on undersea adventure and discovery. Explorers aboard Russian, Japanese, and American deep submersibles have revealed some of the enormous diversity of previously unknown marine life including the proliferation of symbiotic life around deep hydrothermal vents. Craig Ventner, who was one of the first to sequence human DNA, has recently discovered millions of new marine microbial species by analyzing DNA sequences in the ocean.

Top: Fridtjof Nansen making temperature measurements in the Arctic

Left: An Argo float shortly before recovery by the Japan Coast Guard vessel Takuyo

Right: The Soil Moisture and Ocean Salinity Satellite

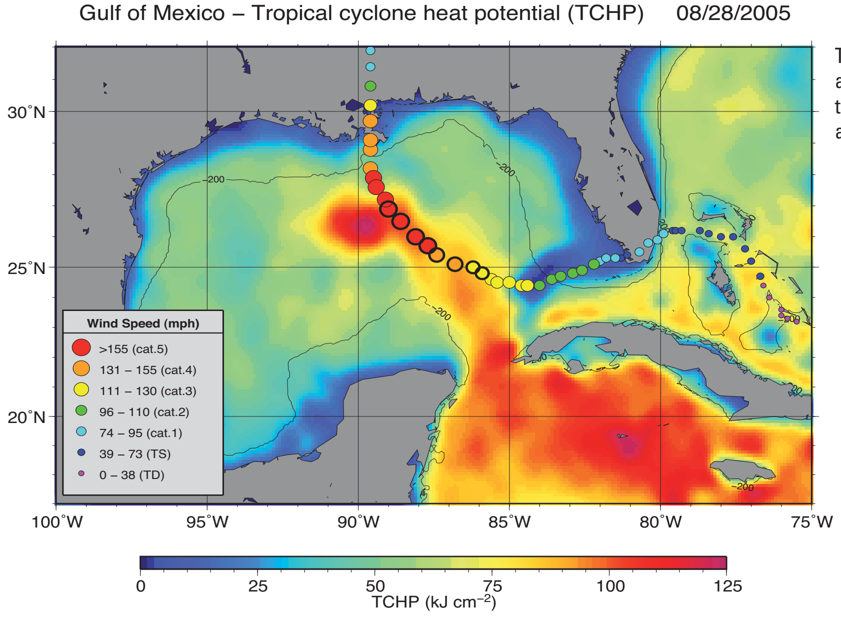
During the 1980's-90's IOC provided the intergovernmental support for the new global research programs which have been changing the way oceanography was carried out: from discrete exploratory cruises to repeated systematic monitoring and modelling. Today, the ocean's physics, chemistry and biology, including its role in governing global climate, absorbing atmospheric carbon dioxide, and the ecosystem dynamics, are far better understood than ever before. In large part this increased understanding is due to a paradigm shift in the methods of observing the ocean from one of exploration to sustained monitoring. Today, the surface ocean is continuously measured from space while thousands of surface drifting buoys, neutrally buoyant floats, and moorings monitor its interior.

The Global Ocean Observing System that has emerged today is thus the end product of a shift from local exploration for the purpose of discovery, to global monitoring to provide ocean services for the purpose of sustainable development of ocean resources, protection from ocean hazards, and delivery of myriad other societal benefits. The system in place today, if sustained and enhanced, can answer many of the most pressing questions about the oceans and climate that will arise in decades to come. Many of these will be about the workings of the global earth system and will require sustained analysis of global datasets to reach a solution.

By monitoring the global marine environment, GOOS provides the information for global research and ocean services. It is a large, diverse and expensive global system, from which all nations can benefit enormously, but no one nation can maintain alone.

All nations with an interest in understanding, protecting, and benefiting from the sea are called upon to look beyond their own territorial waters, to take a global view, and to now reinvest in GOOS.

Sustained Observations: Today's observations cannot be taken tomorrow.



Tropical Cyclone Heat Potential associated with Hurricane Katrina; the location and intensity of Katrina at intervals of 6 hours.

What is needed for the Global Ocean Observing System?

An operational ocean observing system is a simple idea, but is actually a very ambitious target, stretching modern science and technology to their limits. It costs a lot – but is worth the investment.

The data collection of the past decades is becoming more and more valuable because it defines the baseline for future trends that we cannot foresee today.

Let us consider some of the problems facing the modern world, and how ocean modelling and forecasting, especially the forecasting in coastal seas, can help.

On the coasts, where people increasingly live and build expensive cities, ports, and industry, there has been a dramatic increase in vulnerability to inundation from storm surges, hurricanes, and tsunami.

Coastal flooding on Galveston Island in connection with Hurricane Ike September 13, 2008.

World wide fisheries are endangered from a variety of stresses. On the continental shelves and in coastal waters, once staggeringly productive fisheries have been decimated by overfishing and globally systemic habitat destruction. Some huge fisheries have collapsed completely and are not recovering. Coral reefs are threatened by local destructive fishing practices and sediment loading exacerbated by the slow acidification of the global ocean. Oxygen-starved dead zones of the sea have grown at increasing rates. Toxic algal blooms are more frequent. Far from land, in the open

Bloom of blue-green algae near the island of Landsort (Baltic Sea).

ocean, large-scale ecosystem changes have been reported. On top of all this, the changing temperature, salinity and currents associated with climate change add additional stress to the marine environment.

The existence of these threats is known because of extensive scientific research carried out from ships and arrays of instruments in the ocean which have measured ocean processes. Understanding the changes, as the basis for decisions on adaptation and mitigation measures, will require further thorough and sustained monitoring of the marine environment.

The industries and services which operate at sea, such as offshore oil and gas extraction, fisheries, coastal flood prevention, shipping, coastal recreation and tourism, port operations, fish farming, and sand and gravel extraction for construction, require routine information about the sea conditions, and are vulnerable to sudden changes, storms, floods, or changes in temperature and salinity. Ocean services derived from GOOS observations and targeted at coastal industries and services improve the efficiency and safety of these activities, and ensure that they do minimum damage to the environment. Coastal regulatory authorities concerned to minimise pollution, protect the environment, and maintain public health and safety, use the services derived from GOOS to maintain a high standard of water quality.

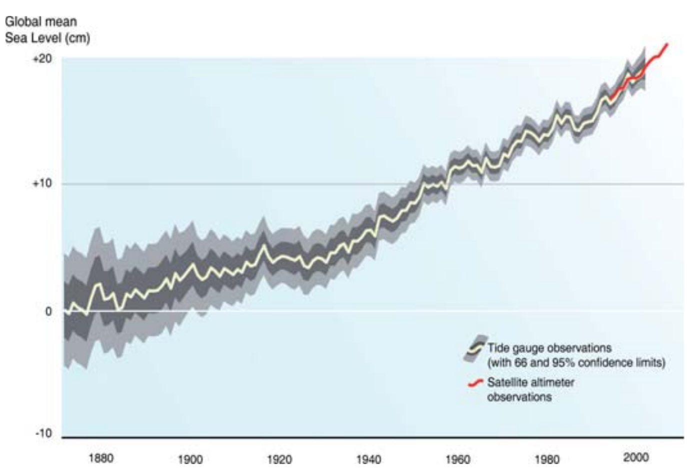
Examples of activities, services and infrastructures in the coastal zones.

The Global Ocean Observing System and climate change

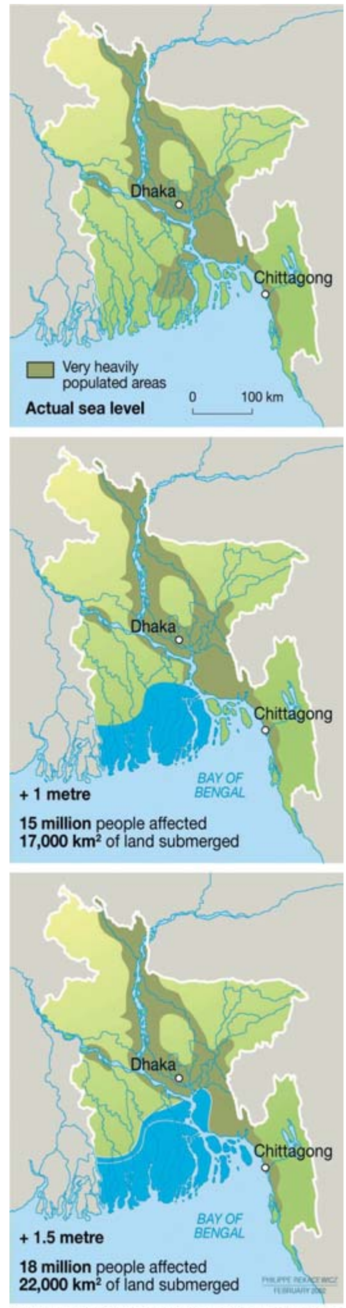
The ocean is an integral part of the global climate system. The ocean has absorbed 50% of the excess heat of global warming, controls weather systems, and adds decadal climate variations by slowly transporting heat around the world. The UN Intergovernmental Panel on Climate Change has emphasized the role the oceans play in controlling climate and how important understanding ocean processes is for informed decision making about societal responses to climate change.

Continuous and homogeneous observation records of essential variables reveal small but systematic changes over a long period of time and provide the basis to understand their causes and consequences.

Sea level change has been identified as one of the most obvious results of climate change. Sea level rise is driven by expansion of the upper ocean layers due to increases in subsurface ocean temperature and slightly modified by transfer of water between the oceans and land-based reservoirs. Local sea level is also strongly influenced by regional and local effects including natural earth movements and human-induced land subsidence due to fresh water extraction. These factors are of critical importance for densely populated low-lying coastal regions prone to storm flooding such as Bangladesh or the deltas of the Nile and Mississippi.



Global averaged sea levels from 1870 to 2007 as inferred from tide-gauge data (blue, with confidence limits given in light shading) and satellite altimeter data (red)

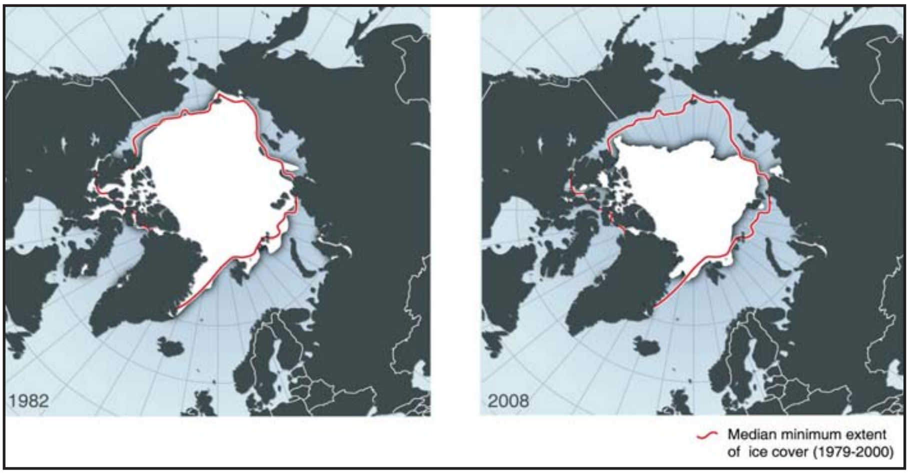


Sources: Dacca University; Intergovernemntal Pannel on Climate Change (IPCC).

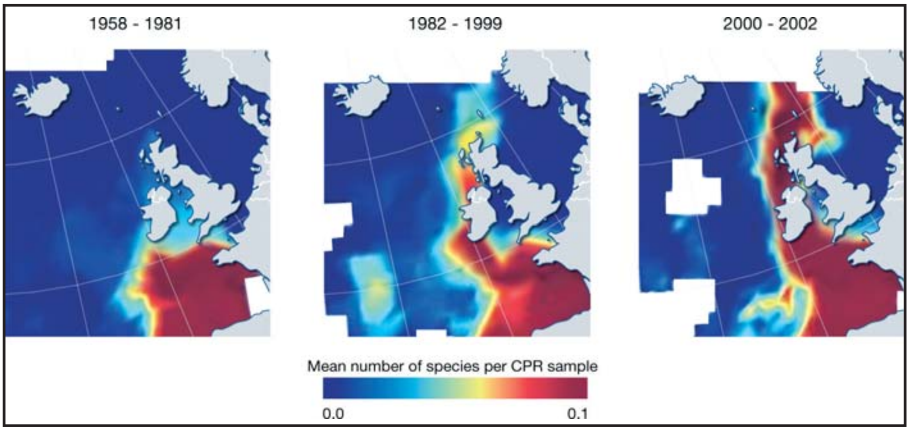
Impact of sea level rise in Bangladesh

An essential element of GOOS required for climate change studies are the satellite data streams. Sea surface temperature is vital for weather prediction and for understanding coupled ocean-atmosphere dynamics required for climate prediction. Ocean color is an indicator of biological activity. Ocean life is dependent on the biogeochemical status of the ocean, which is affected by changes in its physical state and circulation. Sea ice extent is important as an indicator, and driver, of climate change and for its important role in polar ecosystems and navigation.

With the advent of GOOS, for the first time in history, the world's oceans are now beginning to be routinely and systematically observed, and the data processed in time to make useful decisions. By it's very nature, climate change studies require long term observation records. A sustained and complete GOOS is absolutely necessary to understand the impact of changing climate, assess regional vulnerability, and monitor the efficacy of adaptation and mitigation efforts.



Arctic sea ice minimum extent in September 1982 and 2008. The red line indicates the median minimum extent of the ice cover for the period 1979–2000. This figure compares the Arctic sea ice extent in September for the years 1982 (the record maximum since 1979) and 2008. The ice extent was 7.5 million km^2 in 1982 and only 5.6 million km^2 in 2005 and down to 4.3 million km^2 in 2007



Plankton distribution changes in the North East Atlantic. In 2005 the subtropical dinoflagellate Ceratium hexacanthum was found in CPR samples from the North Sea at levels that were 6 standard deviations above previous measurements since 1958

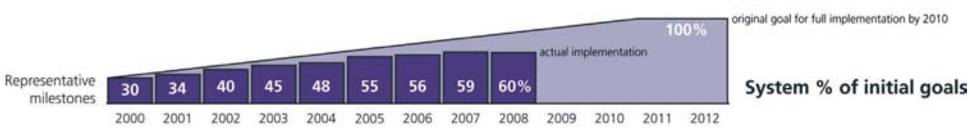
Progress in implementing the Global Ocean Observing System

Despite global economic growth and increasing damage to the ocean system, investments in the ocean observing system over the past decade have stagnated at a level of about 1 billion US$/year.

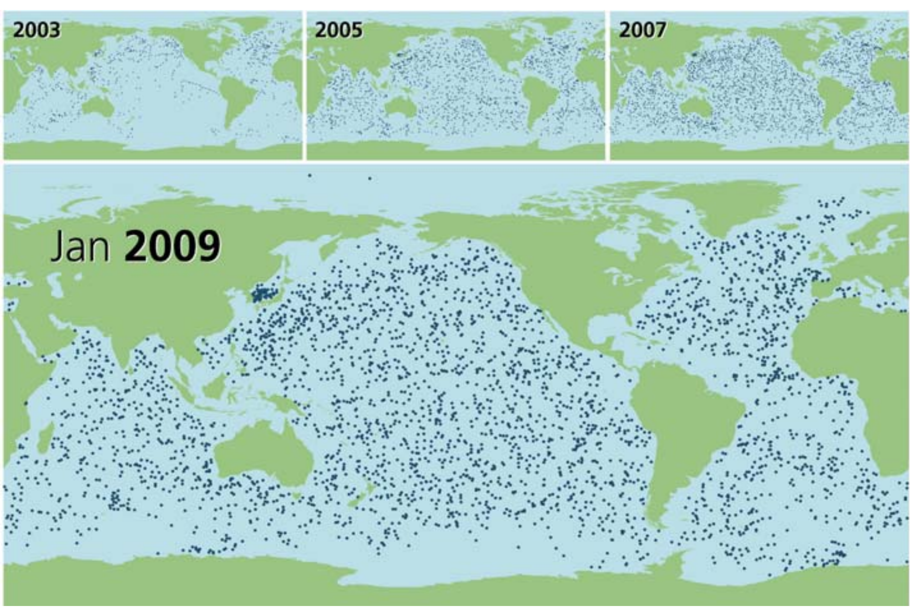
IOC began planning for GOOS in 1990 at the request of member states who recognized the importance of a unified ocean observation system. The socio-economic case for investment in GOOS was first commissioned by IOC for the 1992 Rio United Nations Convention on Environment and Development (UNCED). (The Case for GOOS). There has been useful progress in almost every action called for when GOOS was conceived. Many countries have committed to the implementation of GOOS through national investment in GOOS programs and participation and contribution to the existing 12 GOOS Regional Alliances that have been formed by national institutions to take the implementation of GOOS into the coastal seas.

But the investment to date in GOOS has fallen behind expectations. In fact, most elements of the system require substantial additional investment in order to achieve their 1992 design objectives. A particular shortcoming has been very limited progress in the establishment of national ocean or climate institutions with an explicit mandate for operational ocean observations. The primary agents of implementation remain research organizations, with a focus on short-term results and scientific hypothesis testing, and local regional agencies responsible for activities like pollution control or navigational safety.

The participation of coastal agencies is particularly useful to meet the needs of developing countries, but it is difficult to weld together the large number of small national agencies with limited objectives so as to create an integrated observing and monitoring system.

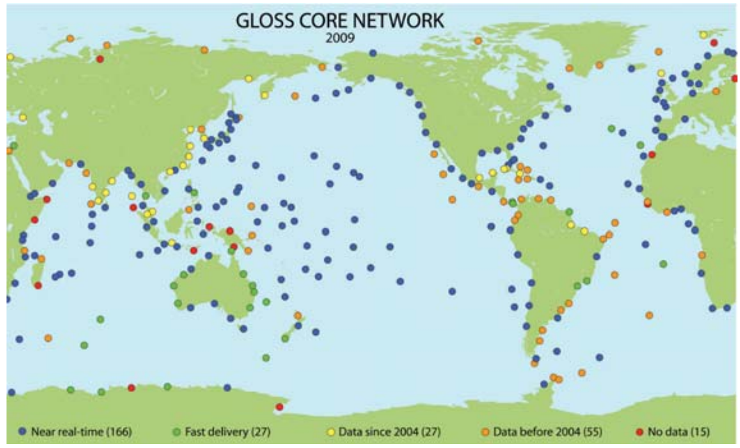


System completion of GOOS as a percentage of initial goals



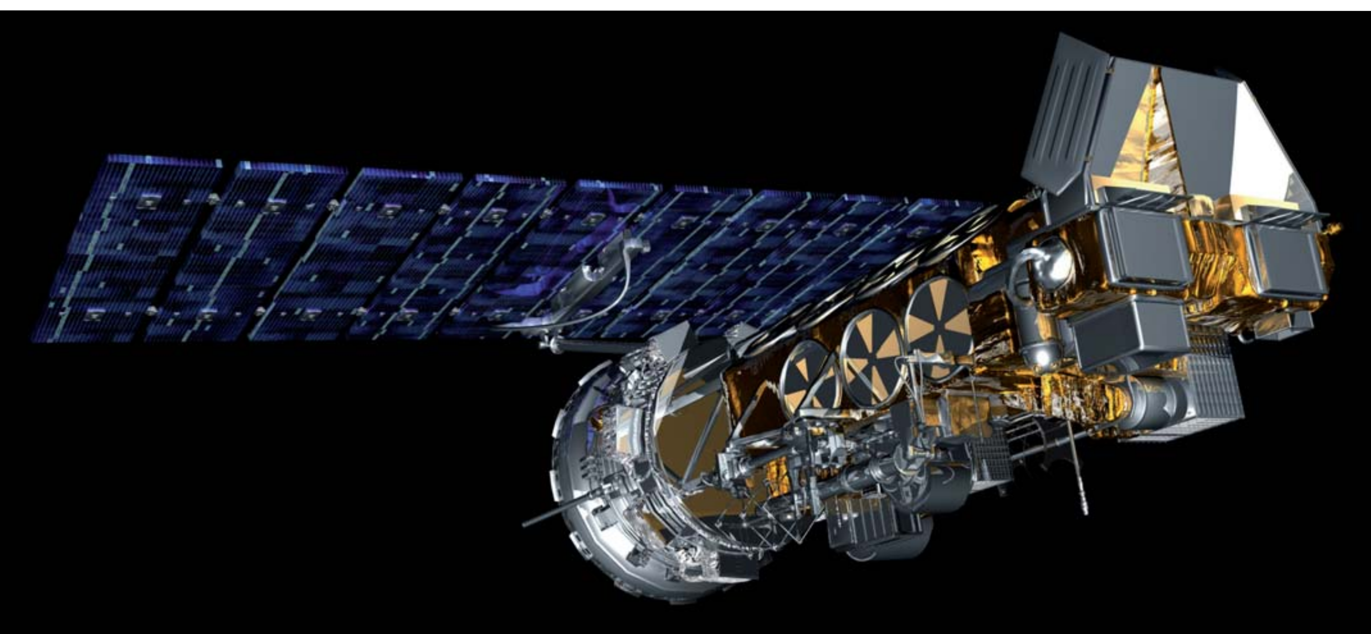
Development of the global array of Argo profiling floats 2003 – present

Notable GOOS milestones achieved in recent years include reaching the target for 3000 Argo profiling floats, which record temperature and salinity in the upper ocean, and 1250 surface drifting buoys, which record surface currents, temperature and atmospheric pressure. There has been a substantial increase in the number of tide gauges now reporting in near-real time providing tsunami-detection capability. Several new reference site moorings have been deployed, and the tropical moored array of buoys, already operational in the Pacific, continues to develop in the Atlantic and Indian oceans. Recent agreements by the Committee for Earth Observing Satellites (CEOS) to support continuity of critical satellite observations of sea level, surface winds, sea ice extent and ocean color holds the hope of sustained provision. Regional collaboration, such as in GOOS Africa, is enabling developing countries to make use of sophisticated GOOS products to aid marine and coastal management.



Present status of the Global Sea Level Observing System which provides in-situ monitoring of sea level change.

Global sea surface temperature has been measured for more than twenty-five years by a series of satellites - the latest being NOAA-19 launched on 6 February 2009



Cost and benefits of coordinated ocean observations

More than 90% of goods are transported by sea, the value from marine activities globally is about 5% of global GDP, that is 2.7 trillion dollars (2007). Even if ocean services from routine ocean observations can protect just a fraction of that value, and reduce risks of damage and loss, both for the natural environment and the economic infrastructure, the investment is well worth its cost.

Maritime activities contribute significantly to national economies. One recent study estimated the world maritime industry market for 2005-2009 is about 4.3 Trillion Euros. Earlier studies of marine industries and activities as a proportion of European national economies have typically shown it to be between 2% and 5% of GNP, while in China maritime activities have been estimated to make up as much as 8-10% of GDP. The accumulated investment in observational and institutional infrastructure to support this large segment of the world economy is quite considerable.

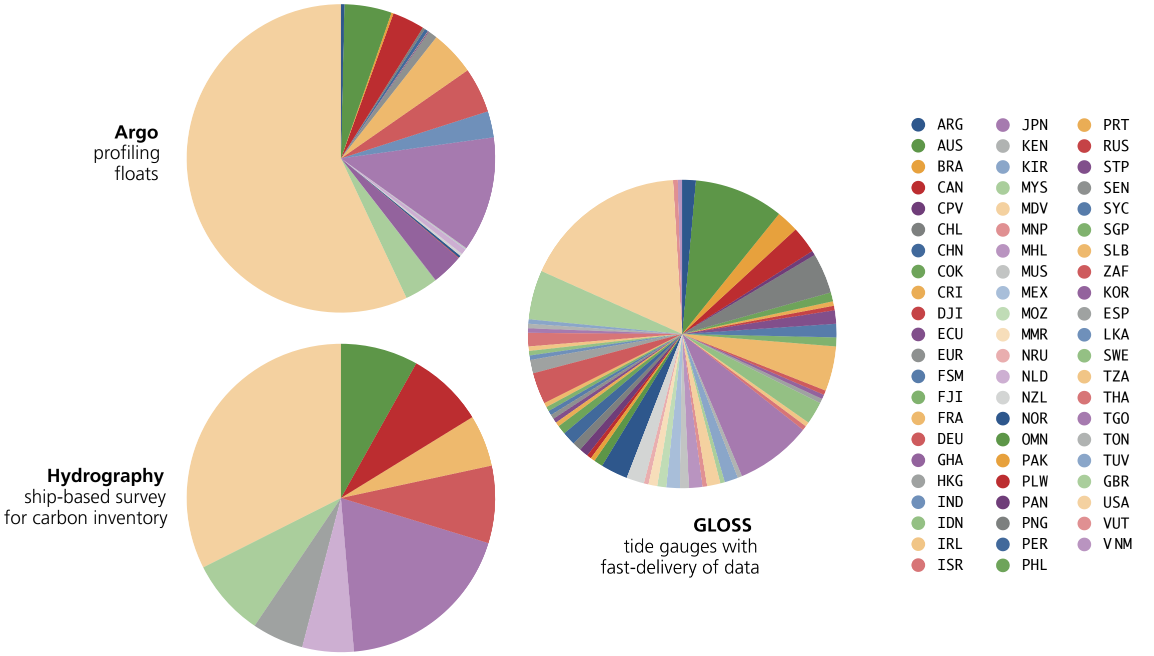
Despite global economic growth and more capital installations and activities liable to marine damage, and in spite of increasing damage to the ocean ecosystem, investments in the ocean observing system over the past decade have stagnated at a level of about 1 billion US$/year.

The market benefits already described may not be the largest benefit from GOOS. Many aspects of weather prediction and climate modeling by which scientists try to look ahead many decades depend completely on observing and monitoring the ocean regularly from top to bottom. In view of the risks of uncontrolled climate change this benefit may also be measured in trillions of dollars per year.

Sustainable management of fisheries also depends on having good ocean knowledge. In 2003, the OECD estimated that over 800 million US$ was spent on research services as part of a total investment of 2.5 billion US$ for managing fisheries in Australia, Canada, European Union, Iceland, Japan, Korea, Mexico, New Zealand, Norway, Turkey, USA.

Globally, at least 240 higher education establishments offer marine courses and carry out marine research thereby contributing to the further development of ocean observing systems. Additionally, at least 110 national oceanographic or fisheries institutions,150 national hydrographic or navigational authorities, and 182 meteorological services in place, many of which are operating under a marine meteorological mandate to provide some ocean observations and services. Some 750 research or hydrographic vessels are in operation around the globe, of which over 170 are more than 70 m long. More than 75 satellites are currently flying with full or partial application to ocean and coastal science and monitoring. In the coastal zones some nations invest substantially in process studies and monitoring to address specific local and regional needs. Although such coastal observations serve primarily national, regional, or local interests they could, if coordinated, also contribute to systematic, international coastal ocean observing efforts.

Many successful and convincing studies of the costs and benefits of sub-components of GOOS have been carried out. Each study shows that the value of regional integration of monitoring observations and processing of data produces economies of scale and avoidance of duplication on the cost side, and benefits in exploitation of the data on the applications side which greatly exceed the costs. When the case for GOOS was first made in the early 1990s it was estimated that GOOS could become fully operational by 2007 at which time on the order of 2 billion US dollars per year would be needed for investment and running costs in order to sustain the system. Funds of this magnitude have not been committed. Furthermore, indications are that global budgets for oceanographic research and marine observations have been largely flat, or even declined slightly over the past decade. The 60% completion of the climate component of GOOS has therefore mainly been implemented through a combination of research grants, institutional baseline funding, reprioritization, innovative sampling approaches and technological advances leading to productivity increases



Pie-charts showing the relative contribution of observing platforms by individual countries for three of the observing sub-systems under the Global Ocean Observing System.

and declining costs, with only limited additional funding.

Given that substantial new funding earmarked for the global ocean observing system or new oceanographic institutions did not emerge as GOOS was developed and expanded, further development of the system seems unlikely. Simply sustaining GOOS for the foreseeable future will be a substantial task that will in all likelihood require the same diverse elements and myriad funding arrangements that have been cobbled together over the last 15 years.

This lack of sustained, multilateral funding commitments to the global observing system appears discouraging. However, given the increasing public demand for information and products in support of operational and long-term coastal planning, monitoring global and regional environmental agreements and marine protected areas, providing data for climate change assessment, adhering to national and international marine directives and policies, sustainably extracting marine resources and managing the coastal zone, it is clear that societies will continue to need ocean knowledge and services at an enhanced level.

It will be necessary for IOC member states to support new investments in research, monitoring and protection of the oceans and in coordination of the efforts to make this work happen. For its part GOOS should better provide the services now paid for from research agencies. Without such changes in marine investment strategies, achieving the target goals for development of GOOS will not be possible. This would be a tragedy for Planet Earth and its human inhabitants.

Implementation of GOOS relies on (i) sustaining existing national observing activities where they are present, (ii) development of capacity where they are lacking and (iii) international coordination. Given the complexity of GOOS, the diversity of

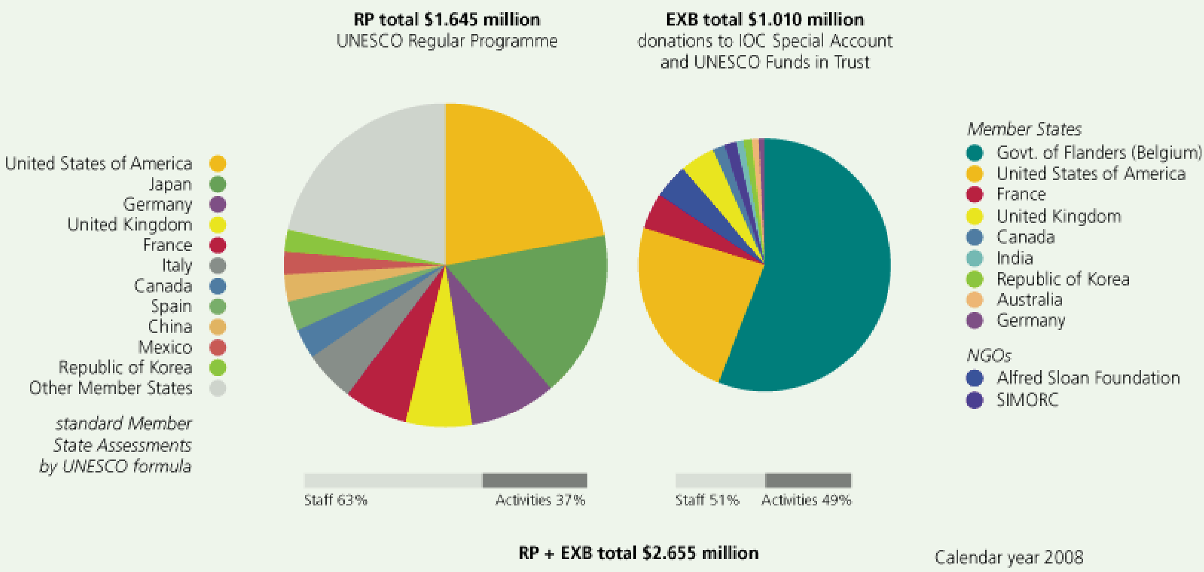
partners and observing elements, a high level of international and intergovernmental coordination, advocacy, and liaison are required. The Intergovernmental Oceanographic Commission of UNESCO presently commits about $1.6 million US$ annually (including salaries) to GOOS coordination. This is complemented by voluntary contributions of about $1 million of additional funds from a handful of countries, less than 0.1% of the investment in the system itself. This annual budget has been slowly decreasing each year, and is down by about 50% as compared to a decade ago. This decrease in funding stands in stark contrast to the initial estimate of a requirement for doubling of funding for international coordination when the system was first envisioned. The decrease in funding also stands in contrast to the avowed policies of governments that have signed up to treaties and conventions such as climate, biodiversity, sustainable development, and pollution control, as the implementation and monitoring of these agreements depends on data and products provided under GOOS.

Therefore, this prospectus has presented the case for an additional 1 million $US/year in national contributions for international coordination to complete and sustain GOOS. Development and support of a coordinated Global Ocean Observing System must be guaranteed to prevent the value of this global asset from slipping away.

More information about GOOS and supplementary material to this brochure is available at: www.ioc-unesco.org/goos

Annual investment in Sustained Ocean Observations by Member States

Funds available for international coordination of the Global Ocean Observing System through IOC/UNESCO in 2008
includes funds for GOOS, JCOMM, JCOMMOPS, IODE, ocean carbon
includes staff and programme costs



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