IBI-ROOS Plan:
Iberia Biscay Ireland Regional Operational Oceanographic System 2006–2010

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1 Executive Summary

1.1 Rationale

The ocean and shelf sea characteristics of the Iberia Biscay Ireland Regional Operational Oceanographic System (IBI-ROOS) region have a great influence on the societal status of the population living in the bordering countries and their economies. A large proportion of the population in the IBI-ROOS area lives in areas influenced by the Atlantic. Air and ground transportation, heating, construction, sports and leisure, health, etc. are also affected.

The Eastern North Atlantic shelf and slopes are large European fisheries. Ocean temperature is one of the key variables that influence fisheries, and fish stocks seem to migrate northwards as the sea surface temperature increases (Drinkwater *et al.*, 2004). Lately fish stocks in the IBI-ROOS area have started to suffer significant decreases. Monitoring of the ocean environment is an important element in the management of fisheries resources. Fish demand is increasing, the number of fisheries is decreasing, and aquaculture is facing multiple challenges. Growth rates and mortality at the aquaculture sites depend critically on temperature profiles, dissolved oxygen, chlorophyll concentrations (phytoplankton), and ambient flow conditions. This information is therefore important in site selection and the granting of licences. Both regulatory agencies and individual aquaculturists have great interest in reliable and synoptic records of these data being supplied by operational services.

Aquaculture and fish farming have great value and potential in the region. France and Spain produce more than 20000 tons/year of mainly molluscs, and Ireland and Portugal have a large potential. Changes in sea surface temperature, salinity, chlorophyll, and storm development influence this production. On the other hand, the aquaculture practices affect the environment where they are carried out. Moreover, a major problem is the development of Harmful Algal Blooms. HABs are a serious problem, with an impact on development and sustainable aquaculture; for example during the 1990s the French Atlantic coast had a total of 4275 closure days in mussel harvesting (Ifremer/Quadridge Database http://www.ifremer.fr/envlit/). Monitoring of HABs is carried out in all European countries but whenever the problems induced are due to oceanic processes, the prediction of HABs is an achievable goal, enabling producers to implement countermeasures at the local scale (mitigation or early harvesting).

Tanker transportations of oil and gas from the Orient follow the IBI-ROOS coast from South Africa and the Strait of Gibraltar, carrying more than 400 million tons a year. This transportation is increasing, bringing an associated increased risk of accidents and damage to the environment. The recent Prestige accident (2002) was a terrible example, and is just one of a large number of incidents. Accidents in such as strong dynamic area affect a very wide expanse of coastline. Among the scenarios of global change, increased strong wind events or storms heighten the danger of these accidents and a quick response is vital to prevent and reduce environmental risk.

New uses of maritime areas are under development — harbours and ship construction, aquaculture development, wind farms, mining, etc. — and have to be clearly regulated and environmentally safe. The IBI-ROOS area can have rough weather which calls for improved operational monitoring and forecasting systems in order to safeguard all types of maritime or coastal operations. The operational services should also include long-term data archiving.

Extreme events such as big storms and flooding have a major economic and social impact. Improved prediction can reduce damage and increase confidence in the operational systems. Maritime transportation, fishing, aquaculture and tourism are strongly affected by these events, as well as the large population living on the coast.

Recent studies show that the ocean climate of the 20th century has undergone major fluctuations, characterised by a significant warming over the last two decades. An increase in the intensity and frequency of strong wind episodes has also been detected. Global warming is supposed to influence Ocean Thermohaline Circulation and manifestations of its slowing have been detected recently in the Atlantic (Bryden *et al.*, 2005). These changes suggest that the East Atlantic region together with the Northern North Atlantic may be one of the more affected areas and a lot of attention should be given to this problem. Warming of the upper waters during the last century was detected by Planque *et al.* (2003) and an intensification of this trend was detected in upper and intermediate waters for the last decade by Gonzalez-Pola *et al.* (2005). Also the sea level trend is moving upwards for most of the area (Tel, 2005).

The IBI-ROOS area has strong interannual variability and it is strongly influenced by modes of atmospheric variability such as the North Atlantic Oscillation (NAO), depending on the latitude. Improved monitoring systems are needed to provide consistent and long-term data on ocean circulation. Monitoring systems should have a central role in detection and verification of climate variability and trends.

The European Union is developing a Marine Framework Directive and has adopted a green paper on Maritime Policy, asking for coordination between member states that share marine areas. IBI-ROOS encompasses a large area of the North East Atlantic covered by this directive. Coordination in this task will safeguard the necessity of future developments and the IBI-ROOS development will contribute towards assessing the required state of the ecosystems.

The key issue for the establishment of an operational oceanographic observing system in the IBI-ROOS region is integration and further development of the existing observational systems and data sets. The objective is to maximise their utility for the specific purpose for which they have been originally designed and, by combining data sets with further stages of modelling and forecasting, to make them available for other relevant purposes and user groups. The combination of data types into a single system will enable higher resolution in models, faster delivery of products, and longer forecast horizons.

The existing observing systems should adapt and integrate new technologies to make observations more complete, more effective and more affordable, and the data infrastructure and management system should be complementary to existing systems and attuned to multiple sources of data and their multiple uses. Ocean observations in the IBI-ROOS region require more effective co-ordination between institutes and countries.

1.2 User needs

Like most coastal waters of Europe, the IBI area supports a myriad of socio-economically important activities. It is a busy commercial highway, a productive aquaculture area, a bountiful source of wild stock, and in some parts an extraordinary recreational domain. Each use of this area, however, is limited by gaps in our knowledge of the physical and biological variables that define this fertile ecosystem. These knowledge gaps present problems that range from the inconvenient to the catastrophic:

- The shipping industry and harbour pilots need information on currents, waves, and meteorological conditions to bring ships safely to ports.
- The livelihoods of commercial ground fishermen are under threat, and resource managers have few tools at their disposal to effectively manage the important commercial species.
- Over the last few decades oil spills have occasionally coated significant areas of our coast, which is one of the busiest oil tanker passages in Europe, and there is still insufficient data to predict the trajectories of the spills and protect coastal wetlands and other marine habitats.

An operational oceanographic service to support these activities would focus on observations together with analysis and model prediction of water level, waves, currents, temperature, salinity, oxygen, nutrients, turbidity, chlorophyll and algae. The technological and scientific expertise exists in the area to use this information to create products that would significantly close these gaps.

1.2.1 A real-time observation system

Real-time data are already collected by separate institutes in the area but these data need to be more widely available and an infrastructure is needed for data exchange. Many different users require access to up-to-date measurements.

1.2.2 Recreational users

Some of the beaches in the IBI area have a huge number of summer visitors, yielding a significant revenue. Companies and associations related to leisure activities (e.g. bathing, surfing, windsurfing and boating) are a growing community of consumers of operational products, mainly wave forecasts. Circulation and wave forecasts are also desirable for boating activities. The leisure community is becoming a strong voice that also

	Portugal	Ireland	Spain (Iberian-Biscay area)	France
% of economic activity related to the sea (including tourism)				
Gross national product (GNP)	5%	0.8%	4.30%	1.3%
Transport				
Commercial ships entering continental ports in the IBI area	10294	16323	14452	6896
Cargo movement (million tons)	55	48	100	56.4
Ships per day of maritime traffic	100	52	51	19
Fisheries				
Fish landings (thousand tons)	154	291	397	194
Economical value (MEUR)	274	184	863	442 (turnover)
Number of workers involved in this activity	16000	16825	32194	2950 (full time equivalent)
Aquaculture				
Production (tons)	5885	60500	225000	131400
Economical value (MEUR) — turnover	38	109	163.5	283
Tourism				
Visitors (million)	11.5	7	2.5	13.5
Economical value (MEUR) — turnover	750	4000	1811	8370

demands a high level of water quality along the coastline.

1.2.3 The scientific community

The scientific community would benefit from a common platform where researchers can store and access data in standard formats and in an efficient way. Operational outputs from buoys, remote sensing, cruises and modelling could help the scientific community focus their energy on the relevant societal and scientific issues. This would attract and stimulate new research activity in the coastal and ocean area by making such research easier and more cost-effective.

1.2.4 Transport

In 2004 almost 50000 commercial ships entered the continental ports in the IBI area, corresponding to a cargo movement of approximately 260 million tons. Galvão (1998) estimates 100 ships per day along the Portuguese coast, and 52 ships per day are estimated around Ireland. A national operational infrastructure together with traffic control systems would create a tool for providing valuable information for improving marine traffic safety while also dissuading illegal activities (e.g. disposal of contaminated material, drug trafficking).

1.2.5 Fisheries

In 2003 the fish landings in the area were approximately 828 thousand tons with a value of 1776 MEUR. Although fisheries are becoming less important economically they are a significant source of employment. There is a tendency towards an increase in fish restrictions and in monitoring activities of the fish stocks evolution. The outputs of an operational oceanographic system are very important to increase the efficiency of these monitoring programmes.

1.2.6 Disasters

Portuguese authorities are one of the promoters of a trans-national system of tsunami alerts for the Atlantic and the Mediterranean. The tsunami of the 1755 earthquake is a catastrophe still remembered in Portuguese history. The Atlantic tsunami alert system would benefit from implementation in cooperation with IBI-ROOS.

1.2.7 Eutrophication

Coastal areas are classified with regard to eutrophication in the framework of the OSPAR Convention for the Protection of the Marine Environment, and also supporting the implementation of the Urban Waste Water Treatment Directive and the Nitrates Directive. Institutes would benefit from an operational infrastructure able to monitor the evolution of water quality parameters (such as nitrate and chlorophyll) along the coast with a high temporal and spatial continuity.

Through river discharges, irrigation and management of the rural environment are related to coastal water properties. As a consequence, a better understanding of the fate of materials carried by rivers would be a great advantage to planning activities in catchment areas. Any decision taken to control nutrient loads to decrease eutrophication in coastal areas will have a huge socioeconomic consequence, and monitoring of the water quality in coastal areas would help to evaluate the success of the measures taken to control nutrient loads.

1.2.8 Alien species

An important issue related to heavy shipping traffic is the introduction of alien species from ballast water. There are already several studies about the introduction of HABs and alien species in the area, and the International Maritime Organization (IMO) and other international bodies have been called upon to take action to address the transfer of harmful organisms by ships (globallast.imo.org/). In future the IBI countries should be prepared to implement the IMO ballast water guidelines and to prepare for the new IMO ballast water Convention.

1.2.9 Aquaculture

Aquaculture (fish farming and shellfish culture) is a growing activity, with a significant potential growth: in Portugal for instance, production is still 40 times lower than in Spain. However, this activity is very vulnerable to harmful algal blooms (HABs), and alert systems of potential periods for HABs would be very helpful.

Growth rates and mortality at the aquaculture sites depend critically on temperature profiles, dissolved oxygen, chlorophyll concentrations (phytoplankton), and ambient flow conditions. Both regulatory agencies and individual aquaculturists have great interest in these data being supplied by operational services.

1.2.10 Accidents

Along the IBI coast there is intense tanker traffic and the International Tanker Owners Pollution Federation Ltd. (www.itopf.com/costs.html) evaluated the cost of the AMOCO CADIZ (France, 1978) accident to a sum of as much as 282 million USD and ERIKA (France, 1999) to well over 180

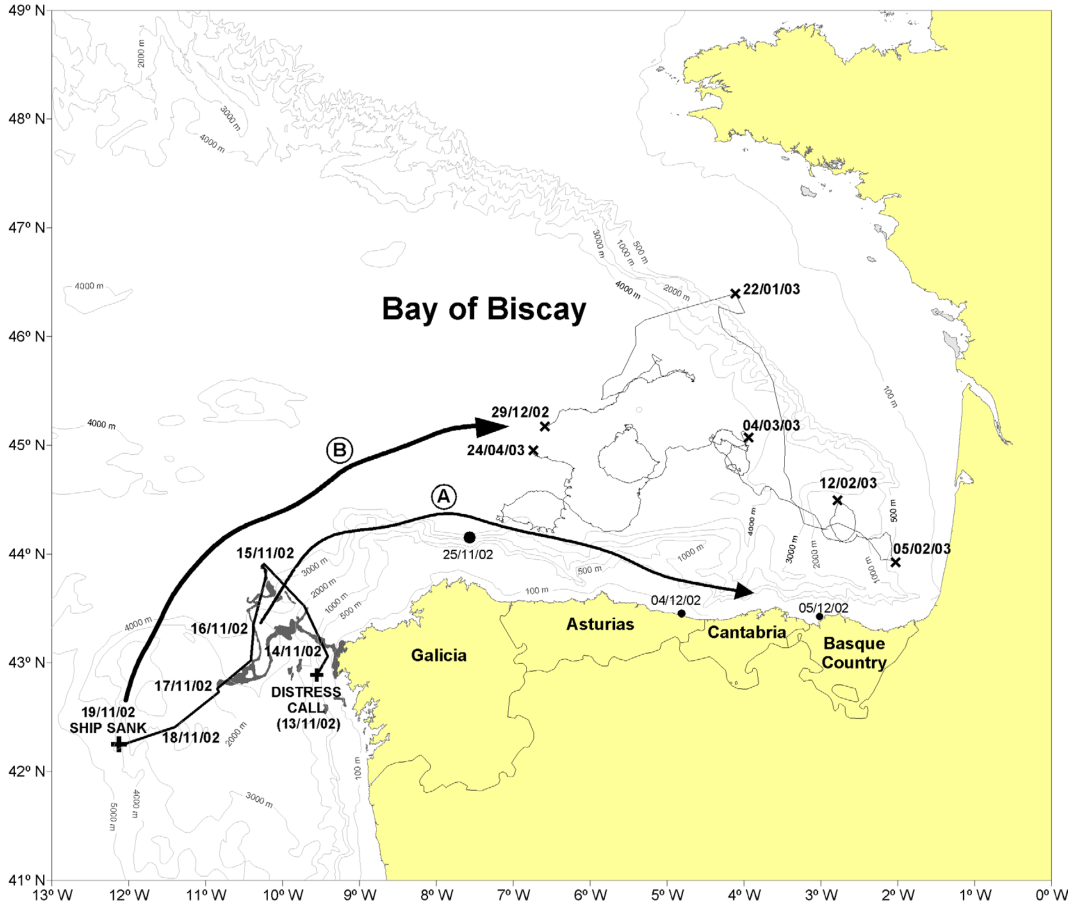


*Figure 1 Patterns of ship, oil and water movement in the Bay of Biscay in connection with the Prestige disaster: +, ships passage, from distress call to final sinking; **shaded area**, release of oil, on the sea surface, during the ship's movement; **(A)** initial movement/arrival of spilled oil; **(B)** main trajectory of oil movement, following sinking; **x**, movement of surface drifter buoys inside the Bay of Biscay*

million USD — showing a huge potential economic loss. The costs of small oil spills are difficult to quantify but, due to their intense frequency, they also have a non-negligible impact on the economy. Institutes with responsibilities in this area could improve their efficiency in detecting and restraining accidents with operational outputs. They need access to data and predictions, as accurate as possible, to carry out the tasks that users have established in their contingency plans. These institutes also need equipment to enable tasks to be performed fully.

1.2.11 Water quality

Due to the fact that a large number of people live on or near the coast, the sea becomes a natural disposal site for waste water. Several waste water companies are responsible for waste water treatment systems that discharge the effluent in the sea using outfalls to minimise conflicts with leisure activities. These companies must have monitoring programmes to prove to the authorities that the treatment system is working properly. Due to the highly variable nature of the coastal system the data resulting from these monitoring activities is difficult to analyse. Coastal operational outputs could help by, for example, identifying whether the values of chlorophyll measurements are high due to the waste water discharge or due to intense upwelling or river discharge.

User requirements vary for different kinds of users:

- Environmental agencies need water quality parameter images (e.g. nutrients, phytoplankton, oxygen) of the system under their responsibility, with enough spatial and temporal resolution to help identify local and large scale trends.
- Waste water management companies need physical and biogeochemical forecasts at the coastal scale of the marine environment so they can improve, for example, their forecasts of pathogenic contamination in beaches.
- The general public needs accessible information that can help to understand how to interact safely with the marine environment.

1.2.12 Coastal protection

Predictions of wave forecasts together with sea level forecasts are important information for a more effective monitoring of the areas sensitive to the impact of the sea. Parts of the coastline have suffered severe changes in the past decades due to human interference (e.g. dams and coastal protection infrastructures). Sea level forecasts together with run-off data can be very helpful to implement useful flood alert systems in shallow, highly populated areas.

1.2.13 Energy production

Coastal power plants can use sea water for their cooling system. Operational outputs can be important in the design phase to estimate the thermal impact of the power plants and the location of the discharge and extraction points. They can also be important in the operational phase to identify the best periods for maintenance and repair activities. They can be used in designing the implementation of windmills in shelf areas. Another important aspect to consider is the forecast of events which could lead to the obstruction of extraction points by macroalgae.

1.2.14 Management

Intergovernmental conventions, international agreements, European directives and initiatives such as GMES and GEOSS include requirements on observations, data and assessments. Regionally coordinated monitoring, data exchange, and forecasting, as planned in IBI-ROOS, will be an effective tool to satisfy these different needs. Such a system will also give the participating institutes the opportunity to decrease costs for the production of mandatory data deliveries.

1.3 Modelling potential

Coastal models on their own represent dynamic currents and fronts where several fish species evolve and can allow a pollutant (such as an algal bloom or toxic material) to be followed as it mixes in the water column. Coupled with an ecological model, the coastal model can contribute to indicating the sanitary quality of an area, explain the presence of life species, or generate alerts prior to a phyto-toxic bloom. Several industries, such as fish farming and nuclear power plants, demand high resolution information and forecasts of coastal currents.

The circulation model output, together with wind and wave fields from other operational systems, would be used for oil spill modelling and, in general, to track any drifting object.

Shoreline Response Management Systems associated with emergency response to coastal oil, chemical and inert pollution from shipping are usually based on scenarios of currents and wind. However in the future a strong link between these systems and coastal operational products should be realised. A detailed high-resolution knowledge of the circulation, together with other means, could be used to detect ships responsible for illegal discharges.

The models would be able to compute the steric anomaly of sea level, therefore complementing and completing the storm surge solutions provided by existing operational systems such as Nivmar (Alvarez *et al.*, 2001). This is of particular interest and importance in areas with strong baroclinic activity.

Coastal models will provide boundary conditions to local models able to solve circulation inside the harbours and, coupled with wave model forecast systems (Carretero *et al.*, 2000), in beaches and other coastal areas.

Realistic circulation data is necessary to study the evolution of suspended particulate matter (SPM) and the dynamics of coastline evolution.

1.4 Current situation in the area

Ocean circulation at the North Atlantic scale is reasonably well-described even when interannual variability is involved, but the inter-gyre region of the IBI-ROOS area is an area of slow general flow with energetic events that need improved knowledge. The area is also influenced by Mediterranean outflow with formation of meddies that need to be studied in more detail. The following points have been identified as needing more attention:

- Knowledge of interaction between open ocean and shelf seas is poor and there is strong seasonality with development of an Iberian Poleward current, mainly in winter, and upwelling in the summer. The impact of seasonal variability on ecosystems still needs some adjustments.
- Several observing systems exist in the area, but are developed at national level, often not coordinated between countries, and not developed enough to be able to efficiently monitor the complete area with the required spatial and temporal density of data.
- There are several national services for sea level and wave forecasting but very little collaboration between the groups.
- A lot of satellite data are available but only a few groups use them operationally, especially near the coast. Improvement of satellite products and merged satellite/*in situ* products should be made for a better service to users.
- Data management activities are spread among institutes, and improvement of data processing and exchange (format, quality control, easy access) should help the use of the data in the community. There is a need for more synergy with international and EuroGOOS groups.
- Several ocean circulation modelling activities are handled at national level but the coupling between large scale and local scale models is still an emerging activity. Additional validation activities are required.
- Several experiments with coupling between hydrodynamic and biogeochemical models have started but still need improvement to reach operational needs.

1.5 Objectives of the task team

The overall objective of IBI-ROOS in partnership with the international community and agencies is to develop and implement a sustainable system for optimal monitoring and forecasting in the IBI marine region using state-of-the-art remote sensing, *in situ*, numerical modelling, data assimilation and dissemination techniques.

In order to meet these objectives there is a need to

- Improve efficiency and reduce redundancy by sharing data, tools and products
- Encourage networking between scientists to improve and share know-how on techniques
- Further develop the observing system network for operational monitoring and forecasting of ocean parameters
- Provide biological data to protect marine ecosystems and conserve biodiversity
- Improve the exploitation and the dissemination of data from existing observing systems for both *in situ* and remote sensing measurements
- Further validate and improve existing modelling systems
- Integrate scales and processes by improving multiscaling, nesting techniques and coupling between bio-physical models
- Develop provider services to process and disseminate data and products for different users
- Improve and provide new services for fisheries, HABs, water quality, sea level and waves, pollution, etc.

1.6 Links with other programmes

One important link to be strengthened is with the North West Shelf Operational Oceanographic System, NOOS, which shares part of the IBI-ROOS area. The organisation of IBI-ROOS will follow the functional structure of GOOS, where "liaison and integration" will include links to GODAE, GCOS, JCOMM, GMES, various EU-funded projects (e.g. MERSEA and MarCoast), IOC, IMO, OSPAR, and national monitoring programmes.

GMES is a key initiative in Europe, aiming to develop European operational services in support of public demand and policy-driven requirements for information. Implementation of operational oceanography in this area provides useful information to existing GMES projects. There will be close collaboration with the MERSEA Integrated Project, as well as the pan-European Coastal project ECOOP that will start in early 2007. The implementation of operational oceanography in the IBI area will build on the observing methods and modelling systems partially developed with support from these projects.

Links also need to be established with activities in USA, Canada, North Africa and other countries with an interest in the IBI area.

1.7 Implementation plans

ECOOP will provide the means to work together in the IBI area, where we propose to work on the Atlantic front in a downscaling strategy from the global scale (MERSEA) to regional, coastal and local scales with specific end users applications — HABs, oil spill and storm surges. This approach is also planned to be addressed over other areas through the ECOOP project to cover all regional European seas in the EuroGOOS sense (NOOS, BOOS, Arctic GOOS, MOON, MedGOOS and Black Sea GOOS).

The EU is developing a Marine Framework Strategy and has adopted a green paper on Maritime Policy. Both documents have strong influence on IBI-ROOS implementation and IBI-ROOS will help with the required coordination between countries. Countries from the region will have to commit to studying the state of the ecosystems, requiring coordination between countries. In the Atlantic area, two or three subregions are involved from the IBI-ROOS area:

- The Celtic Sea subregion
- The East North Atlantic waters of France, Spain and Portugal
- The waters around the Azores, Madeira and the Canaries.

The International Council for the Exploration of the Sea (ICES) has traditionally carried out work on environment and fisheries in the IBI-ROOS region. A yearly ICES Annual Ocean Climate Status Report is published as well as planktonic state. International Commissions such as OSPAR are strongly involved in quality control. The last report of the State of Area IV was published in 2000 and was a collaboration between France, Spain and Portugal, mostly written by IBI-ROOS partners.

Initiatives for a tsunami alert system are being developed by the Intergovernmental Oceanographic Commission (IOC) for both the Atlantic and the Mediterranean.

A number of parallel activities are ongoing which can contribute to the development of operational oceanography in the IBI area. The Global Climate Observing System has produced an Implementation Plan which identifies a number of actions to be taken to establish observing systems, many of which are directly related to the IBI region (GCOS, 2004).

The GMES initiative, initiated jointly by the EU and ESA, aims to develop and establish operational monitoring services by 2008. A number of GMES projects are funded to develop these services, including several Atlantic-related projects such as MERSEA, ECOOP and ESONIM (European Seafloor Observatory Network Implementation Model).

GMES is a mechanism to fund development and implementation of Core and Downstream services based on operational observing and modelling systems. The ESA GMES programme has defined several key service elements to be implemented against the background of user needs and ongoing developments in many applications of satellite data, including risk management and security (e.g. ROSES and MarCoast). GMES includes observations and models, data provision and distribution, service providers, research and development, and links to user groups who are the recipients of the data products. GMES builds links between research institutes and operational institutes and between climate monitoring and operational services (monitoring and forecasting). The Final Report from the GMES initial period 2001–2003 outlines a number of actions for the implementation of operational services within the next five years (GMES, 2004). The marine area is one place where GMES services have been identified to be fast-tracked with the establishment of a marine core service to intermediate users (e.g. agencies) and a downstream service to end users as shown in Figure 2.

It is likely that GMES and other such initiatives will provide funds to consolidate activity in the area of operational oceanography but the key funding for providing these operational services will come from member states in the first instance.

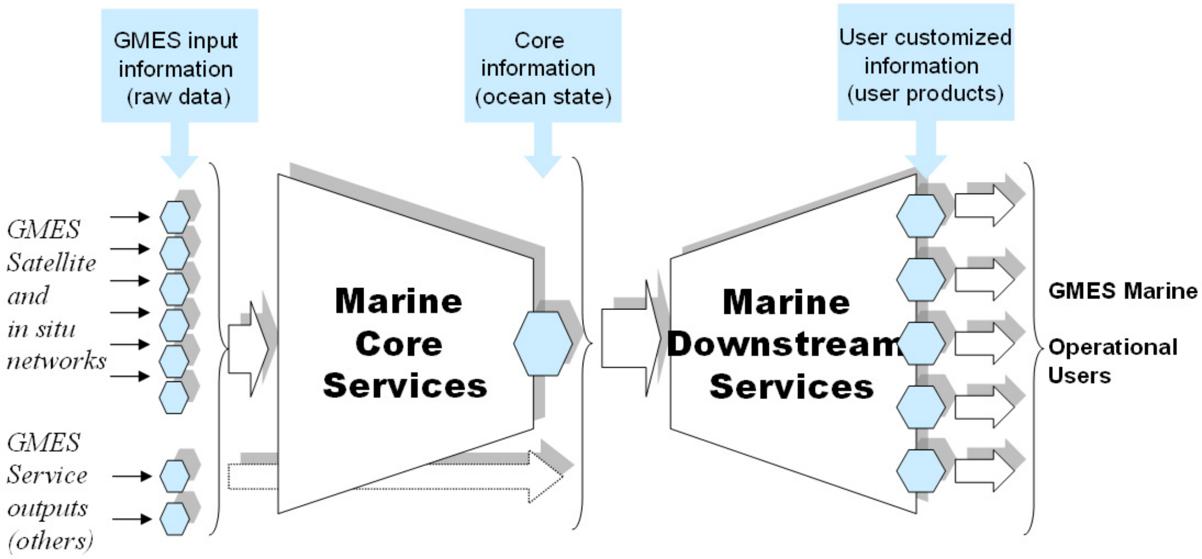


Figure 2 *GMES core services*

2 Background

2.1 Oceanographic characteristics

2.1.1 Definition of the region

The IBI-ROOS region encompasses the Celtic Sea, the western Irish shelf, the whole of the Bay of Biscay, the European sector of the Gulf of Cadiz and the western Iberian margin (Figure 3). The western limit is defined by 30° W and the eastern limit by the continent and 2° E in the English Channel. The northern limit roughly corresponds to Northern Ireland and the southern to the latitude of the southern boundary of Western Sahara (20° N).

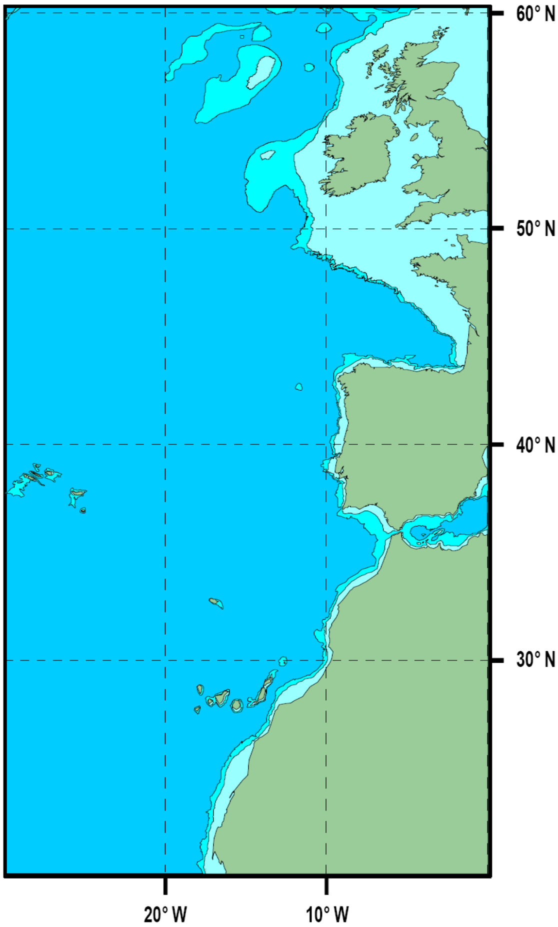


Figure 3 *The IBI-ROOS region*

The IBI-ROOS region includes:

- Deep areas associated with the presence of the first few hundred metres of North Atlantic Central water overlying Mediterranean water masses. Currents are low and present an important variability linked to mesoscale dynamics.
- Coastal regions characterised by strong tidal and wind-induced currents, effects of rivers (Miño, Douro, Tejo, Gironde, Loire, Adour and Guadalquivir), freshwater discharge, and seasonal upwelling in the Western Iberia, but permanent in NW Africa.

The region is characterised by a number of physical processes such as slope currents with marked seasonal variations, eddies and internal tides resulting from the interaction of the continental margin current instabilities with the topography.

2.1.2 Bottom topography

The Iberian continental margin is divided into subregions by seamounts, banks and submarine canyons. Some of these canyons are particularly prominent, such as the Cap Breton (~44° N) and Nazaré Canyons (~39.5° N), where the 1000 m isobath is found only 3 km from the coast.

The continental shelf in the northern Bay of Biscay has gentle slopes that are more than 140 km wide (Vanney and Mougenot, 1981). Along the Cantabrian coast the shelf may be as narrow as 12 km; off western Iberia the wide section is between the river Miño and the Nazaré Canyon, and in the Gulf of Cadiz it is of the order of 50 km wide, particularly to the east.

The shelf is relatively narrow off south-western and north-western Ireland and quite broad to the west of Ireland. The narrow shelf off the south-west coast is adjacent to the shelf break near Goban Spur while Erris Head (off the northwest coast) is located close to the narrowing continental shelf that plunges into the Rockall Trough where depths exceed 2500 m.

2.1.3 Meteorology

Atmospheric circulation in the middle latitudes of the North Atlantic and over western Europe is governed by the existence of two main centres of activity: an anticyclonic zone near the Azores (the Azores High), and a low pressure area near Iceland (the Iceland Low). Between these two areas, the prevailing winds are south-westerly (downwelling favourable) in autumn and winter while they are north-westerly (upwelling favourable) in spring and summer. The average patterns of individual years reveal a great inter-annual variability, enhanced in spring (March–April). The annual mean wind stress near the European ocean margin at about 43º N is directed to the east, while south of that latitude the wind stress turns to a more southward direction (Isemer and Hasse, 1987).

2.1.4 River runoff

Rivers represent the principal sources of freshwater that drain into the Atlantic along the French and Iberian coast. The Loire, Gironde, Miño and Douro are the main rivers with an annual mean outflow about 27000 $m^3 s^{-1}$. Together they contribute 60% of the total freshwater discharge onto the shelf. Each of them has a peak runoff in winter or spring exceeding 3000 $m^3 s^{-1}$ and a minimum in summer of about 200 $m^3 s^{-1}$. Along the French coast, the plume of the Vilaine can merge with the Loire and strengthen its impact, especially in terms of turbidity. The rivers in the Cantabrian shelf are small due to the proximity of the mountains to the sea. In Ireland the river Shannon provides up to 800 $m^3 s^{-1}$ run-off to the western Irish shelf at peak times. It is also worth noting that freshwater sources in the United Kingdom such as the river Severn are likely to be significant contributors to the fresh water flux in the Celtic Sea and western Irish shelf.

2.1.5 Sea level, waves and tides

Sea level is of significant practical importance with regard to storm surges in estuaries; it also constitutes a dimensioning parameter in the design of harbours and coastal infrastructures for land protection, erosion prevention and is a relevant indicator in the context of global warming.

Forecasting of waves and tidal currents are essential for navigation safety and coastal marine activities. There are plans to develop the considerable potential for tidal power generation in some parts of the French, British and Irish coast. At present only the Rance has been operating for 30 years. However, the cost estimates, coupled with concerns over environmental impact, discourage actual construction and currently none of the plans are progressing.

2.1.6 Water masses and circulation

Most of the water masses are of North Atlantic origin, including those that have been transformed after mixing with the Mediterranean water that outflows through Gibraltar (Pollard *et al.*, 1996; Rios *et al.*, 1992).

Between 1000 m and the surface, Eastern North Atlantic Central Water (ENACW) (Harvey, 1982) is found with two main branches: a subpolar branch formed in an area south of the North Atlantic Current (NAC) spreading southwards (Pollard *et al.*, 1996) and a subtropical branch formed in the northern margin of the Azores current, which moves towards the Iberian Coast (Pingree, 1997). They meet near the Iberian NW corner where the subpolar branch subsides to spread southwards under the subtropical branch (Fraga *et al.*, 1982; Rios *et al.*, 1992). Mediterranean outflow in the Gulf of Cadiz splits vertically into several cores at different levels: the shallow core centred at depths around 400 m (Ambar, 1983), the upper core at depths around 800 m and the lower core at depths around 1200 m. In the region off Cape St. Vincent, where the bottom topography turns sharply, part of the Mediterranean undercurrent — mainly the shallow and upper cores — is deflected northward and follows the continental slope along Iberia.

A poleward-flowing slope current at most depths is found along the eastern Atlantic margin west of Ireland. Mean residual currents range from about 5 $cm s^{-1}$ SW and W of Ireland but can increase to 10 $cm s^{-1}$ further west at Porcupine Bank. Residual currents are stronger NW and N of Ireland (15–20 $cm s^{-1}$) along the Malin shelf. Seasonality in the slope current is apparent south of Porcupine Bank (53° N) which is less readily measured in the Rockall Channel margin. Poleward transport along the continental slope south of Porcupine Bank does not vary hugely and is about 3 Sv. Along the Rockall margin, whilst transport varies little with season, interannual variability is relatively large, so that the transports may vary from 0–8 Sv (White and Bowyer, 1997).

Shelf currents are dominated by the tides. Residual currents have a southerly component on the outer shelf but northerly and clockwise around Ireland on the inner shelf. Wind-forced residuals are relatively small but there is a significant difference in the dynamic response to different wind forcing on the shelf currents.

In south-west Ireland the proximity of the Irish Shelf Front (ISF) to the coast determines the strength of the coastal current (Raine and McMahon, 1998). A front close to the coast inhibits the coastal flow, but when the front is further offshore, flows of about 20 $cm s^{-1}$ appear. The presence or absence of northern Celtic Sea Water (NCSW) near Fastnet rock (Southern Ireland) may be linked to the frontal position.

Off south-west Ireland thermal fronts and upwelling events are observed in summer (Raine *et al.,* 1990). The fronts form the boundary between stratified and well-mixed (probably upwelled) waters, and phytoplankton blooms often occur in the vicinity of the fronts. Summer stratification results in the development of bottom density fronts on the inner shelf which drive baroclinic flows clockwise along the Irish coast, reinforcing any buoyant freshwater-forced currents (Nolan, 2004).

In the Bay of Biscay, interactions of tidal currents with bottom topography are responsible for the formation of seasonal thermal fronts, such as the Ushant front off western Brittany. Several other mixed areas occur along the French coast, generally in the vicinity of islands. Along the Armorican and Celtic slopes, frontal zones are induced by internal waves. Coastal upwelling appears off the Iberian Peninsula in spring and reaches a maximum in summer, when it also occurs in the south-eastern Bay of Biscay over the shelf off the Landes coast. Coastal upwelling intensifies off the western Iberian coast at typical periods of four to ten days as the wind forcing the circulation pattern is characterised by along-shore shelf currents stronger that the cross-shelf component. The effect of the upwelling on the chemical parameters of the coastal waters off western Iberia was characterised by Coste *et al.* (1986) and the mesoscale processes such as jets, eddies, and counterflows associated with the upwelling by Peliz *et al.* (2002). The consequences of the upwelling of subsurface waters are not only a lowering of the sea surface temperature (SST) but also an increase in primary productivity and fisheries (Fiúza, 1979; Chícharo *et al.*, 2003). Although upwelling off western Iberia occurs mainly during summer months, there are also winter events which can have an impact on the biology (Santos *et al.*, 2004; Ribeiro *et al.*, 2005).

South of Gibraltar, a lot of knowledge of the coastal upwelling ecosystem was obtained during the intensive studies of the 1970s. The coastal upwelling is maintained by the presence of favourable north-easterly winds throughout the year, although winds and upwelling are more intense during the summer months.

The distribution of water masses in the region has been summarised by Barton (1998). Most of the region, from Cape Finisterre to Cape Blanc, is dominated by North Atlantic Central Water (NACW), responsible for fertilising the coast during upwelling processes, although there is considerable variation in this water mass with latitude.

In western Iberia (Figure 4) there are along-shore flows, mainly towards the north over the shelf (surface and slope) and towards the south (Portugal current) off the continental shelf (Perez *et al.*, 2001; Huthnance *et al.*, 2002; Martins *et al.*, 2002). The Portugal Current is the northeastern branch of the large-scale subtropical surface gyre flowing off Portugal. The Mediterranean Undercurrent flows from the Strait of Gibraltar along the upper continental slope of the Gulf of Cadiz. Off Cape St. Vincent, part of it turns northward and part spreads west and south-westwards into the NE Atlantic. Eddies are shed by the Mediterranean Water Undercurrent off Portugal. A poleward flow along the continental slope off western Portugal exists throughout the year at intermediate depths (carrying Mediterranean Water) and also at the surface layer in winter (Portugal Countercurrent). However, in summer, the surface circulation along the slope reverses, turning equatorwards, in response to the wind-induced coastal surface divergence. The circulation of MOW is towards the north with meanders and meddies as the main significant characteristics, and deeper waters have northeastward drift with less variation and thus less impact on the yearly upper layers oceanic climate.

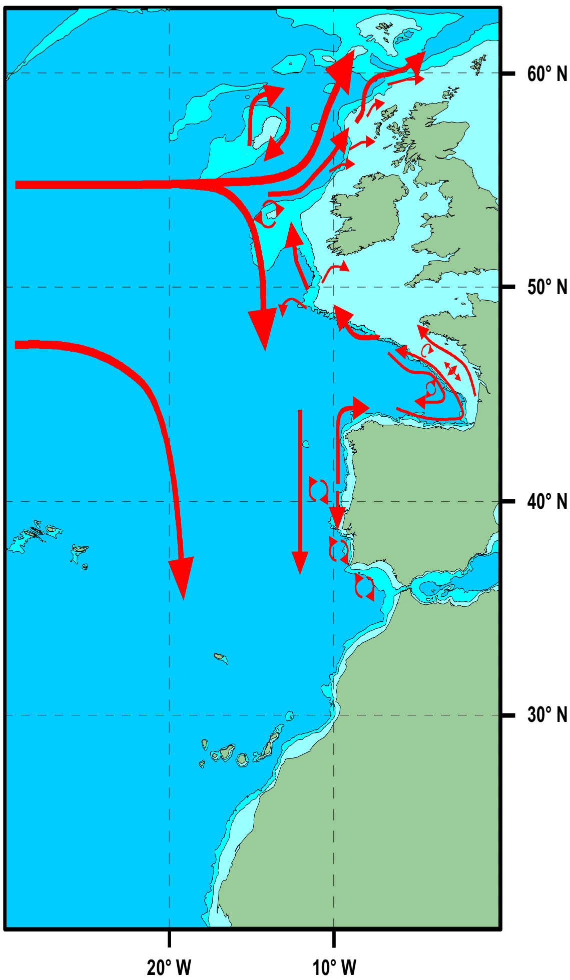


Figure 4 *Surface circulation in the IBI-ROOS area*

In Biscay (Figure 4) there is a weak (1–2 $cm s^{-1}$) and variable anticyclonic surface circulation and the presence of cyclonic and anticyclonic eddies shed by the slope current (Saunders, 1982; Maillard, 1986; Koutsikopoulos and Le Cann, 1996; Pingree and Le Cann, 1992). As the winter Poleward Current enters the Bay of Biscay around Cape Finisterre, warm water moves eastward along the Cantabrian continental shelf and slope. Some flow continues its poleward advance across the Landes Plateau and the continental slope of Cape Ferret canyon. Where topography changes abruptly, as in Cape Ortegal, Cape Ferret canyon and Goban Spur, the slope water is injected into the oceanic region to form anticyclonic eddies that contain a core of slope water (Pingree and Le Cann, 1989; 1990). These slope water oceanic eddies (or "swoddies") contain surface warm water and their movements have been followed using infrared and colour satellite images (Garcia–Soto *et al.*, 2002) and floats (van Aken, 2002; Huthnance *et al.*, 2002).

2.1.7 Synthesis of main oceanographic characteristics

The hydrodynamics of the region are dominated by the following features:

- **Weak anticyclonic circulation** in the oceanic part of the Bay of Biscay where mesoscale features such as anticyclonic eddies have been found, containing a core of slope water (Pingree and Le Cann, 1989; 1990) formed where topography changes abruptly such as in Cape Ortegal, Cape Ferret canyon and Goban Spur.
- **A poleward-flowing slope current** due to the geostrophic adjustment of the cross-shore density gradient that occurs when the large-scale eastward flow meets the continental boundary.
- **Coastal upwelling** particularly evident along the western Iberian coast, although it also occurs off northern Iberia and to a limited extent off south-west France. It results from the persistence of alongshore equator-ward winds during spring and summer, with a southward jet over the shelf, offshore transport in the upper water layers (especially in association with filaments) and compensatory onshore transport at subsurface levels.
- **A northward flow of MW** particularly relevant to the (bottom-trapped) shallow and upper cores, and to the generation and displacement of eddies carrying MW out of the IBI-ROOS region.
- **Shelf circulation** governed by the combined effects of tides (which are particularly important over the Armorican shelf and the southern Celtic Sea), buoyancy (coastal currents induced by run-off from the main rivers) and wind.
- **River plume fluctuations and lower salinity lenses** sustain a cold pool known as a "Bourrelet froid" (Vincent and Kurc, 1969) which is isolated on the middle part of the French shelf and sometimes in the northern Celtic Sea.
- **Cross-shelf transport** acts along the axes of submarine canyons. This is due to amplified tides and non-linear wave-current interactions, and is particularly important in relation to the canyons dissecting the shelf between Cap Breton and Nazaré.

Cabanas *et al.* (2003) showed that a notable shift in the winds has occurred during the last two decades, resulting in a reduction in the spring-summer upwelling off the northwest of the Iberian Peninsula. Koutsikopoulos *et al.* (1998) determined a mean increase of 1.4ºC in the surface waters of the southeast Bay of Biscay for the period 1972–1993 (0.6ºC per decade), which was slightly higher in winter than in summer. Over the last century, Planque *et al.* (2003) showed an increase in the mean annual SST of 1.03°C. In the intermediate Bay of Biscay waters from the mixed layer to 1000 m, temperature and salinity increased during the last decade by 0.032ºC yr^{-1} in the ENACW and 0.02ºC yr^{-1} in the Mediterranean. These rates of warming are two to six times greater than those accepted for the North Atlantic (Gonzalez–Pola *et al.*, 2005).

Cabanas *et al.* (2003) reported a long-term trend in sea level, varying from 2.02 mm yr^{-1} in Santander to 1.45 mm yr^{-1} in A Coruña, where estimates over recent decades are greater than for the whole period (1945–1999).

2.2 Marine activities

In the IBI-ROOS region the marine industries related to fishing, shipping and shipbuilding have been a feature for many hundreds of years. These activities are concentrated in coastal areas and the last century has seen an increase in the utilisation of marine resources and the marine environment linked to economic and social development of the coastal regions.

The most important activities concerning uses of the sea are described in the following subsections.

2.2.1 Transport

For centuries transport related to trade between northern Europe and Africa and Asia has been an important business in the IBI-ROOS region. Increased oil transport from the Middle East has caused occasional damage (disasters) and problems near the seashore. Maritime traffic is more intense and is expected to increase substantially in the future.

In addition to traditional navigational aids — weather forecast, traffic control, lighthouses, etc. — real-time data and forecasts of oceanographic parameters such as water level, current velocity and direction, waves, buoyancy, and wind speed and direction are required by captains in order to ensure a safe voyage.

2.2.2 Ecosystem management

To manage the ecosystem, nowcasts and forecasts of ocean climate are necessary to improve the assessment of renewable resources. Knowledge of expected biological production is necessary to improve management tools such as TAC and quotas, and also the expected aquaculture harvest.

Upwelling intensity, and to a lesser extent other factors such as water stability, retention areas produced by local or general current fields and other mesoscale features like river plumes and eddies affect biological processes in the small pelagic fish community. Global warming has been related to changes in the distribution of several species that are progressively increasing their northernmost distribution limits. Recently, rare species from North Africa were reported in the Algarve and western Iberia (Quero *et al.*, 1998).

Oyster and mussel cultivation dominates aquaculture in France estimated at around 100 000 tons per year. In Spain, the total production oscillates around 300 000 t shellfish — 90% of the total aquaculture production. In Ireland 43 000 t of shellfish were produced in 2004, as well as 58 000 t of finfish (mainly salmon). Production can be affected by the presence of harmful algae or spread of disease.

2.2.3 Environmental protection

For many decades industry, agriculture and the general population (including coastal users and tourism) in the densely populated coastal area have placed the seashore under strong environmental pressure. A large number of cargo ships, oil tankers and hazardous cargo vessels adds an extra risk to the safety of coastal waters and the shore.

Real-time operational oceanographic forecasting is desirable for support in combating accidental oil and chemical discharges into the sea. Both drift forecasts and impact assessments are produced to ensure optimum use of resources available and diminish the damage.

Moreover, for nature conservation, vulnerable or sensitive natural seabed habitats have to be monitored, such as maerl beds, zostera eelgrass or kelp forests. A reliable assessment of the hydrodynamic and biogeochemical environment of these areas can only be provided by the results of operational oceanography obtained at the appropriate scale. For instance, there should be more focus on forthcoming marine protected areas by zooming in on them.

2.2.4 Coastal management

All countries have for decades operated a network of tide gauges and of met-ocean buoys. Reliable data are required for climatic studies, but real-time transmission is still expected so that government agencies can assess the options to manage the coast.

2.2.5 Recreation

The shoreline of the IBI-ROOS region has for generations attracted people for tourism and recreational purposes — an activity that has increased since 1970. The number of people on beaches, leisure boating and wind surfing has especially increased during the past 1–2 decades, resulting in higher frequencies of rescue operations. Ocean forecasts and warnings are improving the safety connected to leisure activities in the region.

2.2.6 Fisheries

This region is a transition zone where both tropical and boreal species are naturally present. This means a complex community structure where typical temperate-water species from the south occur together with those of northern origin and, consequently, high biodiversity indices exist with a large number of commercial and non-commercial fish species caught for human consumption. The fishing activities and the industries related to these activities are of great social and economic importance in the coastal areas. The fisheries exploit demersal and pelagic fish species, crustaceans and cephalopods.

The main pelagic species are sardine and anchovy (small pelagic) and mackerel and horse mackerel (middle-size pelagic). These species form the basis of important fisheries in the Iberian Peninsula and the Bay of Biscay, which represent an important source of income for local economies. Other species more common to temperate and subtropical waters, such as chub mackerel (*Scomber japonicus*), Mediterranean horse mackerel (*Trachurus mediterraneus*), tuna (*tunnus alalunga*) and demersal species, namely hake, megrim, four-spot megrim and anglerfish (*Lophius piscatorius* and *L. budegassa*), are distributed throughout the area and targeted by the fishing fleet.

Different kinds of fleets operate in this area — trawl, artisanal, purse-seine and longline.

The main species landed by the trawl fleet are hake, white and black anglerfish, megrim, horse mackerel, mackerel, blue whiting, red shrimp, rose shrimp and Norway lobster.

The artisanal fishery is composed of a large number (over 10 000) of small boats, operating mainly inshore and using a variety of gear such as gillnets (the majority), seines, beam trawls, longlines, traps and dredges. Some of these boats are licensed for more than one type of gear. The main species landed are octopus, pouting, horse mackerel, hake, mackerel, anchovies and sardines.

The wind, river runoff and oceanographic characteristics greatly affect the fish abundance, distribution and catchability.

The river runoff in the French shelf of the Bay of Biscay benefits species with estuarine dependencies, which are absent in the Spanish area. Species whose recruitment is highly dependent on larval drift processes, such as hake or megrim, show strong links with hydrographic structures of retention and transport, independently of whether they have cyclonic (cold and fresh) or anticyclonic (warm and saltier) characteristics in relation to the general pattern of the surrounding waters (Sánchez and Olaso, 2001).

Upwelling in the Iberian Peninsula has a large influence in the pelagic community, both in terms of productivity and thus food availability, and offshore transport and thus possible increases in mortality rates. Upwelling indices, based on both wind data and hydrographical models have been used to improve environmental-stock-recruitment relationships. Seasonal upwelling, local upwelling and mesoscale-induced upwelling have also been suggested as important environmental features affecting ecosystem production and fish recruitment, although measures of these features on a large scale are necessary to improve understanding of fish recruitment.

2.2.7 Harmful Algal Blooms

An important problem that occurs on this coastline is due to the toxicity of seafood products and to the mortality of sea life induced by the growth/accumulation of some toxic algal species. The main agent of mass mortalities of fish and benthic organisms in the region is the hemolysin-producing dinoflagellate *Karenia mikimotoi*. Dense blooms of this species have been detected in the Bay of Biscay, both by teledetection and by sampling with ships of opportunity (FerryBox).The most serious Harmful Algal Bloom problems that have made an impact on the development and sustainability of aquaculture within Europe are associated with contamination of farmed shellfish with Diarrheic Shellfish Poisoning (DSP) toxins produced by different dinoflagellate species of the genus *Dinophysis*, and Paralytic Shellfish Poisoning (PSP) toxins produced by dinoflagellate species *Gymnodinium catenatum* and *Alexandrium minutum*. The latter species usually blooms in estuaries or semi-enclosed areas. In contrast, *Gymnodinium catenatum* populations build up in Atlantic shelf waters off Galicia (south of Cape Finisterre) and Portugal (Sordo *et al.*, 2001). Intense PSP-toxin outbreaks associated with blooms of this species have re-appeared in the Atlantic coasts of Iberia after 10 years without being observed, a fact that suggests connections with climate variability. ASP toxins also seem to be widely spread in the Channel and in some bays (Rade de Brest), where *Pseudo-nitschia* blooms occur with a wide diversity of species.

The characteristic spatial-temporal scales for population development are 10 n.m. and 10 days respectively. The occurrence of an event at the coast depends on advection and/or dispersal of structures developed offshore. Implementation of 3D hydrodynamical models resolving these scales would allow risk analyses to be conducted for the coastal rias and embayments where intensive mussel aquaculture and other shellfish resources from natural beds are located. Better knowledge of nutritional requirements — for instance, in the case of the mixotrophic species of *Dinophysis* — would be a benefit from refinement of those predictions.

The general approach aims towards prediction of harmful events at the coast based on risk analyses, which could be successively refined, following successive improvement in the knowledge of the ecology of these species. Consequently, the development of *in situ* measuring systems should follow a tiered approach integrating the different improvements in knowledge and technology.

3 Existing Systems in the IBI-ROOS Area

3.1 Introduction

IBI-ROOS constitutes a close cooperation between national governmental marine laboratories and agencies in the countries surrounding the IBI area responsible for collection of observations, model operations and production of forecasts, services and information for industry, the public and other end users.

IBI-ROOS plans to coordinate, strengthen and harmonise the national and international efforts to assess and predict the marine environment and thus effectively improve operational oceanography — defined as the activity of systematic and long-term routine monitoring of the seas, their interpretation, and the rapid dissemination of products (typically forecasts, but also assessments to politicians, and mobilisation of resources to face unexpected events such as the recent Prestige oil spill).

IBI-ROOS is based on a family of existing programmes, projects and modules, financed and operated by different institutes and marine laboratories in the IBI area. The existing ocean observing systems have been developed and maintained to meet their own purpose, including:

- Management of fish stocks for sustainable exploitation
- Preserving healthy marine ecosystems
- Ensuring public health
- Safe and competent navigation.

These purposes, which serve the broad public good, require long-term observations and commitments as well as international cooperation which may be executed only through involvement from governments and governmental institutes.

3.2 Existing activities and observation platforms

IBI-ROOS is being built on existing monitoring programmes and activities at sea and along the coast, sustained by the countries bordering the IBI area. Many of these oceanographic observatories are based on long-term projects assessing practical needs such as fisheries management, sea health and secure transportation.

Protection of this economical value has resulted in pre-operational or on-line monitoring systems of many environmental and biological variables, with a value for IBI-ROOS determined by:

- Real-time/on-line availability
- Spatial and temporal resolutions and coverage in sampling
- Operational status of the measuring systems
- Monitoring status of the observations: routine-based or monitoring oriented projects

Most physical parameters can be measured accurately with sensors from research and commercial vessels, fixed platforms and floating buoys. Although all these systems lack synopticity, remote sensing systems can resolve the spatial variability for some parameters and therefore operational products are offered in near real-time.

Biological measurements are still at an early stage of technical development, and real-time data together with temporal and spatial coverage of processes are bottlenecks that limit the generation of operational products. The creation and introduction of new technology regarding biological measurements should be considered in itself as a challenge to IBI-ROOS.

The various variables of interest are reviewed here together with the techniques presently in use. Innovative technical solutions are mentioned. Table 1 summarises the individual systems and networks which produce this information in the various regions of the IBI area (a more detailed list of the existing observation types is provided in Annex 1). The spatial coverage of these resources is also shown in Figure 5.

3.2.1 Water level

Water level is one of the first variables which has been measured routinely. The IBI waters are not an exception to that rule: 42 water level stations are operated from Dunkerque to Gibraltar, including the Irish coast. Variations can then be traced back for many years. This variable is of high practical importance regarding storm surges in estuaries, and also constitutes a dimensioning parameter in the design of harbours and coastal infrastructures for land protection and erosion prevention. Finally, water level is a relevant indicator in the general context of global warming.

Variables, observing systems and national scores					
					
Water level	Tide gauges	●	●	●	●
	Satellite		●	●	
River discharges				●	●
Wind, waves and surface circulation	Buoys	●	●	●	●
	Meteo stations	●	●	●	●
	Satellite (radar)		●	●	
Hydrological variables	Transects (time series)		●	●	
	Fixed stations	●	●	●	
	Large scale ship observations	●	●	●	●
	Ships of opportunity		●	●	
	Moored systems		●		●
	Satellite SST	●	●	●	
Currents in the water column	Moored systems	●	●		
	Drifters		●	●	●
Hazardous substances	Pollutants (metals, organic, oil)	●	●	●	●
	Microbiological	●		●	
Phytoplankton and zooplankton	Transects/stations (time series)	●	●		
	Harmful Algal Blooms	●	●	●	●
	Satellite (visible)	●	●	●	
	Ships of opportunity	●	●		
Fisheries	Pelagic species (surveys)	●	●	●	●
	Groundfish species (surveys)	●	●		●

Table 1 *Summary of the ocean observing systems and networks in the various IBI-ROOS regions.*

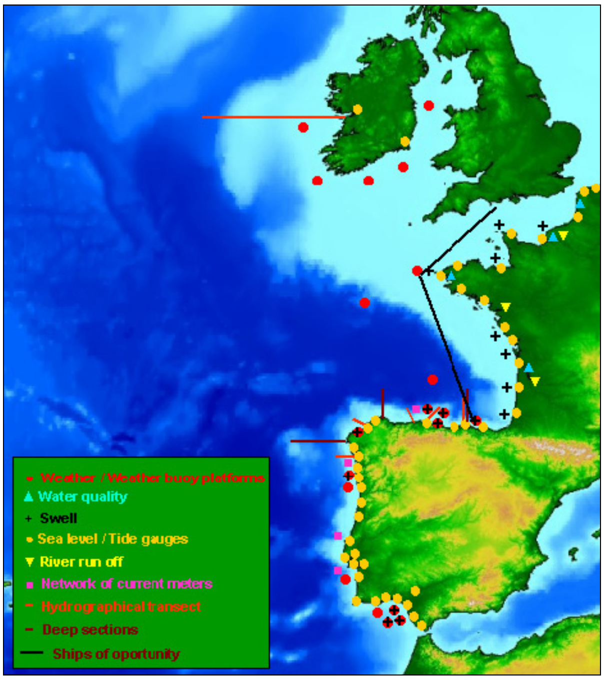


Figure 5 *Map showing the spatial coverage of different ocean observing systems operating in the IBI-ROOS area.*

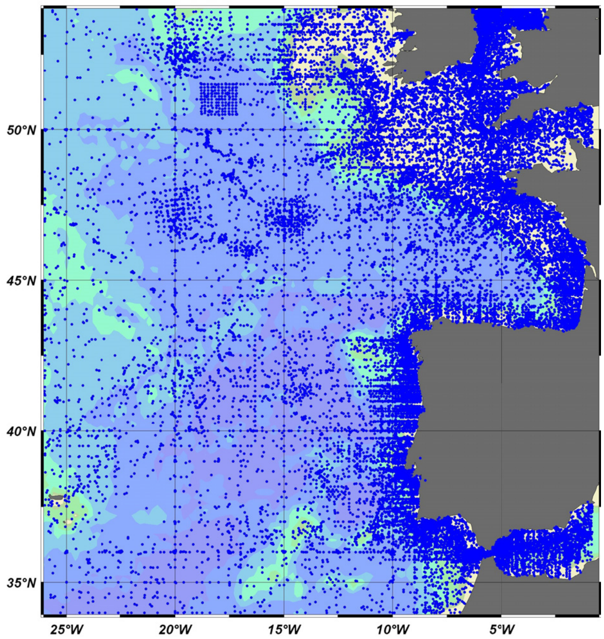


Figure 6 *Spatial distribution of hydrographical stations in the ICES oceanographic database within the area 34°N to 54°N, 26°W to 0.5°W as of May 2005 (courtesy of ICES).*

Therefore, within the IBI-ROOS area, the effort to collect water level data should be encouraged and improved, particularly regarding access to data in real-time. At an international level, the network of European sea level measuring stations contributes to GLOSS (Global Sea Level Observing System) under the IOC (Intergovernmental Oceanographic Commission), see www.pol.ac.uk/ntslf/data.html.

3.2.2 Wind, waves and surface circulation

Monitoring and forecasting of wind, waves and surface currents are essential for navigation safety, harbour construction and most marine activities. Related operational services are generally conducted by national services and concern both measurements (*in situ*, coastal radars and remote sensing) and modelling.

The network of *in situ* monitoring stations in the IBI-ROOS area is composed of 39 permanent installations, most of them transmitting real-time information accessible on the web. On the Atlantic Coast of Spain it should be mentioned that Puertos del Estado has carried out an experiment operating 2 HF radars to measure waves and surface currents during four months with very good results in measurement validation with fixed buoys and utility of technology. A similar experience started in 2006 with two HF radar operated by SHOM/France in the western part of Brittany. These experiences should be capitalised on and extended to other areas. It should also be noted that 3 deep water ODAS buoys (Brittany, Gascogne and Ouessant) are operated by Météo-France for met-ocean measurements, 5 more in Irish waters by the Marine Institute, and 6 others in Spanish shelf-slope waters by Puertos del Estado. In the Basque area there are 7 completely operational coastal met-ocean stations.

Satellite observations will play an increasingly important role in monitoring waves over the entire region. Techniques such as “collocation of satellite and buoy measurements” are very promising when higher-resolution satellite observations provide data closer to the coastline. SLA, SST and colour images provide a synoptic spatial distribution of circulation features.

Within the IBI-ROOS initiative, wind, waves and surface current information should be made available to all actors through a data management system to support the modelling activity.

Collocation of a satellite sensor together with oceanographic (wave spectrum, etc.) and meteorological (surface parameters) buoy networks consists of associating **each** measurement from the satellite product with **all buoy measurements** matching the following criteria:

- distance from satellite projection lower than a given value
- time difference between satellite and buoy measurement lower than a given value.

The process is thus slightly different from satellite/satellite collocation since not only the closest buoy measurement is selected but all of those matching the criteria. The final product contains all the satellite cells for which collocated buoy measurements were found, together with the related list of buoy measurements.

3.2.3 Hydrological variables

The term “hydrological variables” include temperature, salinity, dissolved oxygen, turbidity and nutrients. Observations of temperature and salinity are carried out in real-time by more than 50 fixed buoys and shore stations in the IBI-ROOS area. Additional data are collected regularly from ships during scientific cruises and in connection with monitoring programmes (Figure 6), and by ships of opportunity such as the FerryBox activity conducted by SOC between Portsmouth and Bilbao, weekly since April 2002, or with the cooperation of the coastal fishing fleet (RECOPESCA project). Moreover about 20 Argo floats provide temperature and salinity measurements every ten days in the deep-sea part of the IBI-ROOS area.

3.2.4 Synoptic sea-surface fields

Remote sensing is a major source of hydrological data. As an illustration, IFREMER has developed an image browser for the Bay of Biscay and the English Channel/Southern North Sea (http://www.ifremer.fr/nausicaa). These browsers aim to:

- Present a comprehensive remote sensing data set (Sea Surface Temperature, chlorophyll concentration, mineral suspended matters) over the continental shelf of the Bay of Biscay processed through locally calibrated algorithms.
- Provide inputs to biogeochemical models (surface solar irradiance, winds, river outflow) and satellite data for assimilation.

The following parameters are displayed in the browsers:

- Bathymetry
- Mean climatological SST for the current day (calculated on 10-day periods from 1982–1995)
- SST (4 daily AVHRR passages, data provided by the Ocean and Ice Satellite Application Facility of EUMETSAT/Météo-France in Lannion)
- Chlorophyll concentration
- Inorganic suspended particulate matter
- Irradiance
- Wind (shown on the irradiance maps)
- *In situ* data (when available)
- Outputs of biogeochemical models are included as they become available.

There is however a need to complement the present observation scheme with real-time observations on the vertical distribution of temperature and salinity at least, and hopefully the complete set of hydrological variables, in a synoptic pattern over the geographical coverage of models with a limit as close as possible to the coastline.

The experience of the Coriolis programme will provide very valuable real-time data using a proven powerful data management system.

3.2.5 River runoff

Fresh water fluxes as well as concentrations of the main biochemical variables are of utmost importance as they represent the main source of anthropic perturbation of the coastal environment. They are needed as a forcing variable to models. Data generally exist as climatologies of the main rivers; access to this information has to be improved.

Action should be taken to at least complete the climatologies of the main Atlantic rivers and gather these data into a single database. Plans should be made to implement real-time monitoring programmes in the main estuaries, in close connection with water authorities. Moreover, access to forecasts should be granted for modelling purposes.

3.2.6 Currents in the water column

Currents in the water column are measured by specific moorings carrying current meters at different depths and more recently by bottom-mounted Acoustic Doppler Current Profilers. In both cases, data are not generally available in real-time. Campaigns are regularly conducted using bottom-mounted ADCPs for limited periods of time (a few months), and 7 ADCPs constantly monitor the water column currents along the Basque Coast.

There is a clear need for better geographical coverage and for observations in the open waters to monitor the transports between locations. Experiments to derive turbidity from ADCP signals have been successfully proven (Tessier *et al*., 2003) and should be considered as a candidate technique for future operational activities.

3.2.7 Hazardous substances

"Hazardous substances" are defined as substances that are not only toxic but also persistent and liable to bio-accumulation. The most well-recognised hazardous substances are organic chlorinated hydrocarbons, heavy metals and organo-metallic compounds. The presence of hazardous substances in the water, sediments and biota in the Bay of Biscay is monitored by the IEO and IFREMER and along the coast of Portugal by IPIMAR, and AZTI runs a network for water, sediment and biota quality assessment in the Basque estuaries and coastal area. The objectives of these traditional activities is to monitor levels and general trends of concentrations of these substances by manual sampling and laboratory analysis. The sampling frequency extends from yearly to weekly during accidental spill crisis periods.

Higher frequency monitoring of these variables is needed in order to produce alarms that could signal a discharge from waste water, sewage or ships. Incorporation of remote sensing surveillance of ship routes is recommended in order to identify tank-cleaning activity in open waters.

3.2.8 Primary production, harmful algal blooms and zooplankton

In Portugal, Spain, France and Ireland programmes are carried out to monitor and inform the authorities and the public of potentially harmful algal blooms — HABs (Figure 7).

These programmes are implemented at locations where molluscs (e.g. mussels and oysters) are cultivated for human consumption. Identification of harmful species and data on algal concentrations are provided in near real-time. This system has been in operation for 20 years.

Remote sensing of ocean colour provides a unique means for synoptic observation of the phytoplankton distribution over the continental shelf. Chlorophyll, as an indicator of biological particles and inorganic suspended particulate matter governs

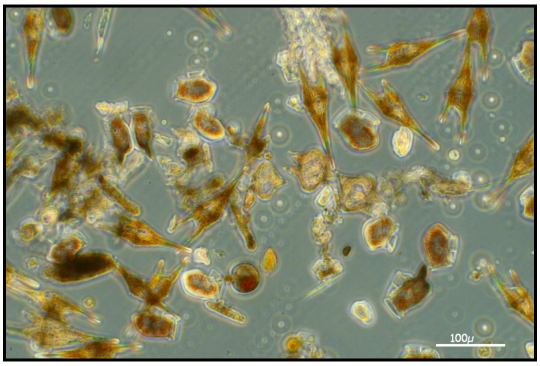


Figure 7 *Live cells from a plankton net-haul, dominated by Ceratium furca, Dinophysis caudata and to a lesser extent D. acuta, collected in Ria de Vigo during a diarrhetic shellfish toxins outbreak, October 2003 (Escalera et al. 2003, Phase contrast micrography, 100X).*

a large part of the absorption and scattering properties of the coastal waters. However, optical techniques from space are hampered by clouds and cannot be used alone for year-round monitoring of phytoplankton; they need to be associated with biochemical models (Gohin, 2005).

Chlorophyll concentrations in the IBI area has been routinely retrieved from SeaWiFS (and more recently from MODIS data) since 1998. This activity has to be pursued as it is a unique source of real-time synoptic information about the biological processes at work in the water masses.

Zooplankton abundance and biomass are a proxy to food availability for fish larvae and for pelagic species. Both parameters are routinely measured in oceanographic surveys and monitoring programmes carried out at specific locations (i.e. Santander, Gijón, Cudillero, Coruña and Vigo). New equipment has recently been developed to measure abundance and biovolume of zooplankton at a fine vertical resolution and a wide range of size classes (e.g. Laser Optical Plankton Counter, L-OPC). Therefore abundance and biomass (dry weight or biovolume) of zooplankton can be obtained in near real-time and the data used for fish assessment. The longest available data series for oceanic phyto- and zooplankton in the IBI area has been monitored by SAHFOS' CPR (Continuous Plankton Recorder) Survey since the early 1950s (www.sahfos.org).

Abundance and seasonal dynamics of zooplankton species can be traced to monitor changes in the ecosystem due to human impact or climate variability. Long-term programmes on biological oceanography were established in 1988–1992 at several locations along the Spanish margin of the Bay of Biscay, and zooplankton species counted every month. Both data and sampling logistics can be mobilised for operational purposes on demand, e.g. historic data have been used to monitor potential changes in the ecosystem after the Prestige oil spill (Figure 8).

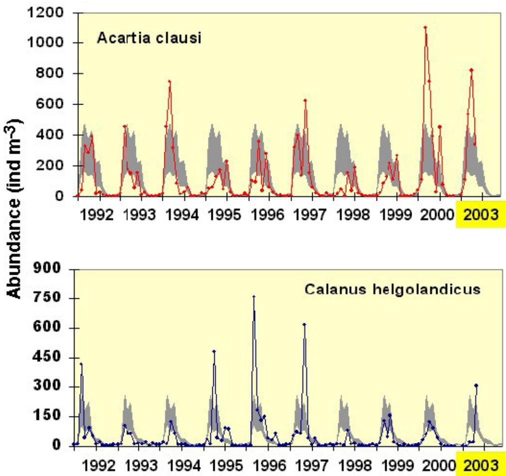


Figure 8 *Abundance of two copepod species before and after the Prestige oil spill (courtesy of IEO).*

3.2.9 Fisheries

Sardine, anchovy, tuna, mackerel and horse mackerel constitute the main pelagic fisheries in the IBI area. Acoustic surveys are carried out during winter and spring and egg surveys are performed during the spawning season of sardine and anchovy and cover the waters from the Bay of Biscay to the Gulf of Cadiz. Sampling combines acoustic methods with plankton tows and fish catches. Results are processed and used operationally for the evaluations within the same year of sampling (ICES, 2006).

The main groundfish species are hake, megrim, anglerfish and *Nephrops*. Bottom trawl surveys have been performed since 1982 (fourth quarter) along the Spanish continental shelf from Vigo to the French border and since 1979 (first and fourth quarter) along the Portuguese continental waters, (from 42°N to 36°N) according to the sampling strategy described in Cardador *et al*. (1997). These maps on the number of recruitments as well as adults are produced in near real-time and assimilated into models (ICES, 2005).

3.3 Existing modelling activities

There is active model development work on the south-western shelf of Europe, an area extending onto the Atlantic Ocean/Margin from Ireland to Morocco. This activity is very diverse due to the objectives to be reached. These objectives deal with operational oceanography and real-time and forecasting data, research improvement on processes and applications such as algal blooms, storm surges, accidental pollution, sediment transport, fishery or primary production. For this reason, the modelling activity of the area concerns several scales:

- regional, coastal and local
- research or operational mode systems
- circulation, wave, tidal, ecosystem, drift, dispersion or sediment transport models on their own or linked together.

These systems are mainly supported by national resources. Most of them are maintained and run — and often also developed — by a laboratory or team for their own needs. Some of them, such as in France and Spain, result from the association of several institutes and laboratories that work together to reach a common objective of operationality.

A selection of operational and future operational modelling systems are described in the following subsections. They address those models run by present EuroGOOS members and IBI-ROOS partners. This list will be able to evolve with time as members or partners increase.

3.3.1 Circulation models

The objectives of the Mercator[1] system are to forecast the global ocean circulation and dynamics, for climate, research, marine security, natural hazards or other end-user oriented applications. Its aim is also to provide initial and boundary conditions to open ocean forecasts and to higher resolution regional or coastal systems. The system, using OPA code, has been developed at global and basin (North Atlantic) scale and is going to be developed at the regional scale, covering the IBI-ROOS area, to improve the circulation near to the coast. At the moment, Mercator runs an operational system of the North Atlantic (9°N to 70°N) and the Mediterranean sea including assimilation of satellite and *in situ* data (Figure 9). This system has been operational since January 2003 and is run every week to forecast the circulation of the complete area for the following 14 days.

1. Mercator is the French sustained programme on operational oceanography led by Mercator Océan, a consortium company composed of 6 members: CNES, CNRS, IFREMER, IRD, Météo-France and SHOM.

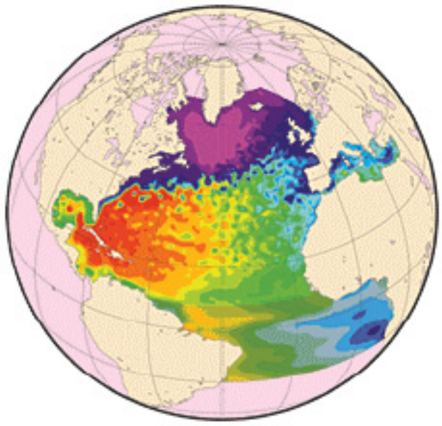


Figure 9 *Mercator North Atlantic operational system.*

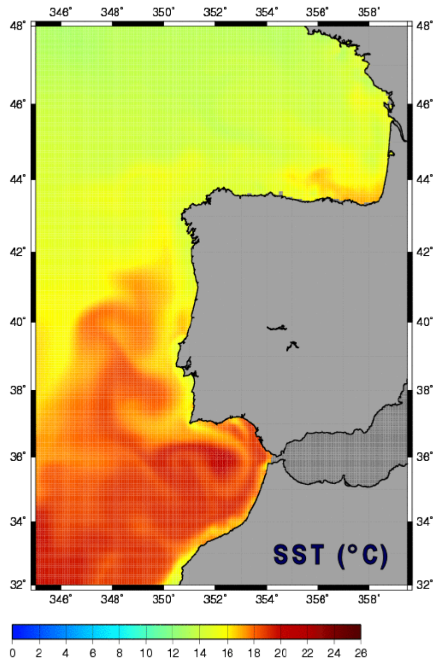


Figure 10 *Atlantic domain (ESEOAT) of the operational ESEOO project.*

The main objective of the Spanish national project ESEOO[2] is to promote operational oceanography in Spain, with special focus on oil spill pollution forecasting at any place along the Spanish coast where an accident might occur. This project is concerned with observation, data management and modelling in an area corresponding to the Spanish waters, i.e. surrounding the Iberian Peninsula on both Atlantic and Mediterranean sides and the Canary Islands. The modelling system is divided into 3 domains to be run in operational mode. The ESEOAT domain, (Figure 10) using POLCOMS code, covering the Western Iberian coast and shelf

2. ESEOO is a 3-year project (2004–2006) composed of 14 Spanish and 4 international partners and coordinated by Puertos del Estado. After the end of the project, a continuation is planned as a consortium company (referred hereafter as ESEOO-II).

(15°W–0.5°W, 32°N–48°N) and the ESEOCAN domain of the Canary Islands are both included in the IBI-ROOS area.

One of the objectives of the operational coastal oceanographic system PREVIMER coordinated by IFREMER is to have routine information on the state of the marine coastal and local environment for the entire French coast. This information concerns various ecosystem applications strongly linked to the circulation in the area. Applications vary with respect to the end-users:

- the public (recreational areas: bathing, diving, fishing, yachting)
- professional users (shellfish farming, HABs, fishing, eggs and larval cruises, turbidity)
- coastal managers (water quality against micro-biological or chemical discharges)
- environmental businesses (hindcasts for strengthening impact studies)
- intermediate users such as scientists (halieutic research, climatic research, interest in hindcasting).

Based upon experimental data and numerical modelling (MARS code), the relevant processes identified range from space scales including the Bay of Biscay, the Channel or the north-western Mediterranean down to the estuaries or littoral bays. Therefore the models used are embedded using AGRIF with the possibility of two-way zooming, and the whole system will evolve with a greater ability to zoom over areas that can be selected for an urgent need (e.g. accidental spills). Ecosystem applications can be studied either directly or by coupling with ecological, wave and sediment transport models. Time scales concerned with these various applications encompass the tidal cycle up to a decade for describing annual variability.

PREVIMER, the current operational system running in the IBI-ROOS area, gives a 2-day forecast. It consists of 4 embedded models (Figure 11) with a mesh resolution range from 5 km down to 200 m and tidal flats for coastal and local domains. Over the Iroise sea, a daily forecast displays both hydrodynamic circulation and sea state.

The Instituto Superior Técnico (IST) addresses coastal and local applications — both recreational (bathing) and ecological (fisheries, shellfish farming) in the estuary and the coastal region of fresh water influence of the river Tagus. The very high resolution circulation MOHID system is used, including tides, run-offs and tidal flats necessary to correctly represent this area of very small depth (a few metres) and the exchanges of Tagus water between the estuary and the coastal sea (Figure 12). The system is operational with a few days forecast.

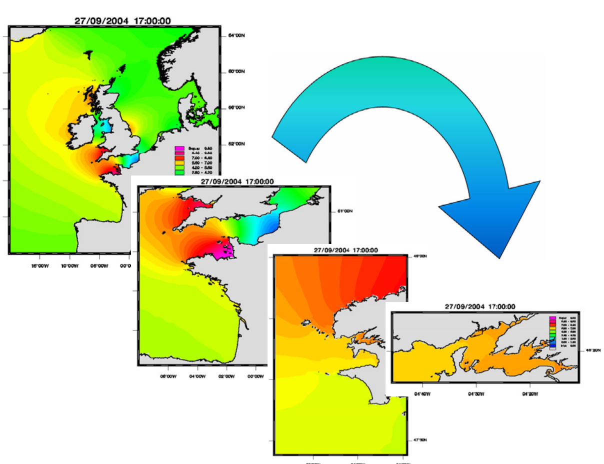


Figure 11 *Operational PREVIMER system: 4 embedded models running simultaneously.*

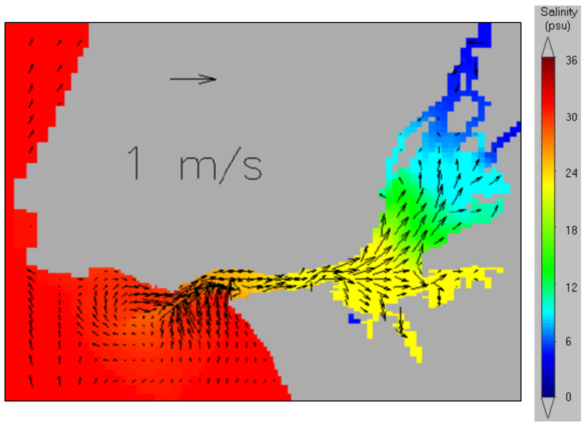


Figure 12 *IST operational system for the Tagus estuary and the coastal area of fresh water influence.*

Several other Portuguese institutes have strong modelling and data assimilation activities off the Portuguese coast with various objectives:

- Mediterranean Water outflow dynamics (IOFCUL[3])
- Dynamics of the Iberian coastal current system (IOFCUL, IST, UA-CESAM[4], IH[5])
- Dynamics of internal waves off Iberia (IOFCUL, IST, IH)
- Regions of Fresh Water Influence (IOFCUL, IST, UA-CESAM).

3. IOFCUL: Instituto de Oceanografia, Faculdade de Ciências de Universidade de Lisboa
4. UA-CESAM: Ocean modelling group of the Aveiro University
5. IH: Instituto Hidrográfico

These teams and subjects are a good basis for the implementation and validation of a future operational coastal circulation system for the Portuguese coast. It would be natural to implement coastal high resolution hydrodynamic models and to nest them in regional scale systems like ESEOO-II and MERCATOR.

The motivation for the modelling effort of the Irish Marine Institute (IMI) falls into 3 main areas: Harmful Algal Bloom (HAB) modelling, larval recruitment and salmon migration on a domain of interest extending to the Rockall Bank in the west to the southern North Sea in the east and from the Bay of Biscay to the Shetlands in the north (Figure 13).

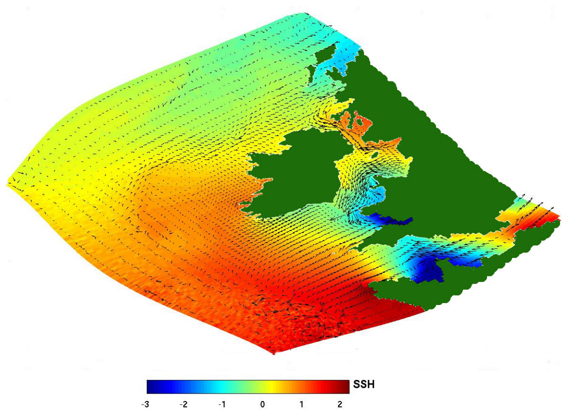


Figure 13 *The Irish Marine Institute shelf domain.*

The IMI has been engaged in numerical modelling for 2 years and all of the IMI's models can be classified as scientific at present. Currently the IMI runs ROMS for this large hydrodynamic model domain where some smaller sub-domains are nested for bays on the west coast of Ireland: Galway Bay and Clew Bay. There are short term plans to nest other bays, which have commercial aquaculture and fisheries interests. Bio-modelling can be added when necessary to the hydrodynamic modelling to study specific plankton species. The IMI also runs QUODDY, a Finite Element Mesh numerical ocean circulation model for the NE Atlantic region, and the SWAN wave model for small domains of interest to groups conducting experiments with wave energy.

AZTI has 3 years of experience in modelling with ROMS and the Cantabrian coastal system is now working in operational mode with meteorological data provided by MeteoGalicia. ROMS outputs are also used to run an IBM pelagic model for the dispersion of anchovy eggs and larvae.

In order to set up a fast-response operational system in the Galician area and the estuaries, the hydrodynamic model MOHID is run by MeteoGalicia in a 3D barotropic version forced by atmospheric pressure, tides and wind. The forecast horizon is 72 hours. A similar system was successfully used during the Prestige accident (Carracedo *et al.*, 2005). Together with Vigo University, Intecmar and IST/Maretec, MeteoGalicia plans to prevent and forecast ecological events such as algal blooms in estuaries where shellfish farming is important.

The IEO aims to provide answers to end users — managers, scientists and the general public — concerning interaction between circulation and ecosystems linked, among others, to fisheries (larval transport, stock management) and HAB monitoring. The area of interest is the Galician and Cantabrian shelf and slope as well as the adjacent ocean. A high resolution system (using ROMS code) solving shelf and slope dynamics with high resolution forcing and full physics that correctly represents freshwater plumes, upwelling fronts, internal tides and internal waves is under development (see Figure 14 and Ruiz-Villarreal, 2006) and coupling to an ecosystem model is one of the main aims.

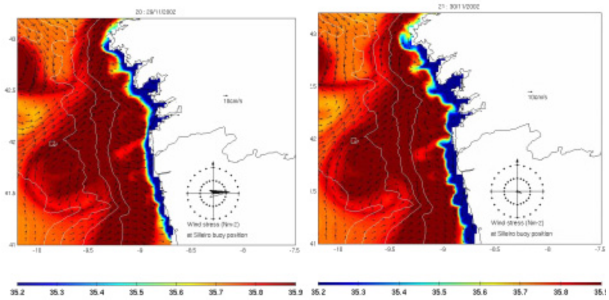


Figure 14 *Variability of river plumes and the slope current in NW Iberia (subset of the IEO coastal domain) in the days leading up to the Prestige oil spill on the Galician coast.*

3.3.2 Storm surge modelling

The Storm Surge forecast system (Nivmar) is a group of applications designed to provide a forecast of the sea level in the Bay of Biscay, Iberian Peninsula and Canary Islands. The system (Figure 15), created in 1998, is based on the ocean circulation HAMSOM model and on the harmonic prediction of tides computed from data measured by the Puertos del Estado tidal gauge network REDMAR. It is executed twice a day using the results from the short-range weather forecasting programme HIRLAM provided by the Instituto Nacional de Meteorología (INM). Moreover, REDMAR data are assimilated, allowing the system to correct systematic errors in the mean sea

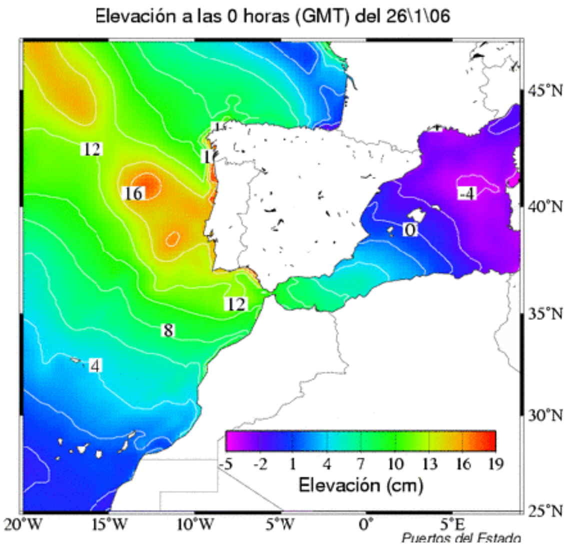


Figure 15 *Sea level residuals computed from the Nivmar Storm Surge forecasting system.*

level due to physicals processes which are not included in the ocean model (i.e. steric height). The forecast period is 72 hours.

3.3.3 Wave modelling

The Puertos del Estado Wave Forecast System (Sistema de Predicción de Oleaje — SPO) was developed in 1995. It was initially created to fulfil the requirement of the Port Authorities to have a planning and management system for their port activities. The system is based on a version of the WAM code with a possibility of two-way nesting developed at Puertos del Estado. High resolution nested applications based on WaveWatch and SWAN codes are also operational in several regions (Figure 16). Data from the REDMAR network of buoys are used for real-time validation. Nowadays, any user can freely access this service through the INM web page. This institute is responsible for keeping the system operational and support Puertos del Estado in the technical development of the SPO.

MeteoGalicia runs the WaveWatch III wave model every day in an operational mode applied to 3 nested grid levels — North Atlantic, Iberian coast and the Galician area — in order to obtain a numerical forecast of sea state. At the same time, for smaller scales, the SWAN wave model is used

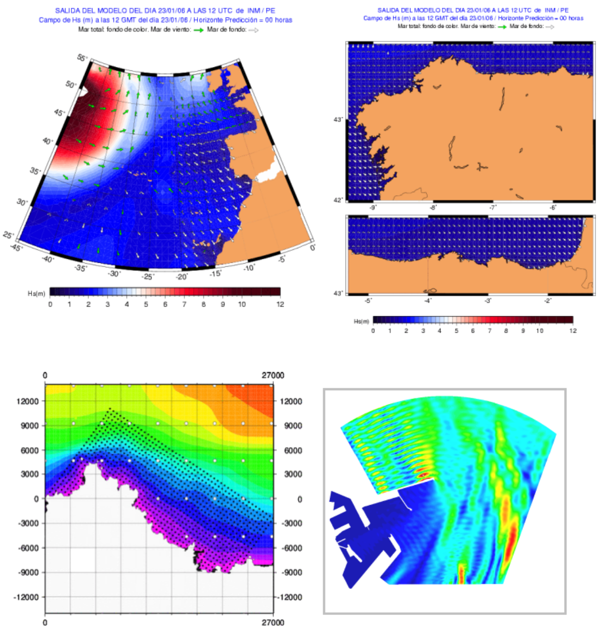


Figure 16 *The wave forecasting system of Puertos del Estado. Nested models from Atlantic scale to Harbour agitation model.*

to downscale the waves to the estuaries in north-western Spain (Figure 17).

WWIII and SWAN wave models are also nested into the SHOM and IFREMER contribution to the PREVIMER system. This provides a well-validated sea-state forecast over the Iroise Sea, taking into account the barotropic currents and the predicted tidal level (and drying banks) for a better description of the wave propagation processes in the shallow coastal waters.

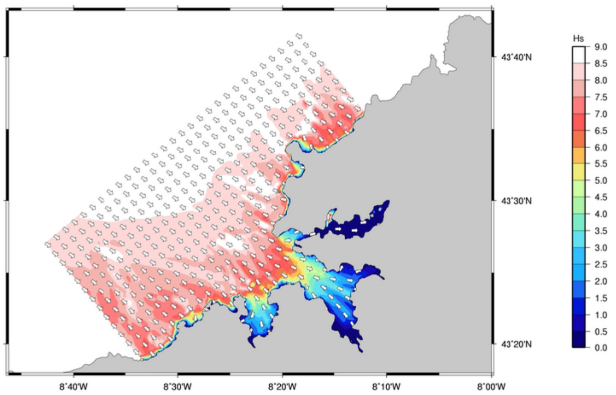


Figure 17 *SWAN model used for the Artabro gulf (NW Spain) by MeteoGalicia.*

4 Future Plans

4.1 Requirements for IBI-ROOS

The applications targeted by IBI-ROOS require long term observations and commitments as well as international co-operation which can only be realised through involvement from governments and governmental institutions.

The key issue for the establishment of an operational oceanographic observing system in the IBI area is integration and further development of the existing observational systems and data sets. The objective is to maximise their utility for the specific purpose for which they have been originally designed and, by combining data sets with further stages of modelling and forecasting, to make them available for other relevant purposes and user groups. The combination of data types into a single system will enable a higher resolution in models, more rapid delivery of products, and longer forecast horizons.

The existing observation systems should adapt and integrate new technologies to make observations more complete, more efficient and more affordable, and the data infrastructure and management system should be complementary to existing systems and attuned to multiple sources of data and their multiple uses as well as quality assurance procedures. Ocean observations in the IBI area require more effective co-ordination between institutes and countries.

The establishment of an oceanographic operational observing system in the IBI area will also be relevant for the work of intergovernmental councils such as

- IOC (Intergovernmental Oceanographic Commission)
- ICES (International Council for the Exploration of the Sea)
- Contributions to GMES (Global Monitoring for Environment and Security)
- EMSA (European Marine Safety Agency)
- EEA (European Environment Agency)
- OSPAR Convention for the protection of the marine environment of the North-East Atlantic
- IHO (International Hydrographic Organisation)
- IMO (International Maritime Organisation)
- WMO (World Meteorological Organization)
- Development of the European Marine Strategy for the sustainable use of the coastal seas

The data collected should fulfil operational needs as well as temporary and long-term demands such as scientific research, national policy on sustainable use of coastal regions and disaster prevention (e.g. Erika and Prestige). Because of the scale of the phenomena it is obvious that these activities and demands cannot be restricted to a national continental shelf: waves, currents, storms, and pollutants move freely across political boundaries. Therefore to meet user requirements we need:

a) More co-operation between the coastal countries in their ship-based programmes and fixed monitoring activities
b) A better geographical coverage of the sampling programmes
c) Regular products on different levels of data aggregation covering the entire geographical region.

A complete operational oceanographic service should be focused on observations, analysis and model predictions of water level, waves, currents, temperature, salinity, oxygen, nutrients, algae, chlorophyll, zooplankton and fish populations.

A well-functioning operational system will require:

- An up-to-date observation system that can provide data with a quality satisfying international standards, combined with an international infrastructure for the capture, exchange and processing of oceanographic and hydrographic (river discharge) data that is capable of supporting real-time or near real-time services.
- A data analysis system that can provide a description of the actual state of the sea and generate input data to operational models. Additionally the analysis system should be able to create statistics and homogeneous time-series of state variables.
- Access to meteorological forcing data and boundary conditions from Atlantic models.
- Operational forecasting models providing forecasts of conditions for the maximum forward look which is achievable by deterministic modelling and statistical forecast of expected conditions for longer periods.

- A presentation and information system specifically targeted to deliver the state and forecasts of the IBI marine environment designed to meet the exact requirements of the user at the site where the work is carried out.

In addition to integration and further development of the existing observational systems and data sets, a key issue for the establishment of an operational oceanographic system in the Bay of Biscay is to improve the speed of data transmission and create a supra-national network connecting marine data archives.

4.2 A coordinated observing system

The review of existing monitoring systems in chapter 3 mainly shows three weak or missing components:

- Access to river runoff data with sufficient temporal resolution in near real time: fresh water fluxes to the coastal seas, and the accompanying nutrient and pollutant loads, are important for accurate monitoring and forecasting the coastal zone ecosystem, pollutant fate as well as for coastal flood management. Observing systems are fragmented, even within nations, and the data are difficult to access, especially in near-real-time (NRT). The IBI-ROOS partners will work towards a more efficient network for the IBI-ROOS area.
- Improved synoptic information for the IBI-ROOS area, especially T,S variables but also the entire set of biogeochemical parameters related to the water column from surface to bottom. This information is requested with a time frame of a day (even an hour or shorter when processes such as tide are involved) with a spatial resolution depending on the variability of the hydrological processes at a specific location. This can be achieved by different means:
    - start deploying continental shelf lagrangian TS profilers (Pagode), first in a limited area—a test case will be defined together with modellers
    - set up experiments to test the feasibility and usefulness of new technologies such as gliders or AUVs
    - take initiatives to install and run measuring systems on supports of opportunity such as ferries, coastal fishing fleet, merchant ships sailing on regular coastal lines, fixed structures (islands, offshore oil and gas platforms) and animals (seals, dolphins)
    - set up experiments with surface drifters (e.g. SURDRIFT floats)
- Improve high resolution bathymetry which is critical for model accuracy especially in shallow waters (<5 m). IBI-ROOS partners will work together in order to improve the bathymetry information available in the area.
- The use of other techniques such as undulating towed fish during scientific cruises or bottom stations could provide good complementary information for applications in specific areas (high variability, point source of pollution, etc.). The deployment of coastal HF radars where the morphology of the shore is favourable will be encouraged and the expertise shared between IBI-ROOS participants.

Improving the reliability of surface moorings (buoys and long-term autonomous instruments) as well as sensors and instruments devoted to biological parameters is considered to be of utmost importance. Partners agree to consider these issues as some of the conditions for future progress.

Finally, IBI-ROOS partners will collaborate to produce advanced remote sensing products for data assimilation in models and a better description of the IBI-ROOS area. Such advanced operational products will be constructed on the basis of the R&D remote sensing results, such as improved algorithms, *in situ*/remote sensing data merging, etc. The new satellite products specialised for the data assimilation in IBI-ROOS models include:

- SST merged with remote sensing/*in situ* products
- Altimetry merged with remote sensing with tide gauges and mean dynamic topography
- Ocean Colour merged with remote sensing/*in situ* products
- Use of SAR data for high resolution winds, waves and surface currents should also be strongly developed, as well as tools for tracking spills and illegal discharges.

4.3 From regional to coastal modelling

Collaboration will enable the IBI-ROOS modelling group to explore the existing different working strategies and, at the same time, to minimise the redundancy between teams. Studies on different scales (regional, coastal and local) complement each other, as the physical processes are different as well as the objectives. At regional scales, the main interest is on large scale and slope circulation, while for coastal scales it is on slope and shelf circulation, river run-off, high frequency processes, tides and upwelling. At local scales, waves, intense circulation patterns associated with estuarine and coastal lagoons mouths, flooding/drying processes and swell are particularly relevant. Another benefit expected from coordinated modelling within IBI-ROOS is that the expertise of several groups will be used to develop comprehensive applications. The simulation of an algal bloom event, for example, could be followed by the different coastal systems of the IBI domain and could in addition be studied in detail by local systems implemented in relevant areas.

The objective of the modelling team is to have a complete and validated pre-operational system from regional to coastal and local scales through a downscaling strategy.

The regional system will extend over the whole IBI-ROOS area, from Ireland to Morocco and from the open sea to the coast. The coastal systems will deal with subdomains of national interest and will together cover the entire IBI-ROOS coastal area (Figure 18). Local systems will be implemented at strategic places directly linked to ecological events and harbour activities. Systems will be developed and run by different IBI-ROOS partners who use different codes. Mercator Océan and ESEOO-II (the continuation of the operational Spanish oceanographic project ESEOO) plan to collaborate in the development of a regional system which includes the IBI area (based on the OPA model). The Irish coast and shelf system is developed and run by the Irish Marine Institute (IMI) and uses the ROMS model. The French coastal system which includes the Channel and the Bay of Biscay is modelled by IFREMER (using MARS code). The North and North Western Spanish system is run by the Instituto Español de Oceanografia (IEO) with the ROMS model. Finally, the Western Iberian coastal system is studied by both the Instituto Superior Técnico (IST) and MeteoGalicia using MOHID code.

Local systems will evolve following needs for applications, such as the circulation inside harbours which is an important water quality issue or the estuaries and coastal lagoons where the main urban and power plant discharges are located. Local systems have been planned or are under development for Galway Bay and Clew Bay (Western Ireland) by IMI, Iroise Sea (Western Brittany), Arcachon lagoon and other local bays by IFREMER, Galician Rias (North Western Spain) by MeteoGalicia and Tagus estuary (Portuguese West coast) by IST.

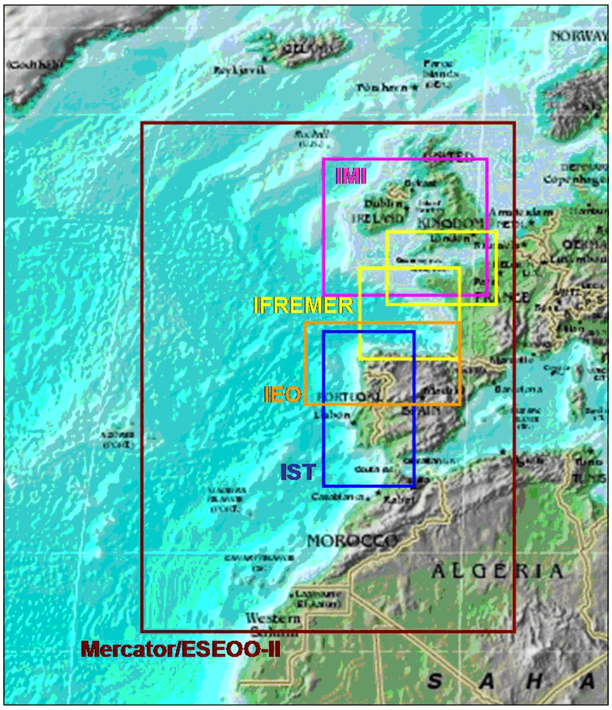


Figure 18 *The IBI-ROOS modelling system.*

Systems with different scales will be linked through downscaling. The regional system will provide data to initialise and force the IBI area coastal systems at open boundaries. These hindcast and forecast data will either be provided on the regional system grid or interpolated/extrapolated with divergence minimisation on the coastal system grid. Moreover a library containing tools and descriptions of techniques for interpolation, extrapolation and optimisation of data used by the different IBI-ROOS modelling teams could be developed and would probably also involve teams other than IBI-ROOS partners that have made important developments on this subject. This library would allow knowledge exchange between teams and, therefore, improvements on the difficult task related to initialisation and forcings. The use of this library would have to follow specific rules (to be defined), for example data format and conventions.

The IBI modelling system including all scale systems will be carefully validated for the different processes described in section 2.1 "Oceanographic characteristics". Some concern the entire area such as the thermal content or a high frequency phenomena, while others are more local, such as the impact of fresh water from rivers. Finally characteristics such as currents and upwellings are linked to the synoptic variability and concern both the regional and the coastal scale. Beyond showing the realism and the limits of the representation of the IBI area circulation, the validation will focus on using a higher horizontal resolution in local and coastal systems in comparison with coastal and regional ones, respectively. Moreover, the work with model validation will support the regional design of the future observing network which will be mainly used as a model validation tool.

By following this common strategy, teams and institutes will be able to focus their resources on specific objectives that are more strongly linked to particular ecological events or problems. These include issues related to algal bloom forecast episodes (MeteoGalicia, Ifremer, IMI, IEO), water quality (IST, Puertos del Estado), bathing water (IST, Ifremer), aquaculture industry (IMI, Ifremer), support to ecosystem-based approaches for fisheries (IEO) and eutrophication (Ifremer, IST).

4.4 Fisheries and their impacts

The impact of different environmental conditions on fish populations and fisheries has been studied extensively. Events such as depletion or increase in abundance of fish species suggest large-scale climate forcing. In addition to large scale forcing, there may be local or regional events such as coastal upwelling or low-range thermohaline-forced currents which can largely contribute to recruitment variability. Most pelagic fish species inhabit areas in which turbulence dominates their environment because it acts on the advection and retention of larvae and so affects recruitment success. These environmental conditions can be represented by indices of upwelling, turbulence, sea temperature, winds or oceanic large or mesoscale circulation as well as atmospheric factors. Operational oceanography activities and products provide scientists and managers with a number of environmental variables and parameters that could help to understand their influence in the distribution of fish spawning, retention areas, production in food webs, and hence availability of food to larval and juvenile fish. Nowadays these operational oceanography products are not in routine use in fisheries assessment and management systems.

Operational fisheries assessment and management is currently performed at annual time scales (at least in ICES waters), and this is likely to be the scale at which operational oceanography products will be of greatest value. In addition, operational products need to be available over multi-decadal time-scales so that they can be compared to historical biological series (e.g. recruitment). Whilst long-term indices of ocean climate are generally based on large scale features (e.g. NAO), process understanding of fish response to the environment is generally more obvious at the mesoscale (10 – 100 km, days – weeks) where oceanographic features such as fronts, plumes, upwelling or eddies occur. An understanding of fish response to climate, compatible with process understanding, requires mesoscale oceanic features to be detected and tracked over long periods of time.

The major trend in the Celtic Sea ecosystem is the steady warming of the area, particularly in the context of the slope current (ICES WGRED). The Rockall trough waters have been warming steadily for several years and have reached an all-time high. The general and continuing reduction of copepod abundance is also of major concern given the major role of these organisms in the food web. Both these factors are likely to have an impact on the life histories of many species, but particularly on the migratory pelagic species—mackerel, horse mackerel and blue whiting.

Both mackerel and horse mackerel migrations are closely associated with the slope current. Mackerel migration is known to be modulated by temperature. Continued warming of the slope current is likely to affect the timing of this migration. The timing and location of spawning by all these species is also likely to be affected by warming. The impact on recruitment is difficult to assess, as mackerel generally recruits well, and the horse mackerel stock depends on very rare massive recruitments. No ecosystem link has been identified for either species.

The widespread and sudden increase in occurrence of non-commercial species such as *Capros aper*, particularly after 1990, might indicate some change in environmental conditions but mechanisms and consequences are poorly understood.

Exploitation of living marine resources in the Bay of Biscay includes a wide range of organisms, from seaweed to shellfish (i.e. Norway lobster, cephalopods), fish (i.e. mackerel, hake, anchovy, sole) and whales. Indeed, it has been reported that molluscs were exploited in the bay as early as the Palaeolithic period and whales in the middle ages (Valdés and Lavín, 2002). The study of the exploitation of some pelagic fish in the Bay of Biscay started in the middle of the last century under the auspices of ICES (International Council for the Exploration of the Sea). The economic and social importance of these and other fisheries and the objective of obtaining appropriate yields led to the development of studies to explain the variability of fish abundance and to predict the strength of incoming recruitment. In this way, important developments have been made in research fields related to marine primary production, ichthyoplankton, zooplankton and applied oceanography. Many of the exploited resources in the Bay of Biscay are managed as a particular unit or stock. In spite of the amount of information about the biology of these species, there is still much ignorance on species interactions, including man, and in their relationships with the variable environment.

In spite of the effort devoted to the description of the marine communities, there are many difficulties in explaining why some species extend and contract their spatial distribution and how their abundance increases and decreases. This is due to the complexity of relationships among abiotic and biotic properties of the ecosystem, which are subjected to different sources of variability (both natural and anthropogenic).

The IBI-ROOS region is populated by a large number of commercial and non-commercial fish species. The fisheries exploit demersal and pelagic fish species, crustaceans and cephalopods. Different kinds of Spanish and Portuguese fleets operate in this area. The main pelagic species in the Iberian Peninsula are sardine and anchovy (small pelagic) and mackerel and horse mackerel (middle-size pelagic). These species form the basis of important fisheries in the Iberian Peninsula and in the Bay of Biscay, which represent an important source of income for local economies. The Spanish and Portuguese fleets operating in the Atlantic Iberian Peninsula shelf also catch a variety of species: hake, white and black anglerfish, megrim and four spot megrim, Norway lobster and blue whiting.

In the Iberian waters, upwelling is the main environmental event that affects fisheries, mainly at the pelagic early stages. Climatic variability of the upwelling and slope current over the IBI-ROOS area will provide information and previews that will benefit the fisheries management, as well as the international cooperation in solving or preventing common problems.

To generate products in the form of easy-to-use indexes, which can be easily transferred to the community of fisheries scientists that relate fish stocks to ocean processes in order to improve the ecosystem management, is of the utmost importance.

4.5 Plan for accidental pollution

Over the last decades there has been a continuous increase in human habitation and industrial and recreational activities in the ocean and the coastal zone, as well as a substantial acceleration in maritime transport and the economic and strategic value of the merchandise transported. This implies an increase in socioeconomic and environmental impacts, sometimes with catastrophic consequences.

The total volume of pollution due to spillage and dumping (associated mostly to human pressure upon the coastline) is substantially larger than the volume from accidental spills. These represent a localised and added impact; their effects, for both shorter and longer time-scales, are relevant and difficult to evaluate. Following the diverse pollution accidents which have occurred in recent years, a number of areas have been directly identified, in which substantial improvements need to be developed in order to advise on pollution impacts and, in case of accidents, to describe the physics and biochemistry of a polluted scenario. Data concerning the local hydrodynamics and detailed chemical composition and properties of the spilled material have to be gathered and combined in order to prepare the best management advice.

1. **Prevention of accidents: risk and danger analysis, prevention measurements, monitoring and prediction**
   - Prepare complete and realistic inventories of areas sensitive to pollution (areas of natural resources, natural beauty, etc.)
   - Investigate pollution monitoring and prediction systems, i.e. efficient systems for the measurement of parameters, with modelling oriented to forecasting.
   - Establish and develop databases of information relevant to common shipping routes—most frequent substances carried and their physico-chemical characteristics, experts and necessary resources for anti-pollution operations, etc.
   - Design surveillance plans and carry out inspections for the fulfilment of regional, national or international laws.
   - Develop and train personnel for local and harbour emergency plans, including both regional and trans-national emergency plans.

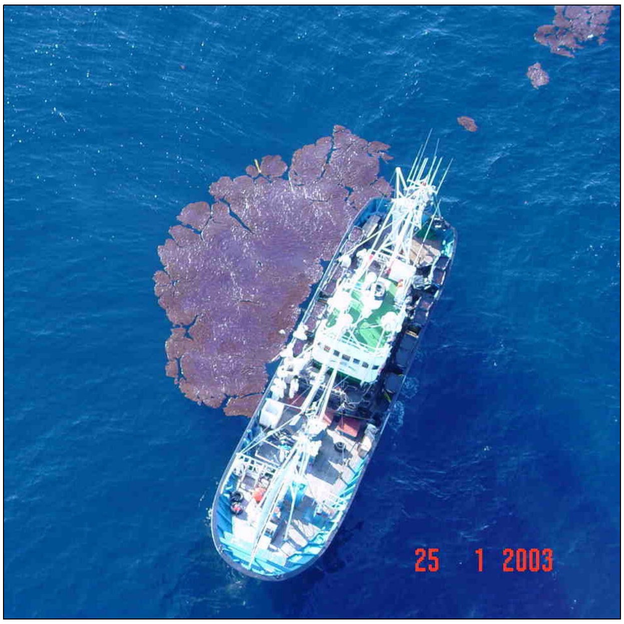
- Identify shipping routes that are secure for both the marine environment and for ships.

2. **Systems of operational forecasting: generation of products and services oriented to emergency event managers and decision-makers**
   - Maintain networks of stations for the measurement of environmental parameters, using different instrumentation systems, including airborne sensors that cover areas with high potential risk of suffering pollution accidents, or that comprise areas under risk.
   - Establish monitoring and pollution forecasting protocols for use during emergency events.
   - Develop new systems for the detection of marine pollution including systems of ‘dissuasive surveillance’ for routine spills from ships.
   - Optimise and install hydrodynamic and particle dispersion models, with high-resolution and reasonable computational costs, working in an operational way and rendering forecasts in real-time.
   - Update, validate and calibrate installed models, using registered databases, supported by information available from the different types of instrumentation systems.

3. **Management of information: advance the use of new technologies for the evaluation of risk events, data distribution and information generation**
   - Circulate data freely and efficiently between managers and administrators involved in the anti-pollution fight.
   - Improve information channels between managers and the media, relating to the anti-pollution operational tasks and the management decisions adopted during the course of the crises.
   - Disseminate information and improve communication. Exploit visual communication tools, sharing opinions on data and previous experiences.

4. **Anti-pollution operations: retrieval and management of residues**
   - Update inventories of available material means, both at a national and international level. Design operational plans, and describe logistics and distribution of means, depending on priorities.
   - Advance the design of new systems for the retrieval of pollution from the sea.
   - Train those sectors related to the sea (professional and sport fishermen, merchant shipping, etc.) for combating pollution. Establish security and health plans for people involved in anti-pollution operational tasks.
   - Define plans of action to deal with/dispose of the retrieved residue.

5. **Impact analysis: evaluation of environmental and economic impact**



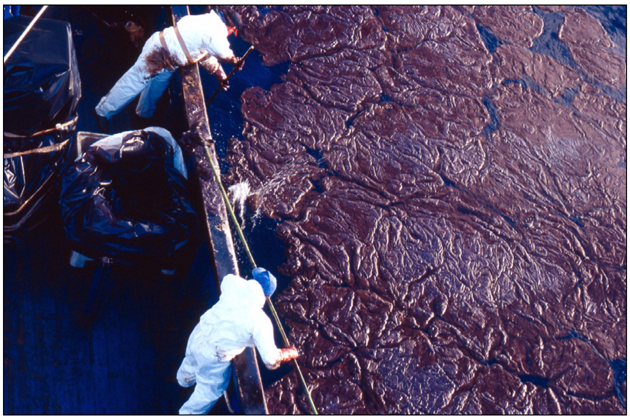


Figure 19 *Retrieval of oil following the Prestige accident.*

- Improve the knowledge of base level marine pollutants, especially in the biological substrate.
- Establish standards for environmental impact studies and derive socio-economic indicators.
- Establish protection measures for public health, with banning and/or closed seasons for commercial fisheries in affected areas.
- Define plans of action for the restoration of the environment.

6. **Follow-up of the impact: networks of measurements and plans**
   - Define pollution monitoring plans
   - Establish restoration plans, considering different aspects (biological, industrial, tourist, etc.)
   - Maintain permanent marine environment observatories.

The services and products provided by operational oceanography will reduce the possibility of the occurrence of an accident in the sea and, if one does occur, enhance the capability of the system to undertake its analysis, monitoring and restoration in a satisfactory and efficient way; as well as minimise the socio-economic and environmental impacts.

4.6 Oceanographic control of HAB events

Blooms of toxigenic microalgae (*Dinophysis* spp., *Gymnodinium catenatum*) that render shellfish unsuitable for human consumption, and of ichthyotoxic species (*Karenia mikimotoi*) that cause mass mortality of caged fish and benthic resources, constitute the most serious natural hazard for the development and sustainability of aquaculture within the IBI-ROOS region. Contamination of farmed shellfish with lipophylic shellfish toxins (DSP, pectenotoxins) above regulation levels and produced by dinoflagellates of the genus *Dinophysis*, is responsible for the longest periods of shellfish harvesting closures.

Information from years of traditional water sampling reveals that proliferations of these species respond to common patterns of physical forcing and to species-specific physical-biological interactions. Another important characteristic is that, with the exception of some *Karenia* blooms, they do not reach high biomasses, and cannot be tracked with ocean colour detection systems. Nevertheless, we can trace the temperature of the water masses they are associated with.

Over the past few years, development of instruments capable of detecting fine structures of the water column have shown that *Dinophysis* spp., *Karenia mikimotoi* and other HAB species often grow and/or aggregate in high cell densities (105–106 cells L^{-1}) in sub-surface thin layers. Investigation on the formation and persistence of these layers, often located in the pycnocline, through the study of interactions between fine scale physical diffusion and net growth, is extremely important, because they can act as retention zones and be transported from shelf waters to coastal areas. Other microscale physical structures, such as anticyclonic gyres, may also serve as retention areas and act as incubators of harmful microalgae. Thus, predictive schemes of *D. acuminata* events in southern Brittany are directly related to the establishment of temporary retentive structures at mid-depth and to their subsequent advection to the coast (Xie *et al.*, 2006); and in the southwest coasts of Ireland, *D. acuta* blooms have been related to transport by bottom fronts. The study of these retention areas constitute the main topic of an ongoing European project, Harmful Algal Blooms in Thin Layers (HABIT), focused on *Dinophysis* spp. in the Bay of Biscay, the Galician coasts and the west coasts of Ireland.

On a larger scale, observations on mesoscale distribution of *Dinophysis acuta* (southwest and west coasts of Ireland, Galicia and northern Portugal), and *Gymnodinium catenatum* (Iberian coast) blooms can be justified by latitudinal differences in the onset of thermal stratification, but also by physical transport (of the conditions, the populations or both) mechanisms that include along-shore transport, cross-shelf transport, bottom fronts, and populations entrained in river plumes after the upwelling season. The offshore boundary of the blooms may be associated with the increased turbulence levels due to internal wave activity.

Monitoring programmes for harmful phytoplankton and phycotoxins established in all EU countries protect public health and control food quality, but increasing demands from fisheries managers and shellfish growers stress the need to improve the predictive capabilities of the toxic outbreaks. Further, monitoring programmes mostly focus on the coastal embayments where shellfish resources are grown and thus provide patchy information on processes that need to be investigated at a larger spatial scale, with the implication of countries that

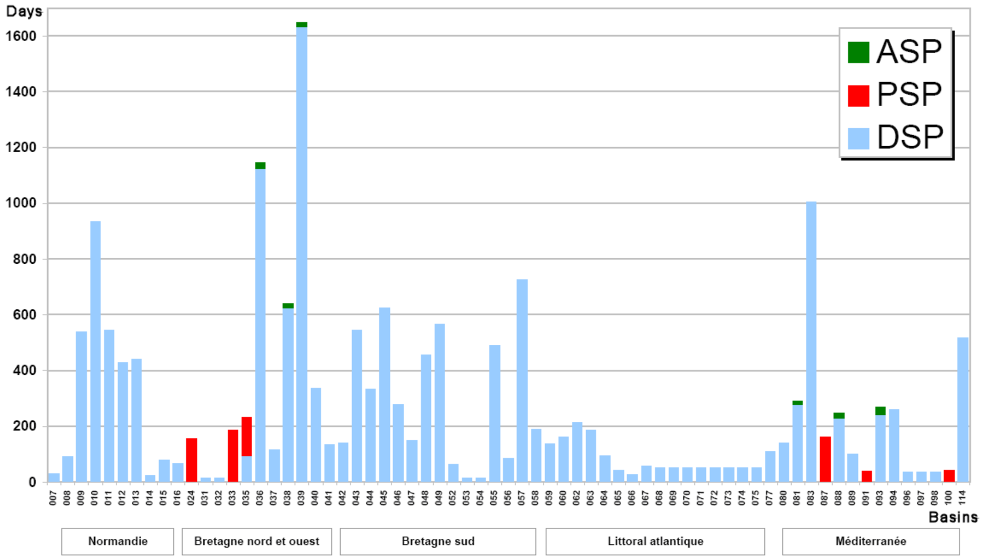


Figure 20 *Total number of harvest closure days, for French basins, for the period 1984–2003, showing that Dinophysis is the main cause of closure.*

suffer a common problem, and with a multidisciplinary approach.

Different approaches have attempted to predict the onset of HAB populations in coastal areas, including artificial neural network analyses, fuzzy logic and hydrodynamic modelling. Given the large influence of the oceanic climate on the IBI-ROOS region coastlines, the belief is that the most appropriate approach would be that based on the concept of operational oceanography.

The ultimate goal is to develop coupled physical-biological models for the main species that cause intoxication in the IBI-ROOS region, especially for those such as *Dinophysis acuta* and *Gymnodinium catenatum*, which seem to be subject to mesoscale along-shore transport and exhibit large inter-annual variability. This is a very ambitious goal requiring a sound knowledge of the physical factors affecting different life history stages (cysts, overwintering populations, vegetative cells) of the species of interest. A preliminary effort should be devoted to the identification of specific HAB situations, parametrisation of the physical and biological processes, and validation of simple species-specific models.

To achieve an operational tool that serves the purpose of HAB prediction, a downscaling of existing models, such as MERCATOR, MOHID, MARS and ROMS to the critical scales at which the physics and the biological processes interact is needed. These scales are of the order of a few tens of centimetres to several metres on the vertical axis, and of a few kilometres to a few hundred on the horizontal axis. Existing or down-scaled physical models can then be used to test situations, such as formation and persistence of gyres and other retention areas, the transport of shelf populations to estuaries during relaxation and downwelling events, and as a consequence, the onset of HAB events at the coast.

The IBI-ROOS region has the appropriate characteristics to fulfil the necessary complementation of expertise and the geographic extent to study physical-biological interactions of HAB species in order to improve prediction of these events. Coordination to carry out simultaneous observations at sea, applying the same techniques, represents an added value. Networking activities, exchange of data and thematic workshops would allow a comparative approach to the study of common problem species, and improved analyses and exploitation of results, through fluid and continuous dialogues between the physicists, modellers and biologists about their respective needs.

The following list of deliverables would encourage interaction between physicists and biologists, networking activity and coordination:

- Construction of HAB species datasets (e.g. *Dinophysis acuta*, *Dinophysis acuminata*, *Karenia mikimotoi*, *Gymnodinium catenatum*, *Pseudonitzschia* spp. and *Lingulodinium polyedrum*) from monitoring stations and oceanographic cruises carried out in the IBI-ROOS area
- Compilation of other relevant data (temperature, salinity, upwelling indices, stratification, species

growth rates, current measurements, satellite images, etc.)

- Identification of specific HAB situations to be used for modelling purposes
- Identification of specific circulation patterns favouring bloom initiation, development and dispersion; retention areas, fronts, etc.
- Development of coupled physical-biological models for the main species that cause toxicity in Irish, French and Galician-Portuguese shellfish, especially for those — such as *Dinophysis acuta*, *Karenia mikimotoi* and *Gymnodinium catenatum* — that seem to be subject to along-shore mesoscale transport and exhibit large interannual variability.

The overall product would be improved predictive skills of HAB initiation, development and dispersion based on understanding the physical forces underlying the areas of bloom development.

4.7 Water quality services

During the last few decades, human intensified use of water has led to a progressive decrease of water quality in aquifers and interior, transitional and coastal waters. The coastal waters support a very rich environment from the ecological point of view which are, at the same time, located downstream of all the main regions of water use (e.g. agriculture, urban and industrial discharges).

In order to identify and understand the majority of water quality problems, it is necessary to have access to data that can contribute to an appropriate description of the carbon, oxygen, nitrogen, phosphorus and silica in the different mineral and organic forms.

The ecological and chemical status must be monitored in continuum and compared with a reference scenario considered to be a "good ecological and chemical status".

The main barriers to overcome in relation to operational water quality services in coastal areas can be be referred to gaps in:

1. **Legislation**: The integrated approach derived from the new Water Framework Directive is going to increase the level of commitment of water users, legislators and the scientific community. This new approach will demand greater exchange of information between all partners.
2. **Monitoring**: The definition and monitoring of the good ecological and chemical status of each system will demand a huge effort. The existing monitoring programmes need to optimise classical field campaigns with automatic data acquisition systems, remote sensing and modelling.
3. ***In situ* sensors**: New and cheaper sensors need to be deployed to automatically measure relevant water quality parameters such as nutrients, pathogen indicators and plankton structure.
4. **Remote sensing**: New products derived from SST and ocean colour can be developed to assess water quality in coastal and transitional waters.
5. **Modelling**: The number of approaches to simulate biogeochemical processes is very diverse and the level of complexity can change a lot. Present data assimilation methodologies applied to biogeochemical models tend to be computationally burdensome; new and more computationally-efficient techniques must be promoted.
6. **Land interface**: The land inputs can be divided into urban and industrial discharges and river discharges. All all these inputs must be monitored in a proper way as the interconnection of the ocean and land water quality observing systems is a critical issue.

IBI-ROOS will be an additional platform of debate in the implementation of the WFD. Work towards a water quality forecast system in the IBI-ROOS area will optimise the definition of the ocean boundary condition for any type of local water quality services.

4.8 Plan for sea level application

Today, sea level operational applications are mainly based on the use of real-time tide gauges to provide the current sea level situation, combined with numerical models to create forecasts. Several networks and forecast systems are available in the IBI-ROOS area, but they work without any kind of inter-communication or connection.

One of the aspects where the lack of co-ordination is more evident is the total absence of real-time data exchange, which affects the service provided. A good example is the sea level forecast systems. Numerical models make use of real-time data by means of data assimilation. Existing systems could and should take advantage of all the data available. This is not the case due to the absence of a mechanism to exchange data in real-time. This problem has been recently addressed by ESEAS at European level, but a contribution is clearly expected from IBI-ROOS.

The GLOSS strategy is trying to change the concept of a tide gauge station from the classical view of a device able to study tides, storm surges and trends to a fully multi-hazard study system, with the ability to monitor phenomena such as seiches and Tsunamis. The tide gauge networks in the IBI-ROOS area use different measuring principles, which hampers the capability of creating stations ready for multi-hazard studies.

Finally, the storm surge operational systems in the region are completely unlinked. This situation is clearly deficient and could lead to serious problems in the case of a severe discrepancy between forecasts.

One of the activities to be carried out in IBI-ROOS is the real-time data exchange of oceanographic data, including sea-level. This work will be done in co-ordination with other European level initiatives such as ESEAS and SEPRISE. Additionally, these steps can also be understood as an advance towards the tide gauge component of an IBI-Tsunami warning system. Tide gauges are a critical component of a future Tsunami and storm surge warning system and it is mandatory to develop systems for the real-time transmission and dissemination of sea level high frequency data at European level.

In the field of sea level forecasting systems, action will be taken in order to create a super-ensemble forecast system for the IBI-ROOS area. In order to do so, atmospheric model data will be shared between the IBI-ROOS partners in order to perform simulations. Results from the different ocean models will be additionally presented in an integrated way, giving the user an estimation of the level of dispersion and confidence of the forecast. This work will be done in full co-ordination with the existing plans derived from the ECOOP project.

The activity derived from IBI-ROOS with respect to sea-level can be understood as one of the necessary steps towards a truly European sea level service, always in co-ordination with other initiatives such as ESEAS.

4.9 Data management and exchange

A number of systems for managing, archiving, and distributing data already exist in the IBI-ROOS area but they are handled at national or institute level with poor coordination between institutes, especially for coastal and real-time applications. Moreover, *in situ*, satellite and model data are often processed, archived and distributed through separate non-interoperable means, which does not help the development of value-added applications.

IBI-ROOS will take advantage of these systems to create a “system of systems” which will provide oceanographic and environmental information to a wide range of users. This “system of systems” will be built on existing components and networks; it will be based on MERSEA developments and the SEADATANET initiative funded by the 6th EC Framework Programme. The aim is for users to be able to access information stored at different locations from a ‘one-stop’ shopping point, which would also make the link with global networks.

To meet the requirements of this wide range of users, IBI-ROOS needs to:

- Make an inventory of all the existing data and products that are available for the IBI-ROOS area
- Implement advanced quality control and validation systems taking into account the large volume of collected data
- Ensure the long-term storage and safeguarding of the data and metadata, built on existing archiving systems
- Move towards a common data policy which will follow the EuroGOOS data policy, implying free exchange of data among IBI-ROOS partners
- Define a common strategy to offer services and common standards for sharing of data and metadata. This common strategy should improve mutual cohesion, cooperation, data exchange, harmonisation of data quality and harmonisation of protocols for data access and visualisation.

The plan would ease data sharing between the different contributors, extending existing services to lead to an integrated data and product service for the IBI-ROOS community. For this we will build the IBI-ROOS box in Figure 21 that will make the link between the global system — under construction within the MERSEA Integrated Project and GMES Marine Core Service — and existing local/coastal systems that are in direct connection with the coastal application users at governmental and commercial level.

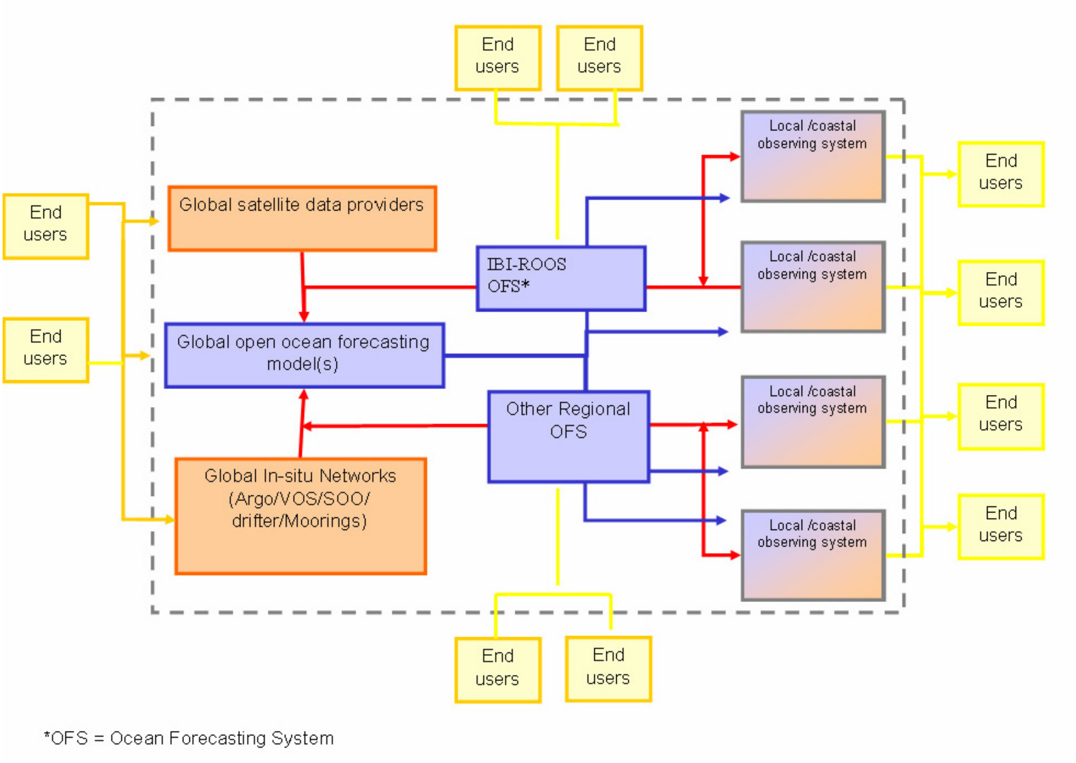


Figure 21 *THE IBI-ROOS Ocean Forecasting System.*

5 Action Plan for IBI-ROOS

5.1 Strategic development

The strategic development of IBI-ROOS activities can be organised along the following five key areas:

1. **Organisation of the cooperation between the different partners**

   The EuroGOOS Agreement provides a general framework and set of objectives for operational oceanography in the European areas of interest, which can be supplemented by more detailed and binding documents and agreements where Members commit themselves to delivering services or resources on a regular basis. For the Iberia Biscay Ireland region, a Memorandum of Understanding will be prepared, setting out the practical methods of collaboration, and the types of commitment which are needed to develop and run collaborative operational systems.
2. **Improve data exchange at IBI-ROOS level**

   This will be done in collaboration with the EuroGOOS Data Exchange Working Group (DATA-MEQ), and European projects such as SeaDataNet and ECOOP following international recommendations from JCOMM or IODE. Free exchange of data will be promoted within IBI-ROOS. The initial focus will be on real-time needs followed by delayed mode exchange.
3. **Define the IBI-ROOS basic monitoring network** (VOS, Argo, Mooring, Satellite SST, SSH and Colour)

   This is achievable by networking activities between the different countries surrounding the region to improve sampling by avoiding duplications. Moreover special efforts will be placed on improving the collection of river runoff information, and implementing emerging technologies such as gliders or shelf lagrangian profilers. The improvement of satellite products in coastal areas will also be studied.
4. **Ease the development of a complete pre-operational system from regional to coastal and local scales through a downscaling strategy**

   The regional system will cover the Atlantic front from Ireland to Morocco and will be used to force coastal systems distributed all along the South Eastern European coastline. Some of these coastal models will themselves force local areas with a specific end user interest. Regional systems will include modelling and assimilation, with a difference between regional and coastal models. This will be done in collaboration with the MERSEA and ECOOP projects.
5. **Improve inputs to downstream services** for the five applications that we have identified as critical in the IBI-ROOS region.

5.2 Priority projects for IBI-ROOS (2007-2009)

Data Exchange: The need to exchange data between operational agencies and end users has never been more acute. IBI-ROOS will establish a data exchange project that will consider:

- Data management
- Data quality
- Data exchange between partners.

The work will be done in collaboration with the EuroGOOS DATA-MEQ working group, first focusing on real-time data exchange, homogenising quality control for core parameters and then delayed mode data exchange for re-analysis purposes.

Model downscaling: Ocean processes within the IBI-ROOS region are governed by local processes (e.g. wind stress, surface heating, river inputs) and by large scale processes within the wider northeast Atlantic Ocean. To ensure that local area models are realistic the IBI-ROOS partners propose to downscale from basin scale models (e.g. MERCATOR, FOAM) through regional models to local high resolution models at the coast. A model downscaling project is envisaged for early development and implementation within IBI-ROOS.

River discharges: There is a growing recognition of the role than river discharges play in governing the physical, chemical and biological characteristics of the IBI-ROOS region and other shelf regions. Accurately measuring these fluxes and prescribing them in models is critical to successfully forecasting coastal dynamics of the region. IBI-ROOS will initiate a project on near real-time and delayed mode delivery of river discharge data sets so that these data can be included in model simulations of the area.

Observing system design: With national and European requirements to optimise and in some cases rationalise observing system platforms, IBI-ROOS will have a dedicated programme of work examining the current observing system assets within the region (buoys, tide gauges, gliders, etc.) and examining ways in which the system can be enhanced to provide a high quality integrated data set at a reasonable cost. Ferrybox systems and new technologies will be considered in this context for the IBI-ROOS region.

Coastal contamination: IBI-ROOS will examine issues of concern with respect to contamination of coastal waters, principally:

- Harmful Algal Bloom (HAB) dynamics
- Oil spill events.

These types of events are common in the IBI-ROOS region and require detailed understanding if they are ultimately to be predicted and mitigated.

The IBI-ROOS partners will produce indicative time-lines and milestones for achieving the objectives of these projects in early 2007.

6 Glossary

ASP	Amnesic Shellfish Poisoning
DSP	Diarrheic Shellfish Poisoning
ECOOP	European COastal-shelf sea OPerational observing and forecasting system
EcoQOs	OSPAR Ecological Quality Objectives
ESEOO	Establecimiento Español de un Sistema de Oceanografía Operacional www.eseoo.org
ESONIM	European Seafloor Observatory Network Implementation Model www.oceanlab.abdn.ac.uk/esonet/esonim.shtml
GODAE	The Global Ocean Data Assimilation Experiment www.bom.gov.au/GODAE
GCOS	Global Climate Observing System www.wmo.ch/web/gcos
GLOSS	Global Sea Level Observing System pol.ac.uk/psmsl/programmes/gloss.info.html
GMES	Global Monitoring for Environment and Security www.gmes.info
GOOS	Global Ocean Observing System www.ioc-goos.org
HAB	Harmful Algal Blooms
ICES	International Council for the Exploration of the Sea www.ices.dk
IMO	International Maritime Organization www.imo.org
IOC	Intergovernmental Oceanographic Commission ioc.unesco.org
IODE	International Oceanographic Data and Information Exchange www.iode.org
JCOMM	Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology ioc.unesco.org/jcomm
MarCoast	A GMES Services Project marcoast.info
MERSEA	Marine Environment and Security for the European Area www.mersea.eu.org
OSPAR Convention	The Convention for the Protection of the Marine Environment of the North-East Atlantic www.ospar.org
PSP	Paralytic Shellfish Poisoning
ROSES	Real-time Ocean Services for Environment and Security roses.cls.fr
SeaDataNet	Pan-European infrastructure for Ocean & Marine Data Management www.seadatanet.org
SEPRISE	Sustained, Efficient Production of Required Information and Services within Europe www.eurogoos.org/seprise
TAC	Total Allowable Catches
WFD	Water Framework Directive www.euwfd.com

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Annex 1: Existing Observations in the IBI-ROOS Area

		Platform/Observation	Spatial and temporal resolution	Programme, Institute	Web Sites
	1	Tide gauges: Sea level	5 tide gauges in Santander, Coruña, Vigo and Cádiz operating since 1940. Real-time	Mareógrafos, IEO	www.ieo.es/indamar/mareas/mareas.htm
	2	Tide gauges: Sea level	6 tide gauges in Galicia and Cantabrian sea. Real-time	Mareógrafos, Puertos del Estado	www.puertos.es/index2.jsp?langId=2&catId=1024462535987&pageId=1053533857296
	3	Tide gauges: Sea level	13 stations on continental coast, 5 in the Azores archipelago and 2 in Madeira	Hydrographic Institute (IH)	
	4	Tide gauges: Sea level	17 tides gauges are installed from Dunkerque to St Jean de Luz. Ifremer is planning to operate real-time diffusion	SONEL/RONIM, SHOM	www.shom.fr/fr_page/fr_act_oceano/maree/maree14_f.htm
	5	Tide gauges: Sea level	5 tide gauges around Ireland	Marine Informatics, Marine Institute	www.irishtides.com/
	6	GLOSS stations	Once every 5 minutes	Department of Communica-tions, Marine and Natural Resources	www.dcmnr.ie
	7	Fixed structures: Ocean & meteorological	ADCP, tide gauges and meteo at 7 locations in the Basque country. Real-time	Ocean-Meteorological stations, AZTI Tecnalia, Spain	http://www.euskalmet.euskadi.net/s07-5853x/es/meteorologia/selest.apl?e=5
	8	Automatic buoys: Waves & current	5 buoys (3 on the continental coast and 2 in Madeira). Delayed mode	Hydrographic Institute (IH)	
	9	Automatic buoys: Waves, current and temperature	4 coastal wave buoys, 3 coastal buoys measuring waves and surface temperature and 6 deep water buoys measuring waves, currents, temperature, salinity and meteorology. Real-time	Buoy network, Puertos del Estado	www.puertos.es/index2.jsp?langId=2&catId=1024462535987&pageId=1053533857296
	10	Automatic buoys: Waves	20 buoys from Dunkerque to Bayonne. Real-time	Candhis, CETMEF	http://www.CETMEF.equipement.gouv.fr/donnees/candhis/
	11	Automatic buoys: Waves	5 ODAS buoys. Real-time	Marine Institute	www.marine.ie/databuoy
	12	Temperature and Conductivity	5 ODAS Buoys non real-time (once every 30 minutes)	Marine Institute	www.marine.ie/databuoy
	13	Automatic buoys: Meteo data, waves	3 buoys Gascogne, Brittany and Ouessant operated by Meteo France and UKMO	Meteorological programme	www.ndbc.noaa.gov/Maps/France.shtml
	14	Automatic buoys and Ships of opportunity: Meteorological data	Buoy data from GTS and ships of opportunity	IM	

		Platform/Observation	Spatial and temporal resolution	Programme, Institute	Web Sites
	15	Automatic buoys Meteoro-logical	5 ODAS buoys. Real-time	Marine Institute	www.marine.ie/databuoy
	16	Moorings: Currentmeters, ADCP and sediments	2 arrays in Nazaré Canyon area 1 CORSED platform in Nazaré Canyon area	EUROSTRATAFORM, IH MOCASSIM, IH	
	17	Moorings: Currentmeters	1 mooring off Cascais (adjacent zone to Tejo river)	SIGAP, IPIMAR's fixed station for long-term physical, biological measurements	
	18	Ships of opportunity: Ferry Box, hydrological parameters	Line Portsmouth-Bilbao, Real-time, weekly	SOC	www.soc.soton.ac.uk/ops/ferrybox_index.php
	19	Ships of opportunity: Plankton	CPR IB and SB lines, Monthly, since 1958	CPR project, SAHFOS and IPIMAR, UK and Portugal	
	20	Underway Data from Irish Research Vessels Surface Temperature, Conductivity, Fluorescence	Every 10 s along ship track during survey. Typically Irish waters	Marine Institute	
	21	Satellite remote sensing: Temperature	The whole area is covered every day	AVHRR-NOAA, AZTI Tecnalia and IEO	www.teledeteccion-oceanografica.net
	22	Satellite remote sensing: Ocean colour	The whole area is covered every day	SeaWIFS, AZTI Tecnalia	
	23	Satellite remote sensing: scatterometer	The whole area is covered every day	(QUICKSCAT), AZTI Tecnalia	
	24	Satellite remote sensing: altimetry (sea level)	The same region is covered every week	Jason1, GFO, ENVISAT, AZTI Tecnalia	
	25	Satellite remote sensing: Radar	The same region is covered every 10 days	SAR/ ESA, IFREMER	www.ifremer.fr/cersat/en/data/gridded.htm#backscatter
	26	Satellite remote sensing: Topography	The same region is covered every 10 days	Feng Yun, AZTI Tecnalia	
	27	Satellite remote sensing: Monitoring of SST, Chlorophyll using Ocean Colour	Image browser covering Bay of Biscay since 1985	IFREMER, CLS Login: gascogne Password: gascogne	www.ifremer.fr/cersat/facilities/browse/del/gascogne/browse.htm
	28	Satellite remote sensing: Monitoring of SST, Chlorophyll using Ocean Colour	Image browser covering the English Channel since 1985	IFREMER, CLS	www.ifremer.fr/cersat/facilities/browse/del/roses/browse.htm

		Platform/Observation	Spatial and temporal resolution	Programme, Institute	Web Sites
	29	Satellite remote sensing: Temperature and ocean colour	The whole area is covered every day	AVHRR-NOAA and SeaWIFS-ÕrbView2, DOP-Univ. Açores AVHRR-NOAA and SeaWIFS-ÕrbView2, CEM-Univ. Madeira AVHRR-NOAA, IO-Univ. Lisboa	
	30	Satellite remote sensing: Temperature	The whole area is covered every day	AVHRR-NOAA and Meteosat, IM	
	31	Floating (drifting) buoys: Temperature & Salinity	~10 drifting buoys, 14 days	CORIOLIS-ARGO, IFREMER, IEO, France & Spain	www.coriolis.eu.org/cdc/default.htm
	32	2 Argo floats	Operational since Feb 2004	Martin Ryan Institute, National University of Ireland, Galway	www.nuigalway.ie/eos
	33	River discharge	National flood prevention service	Ministry of Environment, SHAPI	www.ecologie.gouv.fr/article.php3?id_article=119#
	34	River discharge	Approx 1000. Some are digital and some are analogue	OPW, ESB, Local Authorities, EPA	www.opw.ie www.epa.ie
	35	Fixed automated stations in Gironde estuary	4 coastal MAREL stations high frequency measurement, real-time transmission: temperature, salinity, DO, turbidity and sea level	IFREMER & Water Agency	http://www.epoc.u-bordeaux.fr/fr/geotransfert/rogir/index.php?page=accueil
	36	Fixed automated station in Iroise sea	MAREL buoy high frequency measurement, real-time transmission: temperature, salinity, DO, turbidity, fluorescence, pCO_2	University of Brest, IFREMER	www.ifremer.fr/mareliroise/fr/
	37	Fixed automated station in Seine estuary (Honfleur)	MAREL buoy high frequency measurement, real-time transmission: temperature, salinity, DO, turbidity, pH	CETMEF, IFREMER	www.ifremer.fr/marel/
	38	Fixed automated station in Boulogne/mer	MAREL buoy high frequency measurement, real-time transmission: temperature, salinity, DO, turbidity, fluorescence, pCO_2	City of Boulogne, IFREMER	www.ifremer.fr/difMarelCarnot/
	39	Fixed stations and transects: Temperature & Salinity	Deep waters, 3 transects (Galicia & Cantabrian Sea), 2/year since 2004	Deep water standard sections, IEO	
	40	Fixed stations and transects: Physical & biological	Coastal waters, 5 transects (Galicia, Cantabrian Sea), monthly since 1988	Radiales, IEO	www.seriestemporales-ieo.net
	41	Fixed stations and transects: CTD, plankton and harmful algae	Coastal stations, (Galicia), weekly since 1992	INTECMAR, Xunta de Galicia	www.intecmar.org
	42	Fixed stations: Contaminants and hazardous substances	Coastal stations (Galicia), annual or biannual since 1995	INTECMAR, Xunta de Galicia	www.intecmar.org
	43	Fixed stations: Contaminants and hazardous substances	~30 stations along Spanish coast sampling water, sediments and biota	Contamination programme, IEO	

		Platform/Observation	Spatial and temporal resolution	Programme, Institute	Web Sites
	44	National monitoring networks RNO/ REPHY/REMI	50 stations from Dunkerque to St Jean de Luz. Hydrological parameters, chemical pollutants in sediment and fish/phytoplankton	IFREMER, Ministry of Environment	www.ifremer.fr/envlit/surveillance/index.htm#
	45	Fixed stations and transects: Harmful algae	Coastal stations (France)	GEOHAB, IFREMER	
	46	Fixed station: Physical parameters and plankton	1 shelf station (Cascais), monthly, temperature, salinity, chl-*a*, phyto- and zooplankton communities, copepod egg production. 1 coastal station (Cascais), bi-monthly, long-term phytoplankton cyst studies	SIGAP and Profit projects, IPIMAR, Portugal Collaboration in the National HAB Watch Network, IO	
	47	Fixed stations and transects: Plankton and harmful algae	28 coastal stations (entire Portuguese coast), weekly, HAB	National HAB Watch Network, IPIMAR	
	48	Fixed stations: Contaminants and hazardous substances	Stations at beaches along Portuguese coast for water quality analyses. Sampling starts 15 days before the bathing season and is weekly, bi-weekly or monthly depending on quality conditions. Monitoring waste water systems along the Portuguese coast Contaminants studies along the Portuguese continental shelf, monthly sampling in the mouths of main rivers	VivaPraia Programme, INAG and IA National Programme for Water Supply and Sanitation Monitoring, Águas de Portugal e Associated Co. Contamination of the Coastal Zone Programme, IPIMAR	
	49	CTD section along 53 deg N on western Irish Shelf	Annually (summer) since 1999	Marine Institute	
	50	Nutrient Monitoring Programme	Irish and Celtic Sea (annually)	Marine Institute	www.marine.ie
	51	Phytoplankton monitoring	Weekly during the summer at 60 sites	Marine Institute	www.marine.ie/HABSdatabase
	52	Shellfish Toxins Monitoring Programme	Weekly during the summer at 60 sites	Marine Institute	www.marine.ie/HABSdatabase
	53	Radionucleids	6 offshore stations seawater samples annually, 5 coastal stations seawater samples quarterly 13 locations where fish species are routinely monitored	RPII	www.rpii.ie
	54	Regular research vessel cruises: physical & biological, including fish stocks using acoustic methodologies	Continental shelf of Spanish waters, Spring surveys since 1988	ICES Pelagic fisheries, IEO	

		Platform/Observation	Spatial and temporal resolution	Programme, Institute	Web Sites
	55	Regular research vessel cruises: physical & biological, including fish stocks using bottom trawl	Continental shelf of Spanish waters, Autum surveys since 1982	ICES Demersal fisheries, IEO	
	56	Regular research vessel cruises: physical & biological, including fish stocks (anchovy)	Continental shelf of inner Bay of Biscay from Santander to Nantes, Spring	Anchovy evaluation, AZTI Tecnalia	
	57	Annual cruises ICES		Fisheries monitoring, IFREMER	
	58	Regular research cruises: physical & biological, including fish stocks using acoustic methodologies	Continental shelf of Portuguese mainland waters, Spring and Autumn surveys since 1984	ICES Pelagic fisheries, IPIMAR	
	59	Regular research vessel cruises: physical & biological, including fish stocks using bottom trawl	Continental shelf and slope of Portuguese mainland waters, Spring and Autumn surveys since 1979	ICES Demersal fisheries, IPIMAR	
	60	Fisheries cruises; herring acoustic, blue whiting, groundfish, nephrops	Yearly	Marine Institute	www.marine.ie
	61	Mackerel egg	Tri-yearly	Marine Institute	www.marine.ie
	62	Meteorological automatic stations: air temperature, pressure, wind, humidity, precipitation and sun radiation	Galicia (NW Spain), every 10 min since 2000.	MeteoGalicia, Conselleria de Medio Ambiente, Xunta de Galicia.	www.meteogalicia.es
	63	Fixed structures: Meteoro-logical data	23 coastal meteorological stations 15 automatic stations at coast	National Meteorological Stations Network, IM	
	64	Coastal meteorological stations	6 stations; Dublin Rosslare Valentia, Malin, Roches point, Bellmullet hourly data	Met Eireann	www.met.ie

Annex 2: Existing Models

Institute and country	Characteristics/area of interest	Model name	Type	System results web page	Resolution
MERCATOR France	3D circulation system/ North Atlantic	OPA	Operational: 2 weeks forecast	www.mercator.eu.org	1/12° (5–7 km)
ESEOO (Puertos del Estado) Spain	3D circulation system/ French and Spanish coasts and shelves (ESEOAT)	POLCOMS	Operational: 72h forecast	www.eseoo.org	5 km
IMI Ireland	3D circulation system/ Irish shelves	ROMS	Scientific system up to now		1 km
IST Portugal	3D circulation system/ Tagus estuary and area of fresh water influence	MOHID	Pre-operational		300 m
IST Portugal	2D circulation system/ West Iberian coast	MOHID	Pre-operational		2 km
MeteoGalicia Spain	2D tidal circulation/ Galician coast	MOHID	Operational	www.meteogalicia.es	
IFREMER France	2D and 3D circulation systems/ French coast	MARS	Operational and pre-operational: 9 models along the coast. Hindcast to 1 week forecast	www.previmer.org	5 km to 200 m
IEO Spain	3D circulation systems/ Galician and Cantabrian shelf and slope	ROMS	Pre-operational.	www.ieo.es	1.8 km
Puertos del Estado Spain	Nivmar storm surge forecasting system	HAMSOM	Operational: 72h forecast	www.puertos.es	18 km
Puertos del Estado-INM Spain	Wave forecasting system	WAM/ WaveWatch III /SWAN	Operational: 72h forecast	www.inm.es	Variable with downscalling
MeteoGalicia Spain	Wave forecasting system/ North Atlantic to Spanish coast	WaveWatch III/ SWAN	Operational: 72h forecast	www.meteogalicia.es	Variable with downscalling