JRC Scientific and Technical Reports

Availability of coastal and marine data and potential applications for development co-operation

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EUR 23213 EN - 2008

EUROPEAN COMMISSION
Institute for Environment and Sustainability

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European Commission
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JRC 42777
EUR 23213 EN
ISSN 1018-5593

Luxembourg: Office for Official Publications of the European Communities

Printed in Italy

Key questions

Why has the JRC carried out this work?

The JRC has for more than 2 decades been pioneering the use of remote sensing data for marine applications. Initially for Europe but as a consequence of a broadening of science networking gradually applied in Africa as well. The applications to Africa have been carried out in accordance with the development of the JRC's mission in support of the European Union's development policies.

What is the role of the marine and coastal environment for development in Africa?

The ocean provides a range of goods such as fish, minerals, oil and gas, and services such as tourism and transport of important economic value for civil population. The ocean is also well recognized as being the home of a rich biodiversity and habitats for a wide variety of animals and plants. The protection and restoration of the marine ecosystems and their services are long-term objectives for many local communities in Africa. However these objectives are difficult to realize under the increasing pressure of land-use and urbanization and under the climatic changes causing rising sea level, erosion and flooding. A sustainable management of the coastal areas without further decreasing livelihood opportunities is an urgent objective in many African countries.

Why use remote sensing data for understanding the marine environment?

Marine ecosystems do not in general follow national political borders. This is particularly true for some of the so-called Large Marine Ecosystems including the very productive upwelling areas along the African coast. Remote sensing provides the opportunity to sample theses ecosystems in a uniform way independent of national measurement or sampling programs. Furthermore, many African countries have limited amount of data sampled at sea, which are notorious expensive to collect, so remote sensing data offer excellent means to obtain a first low-cost view of the marine and coastal environments especially in data sparse regions. While remote sensing data do not substitute traditional methods of data collection they have their own and complementary role in understanding the marine environment.

How could the work presented in this report serve the objectives of the development policy of the European Union?

The European Union is actively involved in biodiversity conservation, Integrated Coastal Zone Management (ICZM) and fisheries activities. However, for these areas, the production of targeted scientific information in support to development issues and the coordination between research institutions and the donor community is still limited. This report aims at listing and describing JRC activities and products of potential interest for development policies, as well as possible applications in support to situation and trend assessment, to decision making and to program design and implementation. At the same time, such information can serve as a feedback for the development of a structured approach to EU policies in development countries and to the success of supportive measures to national and regional bodies.

Summary – our experience

Our science base

More than 25 years of proven experience in remote sensing of the oceans with focus on sea surface temperature (SST) and ocean colour. Starting from the late 1970'ies the JRC has been one of the leading institutes in Europe in ocean colour remote sensing with a continuous involvement in a variety of international projects. SST was added to the range of applications during late 1980'ies and both branches of remote sensing have been maintained since then. The scientific achievements of JRC is documented in peer-reviewed publications covering virtually all aspects of remote sensing from calibration, data processing and data management to user applications.

International networking

Satellite data alone is not sufficient but other biogeophysical parameters are needed as well for a comprehensive understanding of the marine environment. Access to such data is assured through international collaboration with national European and African institutes or with other international organizations. The JRC has a long standing reputation in setting up and participating to international networking creating strong teams for solving transnational scientific issues.

Multi disciplinary

A true holistic view of the marine environment and its implications for human life requires a multidisciplinary approach from many branches of science. While the key competence at the JRC is centered on physics and biology, other disciplines are employed through the international networking mentioned above of acquired through the contracting mechanisms which is an integral part of the JRC operations.

Summary - perspectives

Climate change issues

With remote sensing data it is possible to derive a large scale view of the past, up to approximately 25 years ago, of SST and of chlorophyll pigment/primary production of the ocean. This may form the baseline against which future changes can be measured. It may also serve as an entry point to understand where and when changes have taken place, and where future attention has to be focused. Integrated with meteorological data and modeling tools, it is possible to set-up scenarios for short term changes in the coastal environment, which can be used as management tools for precautionary measures.

Coastal zone management

The coastal zones are under increasing pressure from demographic changes and sectoral activities in the near coastal areas with severe coastal degradation as a result. Integrated coastal zone management is one of the tools used for planning and management of the conflicting interests in the coastal zones. Satellite data and derivatives can be integrated in such systems for:

- Identifying Marine Protected Areas
- Establishing basemaps of algal blooming, biomass availability, and SST along the coast
- Providing cartography of mangroves and reef systems.
- Establishing shoreline cartography and identifying areas of major changes
- Using models to give dynamic view of coastal currents

At present, downstream estuarine and coastal impacts are often poorly understood and monitored, especially in large or remote ecosystems, because of the difficulty and expense of monitoring marine indicators at appropriate time and space scales.

Supporting development policies

In the particular case of the programming phase of the EC 'Cycle of Operations' the satellite data and the knowledge inherent to the use of satellite data is of interest for the 'Country Environment Profile'. Satellite data may also be of interest for the analysis of environmental impacts of projects and programmes, and to identify and assess environmental issues to be considered during the preparation of a Country Strategy Paper which will directly or indirectly influence European Union cooperation activities.

Natural resources including fisheries

The approach of managing fisheries in the context of an ecosystem management is now fully established as a most sustainable way of managing living resources. Fishing communities as a natural resource are increasingly subject to climate change as reduced primary productivity may limit the food available for fish and furthermore fishing populations may move out of their normal habitats due to climate shifts. The involvement of environmental data in managing natural resources such as fisheries is not stand alone activity as most fisheries in developing countries are subject to overexploitation, often caused by unsound management principles and illegal and unreported fishing.

Training and capacity building

The JRC is in a unique postion to offer specific training opportunities such as on-the-job training in use of specific satellite data and relevant software or general training in use of satellite data for environmental monitoring and assessment. Such training is often carried out with other institutions through international networking.

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1. Introduction

The objective of this report is to summarise the availability of coastal and marine data and to highlight some of the potential applications such data may have in the context of development co-operation. The focus is on the data and the applications which already exist at the Global Environment Monitoring (GEM) Unit of the Institute of Environment and Sustainability (IES), and is not intended as a global overview of all possible use of data. The report will highlight some potential new activities targeted to provision of information relevant for thematic policies and actions in EC and beneficiary countries and regions.
The use of satellite data in what is today the GEM Unit has roots back to some 25 years ago. Over the years the application of satellite data has been carried out in the frame of different Directorates, Institutes and Units following the various organizational changes that have been carried out internally at the JRC over the years. However, this report describes the current situation at the GEM Unit independent of previous nomination of the Unit and/or the Institute.

2. Availability of coastal and marine data at GEM for development

Remote sensing data at GEM fall basically into 2 categories:

- The use of a single parameter, sea surface temperature (SST), derived from a series of meteorological satellites. SST in itself is an indicator of thermal properties in the surface layer, but the parameters derived from SST are often used in understanding physical aspects of the marine surface layer.
- The use of different parameters derived from so-called 'ocean colour' sensors which allow for the study of the optical properties of the oceans and the biology of the marine ecosystems.

Data from any the two categories are rarely used on their own but are always integrated with other data such as meteorological, climatologic and bio-geochemical data obtained from in-situ observations. Models are frequently used as tools for integrating and analysing data.

2.1 Sea surface temperature (SST)

Historically GEM has used SST retrieved from space borne instruments for more than 15 years. The basic instrument used was the Advanced Very High Resolution Radiometer (AVHRR) onboard the NOAA series of satellites. Centrally in the application has been the study of coastal upwelling along the west coast of Africa. At the time of initiating the application only satellite images of 18 km resolution were available and it was decided to enter collaboration with NOAA through which the raw data were made available and subsequently processed to final SST maps in-house at the JRC. The resolution was 4 km, which was judged sufficient to study many of the mesoscale processes over the continental shelf of Africa. During recent years additional applications related to other geographical areas than the west coast of Africa have emerged and it was deemed necessary to aim for global data coverage rather than focusing on the west coast of Africa.
Fortunately with the development of the so-called "Pathfinder" SST dataset, processed by JPL, there is basically no need anymore to process data to the desired resolution at JRC. 4 km global SST data are now routinely available free of charge from the JPL. The Pathfinder SST dataset has global coverage; hence it has been downloaded to form the baseline of SST applications at GEM.

For the future, applications of SST data at GEM should be aligned with the scientific activities in the international community that is bringing together all sensor systems measuring SST. That effort is carried out in The Global High-Resolution Sea Surface Temperature (SST) Pilot Project (GHRSST-PP). GHRSST-PP aims at providing a new generation of global coverage high-resolution SST data products to the operational oceanographic, meteorological, climate and general scientific community, in real time and delayed mode.

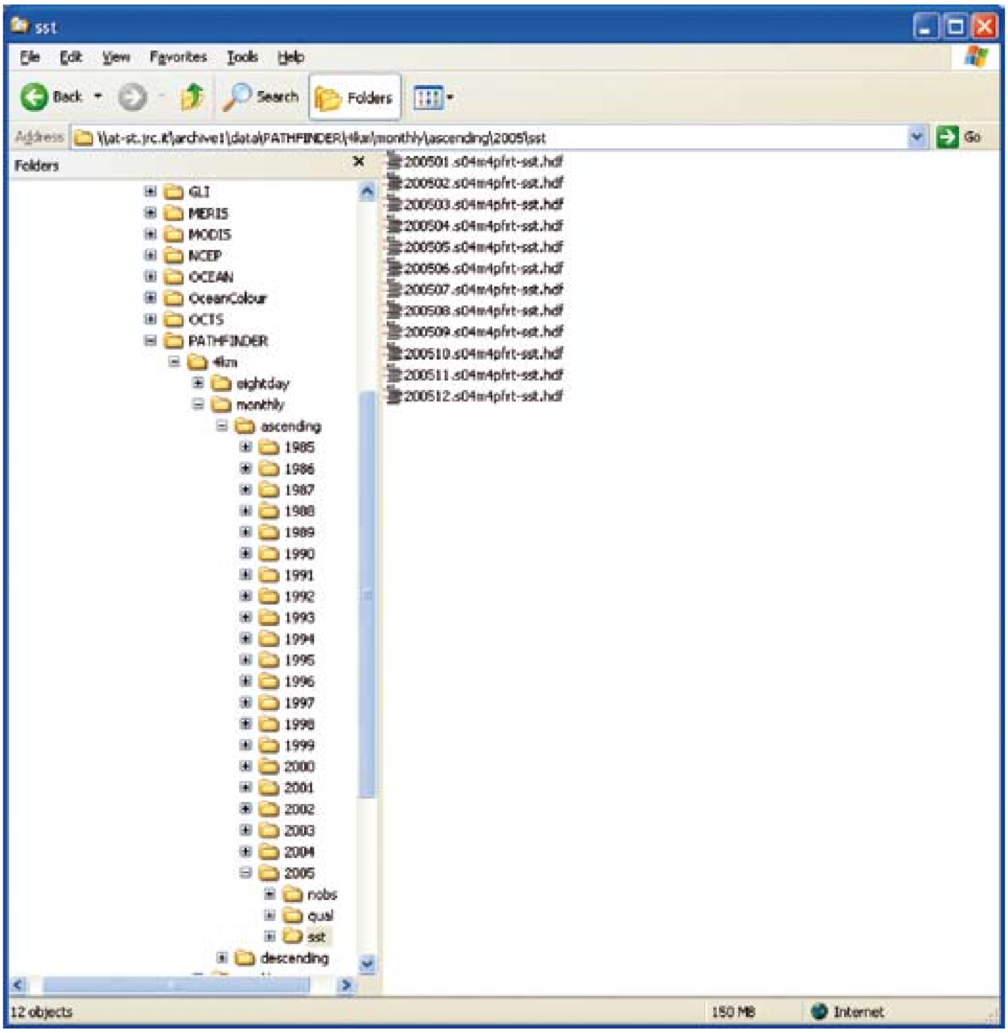
Every day, GHRSST-PP global processing systems produce SST products from several complementary satellite and in situ SST data streams to a common format. Both integrated observations and analysis products are available. Starting point for data is www.ghrsst-pp.org.

2.1.1 The basic dataset

The basic dataset is composed of global 4 km SST data. It is known as version 5.0 of the Pathfinder SST dataset. Characteristics are:

- Global coverage
- Weekly and monthly composites (8 day averages from 1985 to 2001 and weekly from 2002 to 2004)
- Day and night scenes are composed separately
- 4 km resolution
- Time coverage is 1985 – present
- Format is HDF SDS

The data set is downloaded into an archive maintained by GEM and located at /archive/PATHFINDER/4km... From a PC the dataset is visible from \\Toque\archive\PATHFINDER\4km. The data are separated into daytime passes, also called ascending passes and nighttime passes called descending passes. An example of the directory structure pointing to monthly data of daytime passes for the year 2003 is shown below.



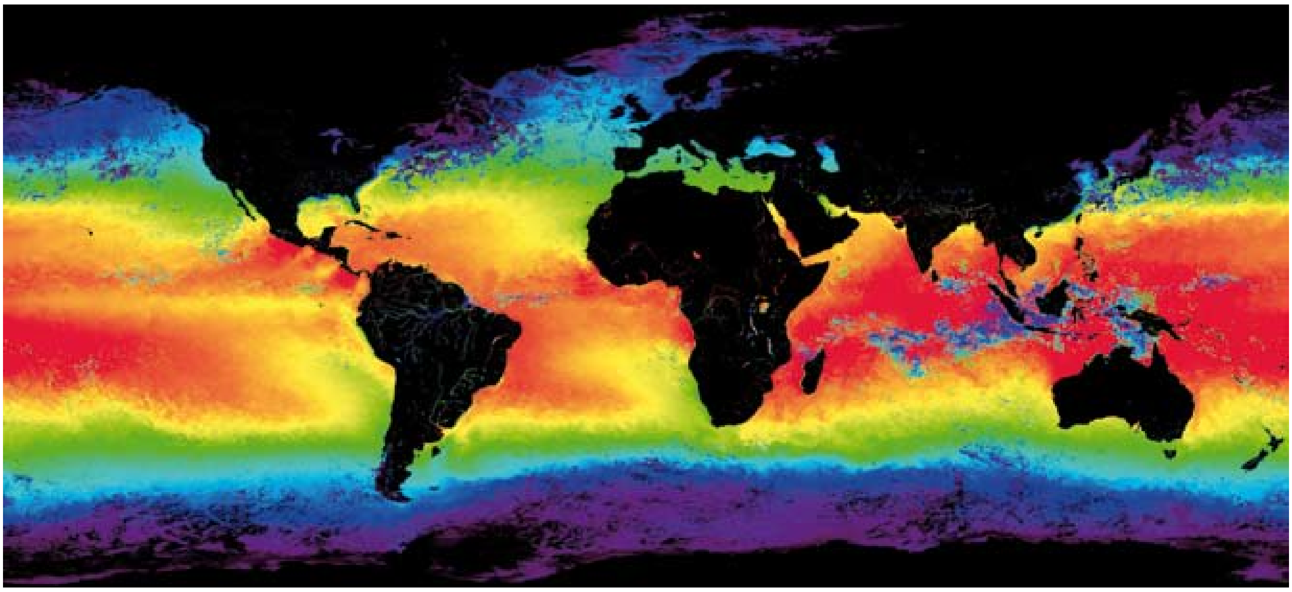
Pathfinder SST since 1985 are conveniently stored in the GEM archives

2.1.2 Documentation

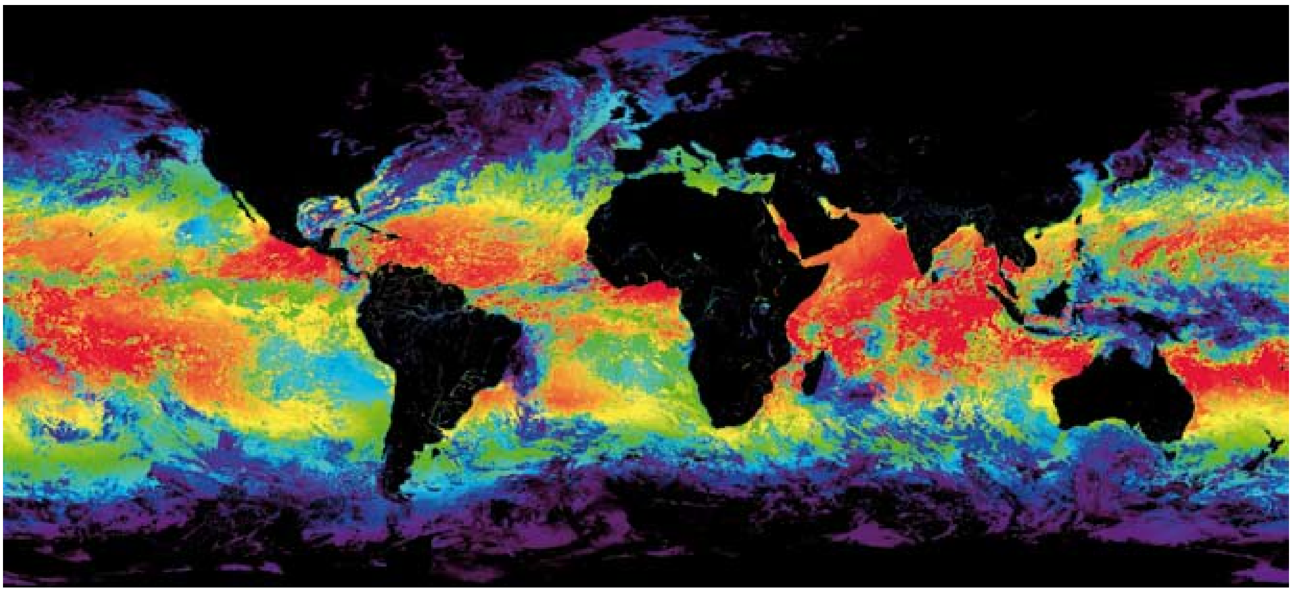
Online documentation is saved in the file \\Toque\archive\PATHFINDER\prog_v5\avhrr_pathfinder_sst_v5.html. The documentation should be sufficient for an immediate understanding both of the file name conventions and access to the data but also of the scientific background for processing which has been applied to the images.
All images are stored as HDF SDS format. They are conveniently read with commonly used software such as ENVI or IDL. For IDL applications a procedure is available at \\Toque\archive\PATHFINDER\prog_v5\IDL\ read_pfsst_dataV5.pro.
Different utilities for accessing the files through the 'C' programming language is found at \\Toque\archive\PATHFINDER\prog_v5\C.

2.1.3 Examples

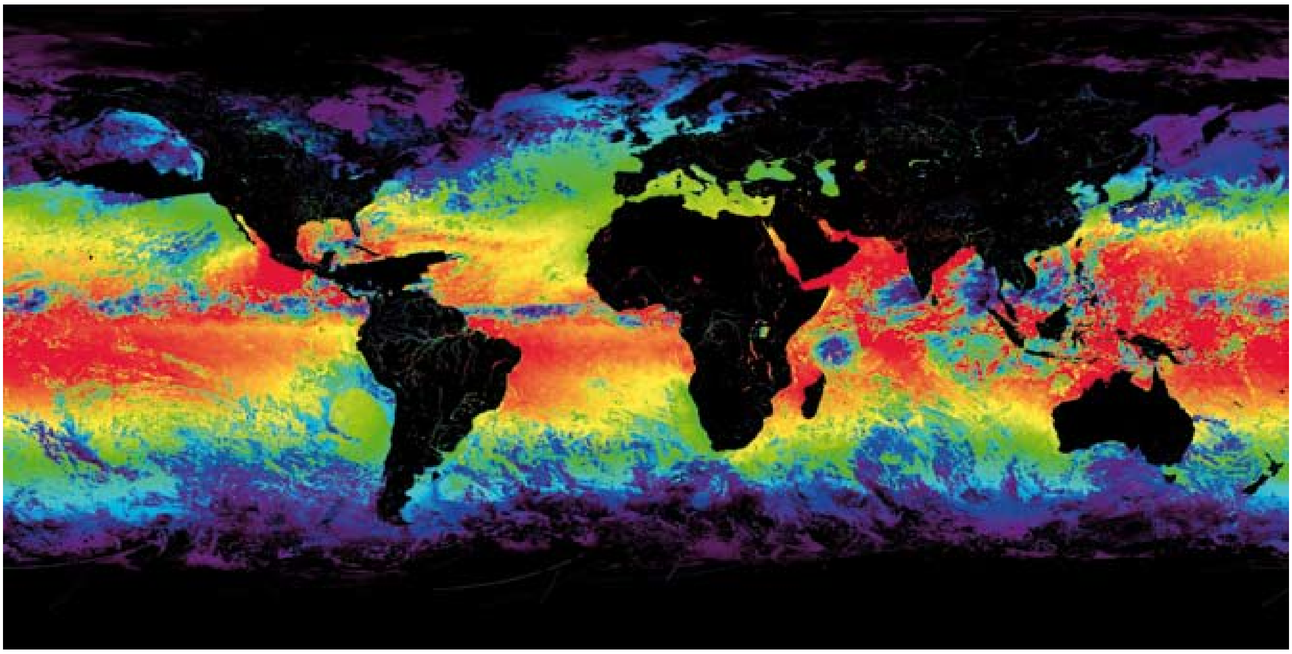
A few examples are shown here to illustrate the dataset. The examples have been extracted from the archive using ENVI.



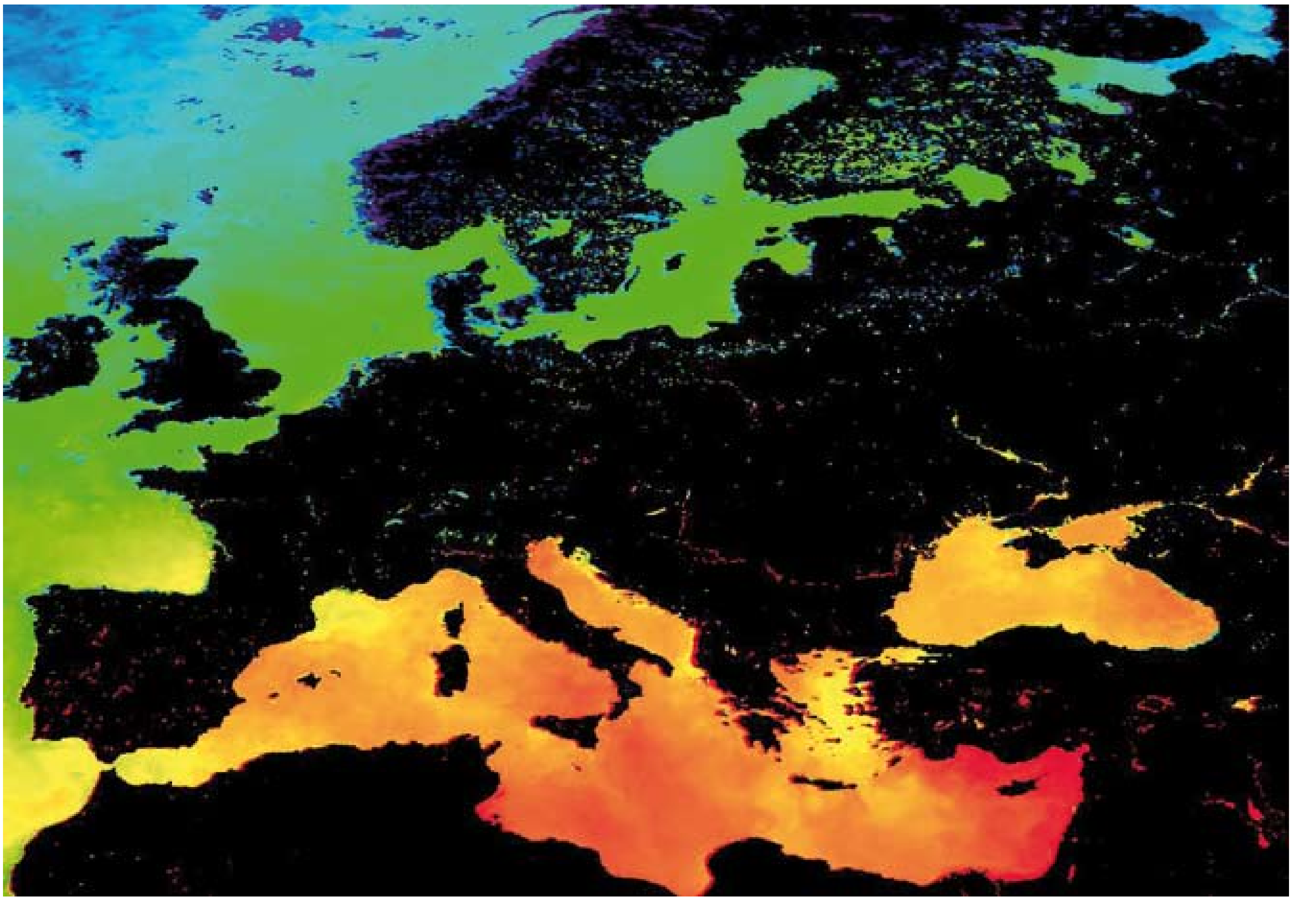
Monthly daytime SST composite for January 2001



Weekly nighttime SST composite for the first week of 2002



8-day composite daytime SST for 16-24 May 1990



Subset of monthly daytime SST August 2000

2.2 Ocean colour derived data sets

Satellite ocean color sensors have given over the last two decades another dimension to marine biogeochemistry studies, providing key information on the timing and spatial distribution of phytoplankton blooms, and the magnitude of primary production. In spite of being scheduled for one-year demonstration program, the success of the NASA Coastal Zone Color Scanner (CZCS) experiment, generating a huge dataset over the global ocean for more than 7 years from 1976 to 1983, stimulated the international scientific community to launch regional programs to archive and exploit all of the usable data at various scales. On that occasion, the Ocean Color European Archiving Network (OCEAN) project was established in 1990 as a common initiative between the JRC and the European Space Agency (ESA) to produce a European ocean color database from the historical CZCS data covering marine regions of European interests and to promote its use through an Application Demonstration Program. The project distributed a large amount of ocean color data products and dedicated software to more than 40 user groups in Europe and beyond, to support a number of studies in European seas which have been reviewed in a special issue of the International Journal of Remote Sensing.

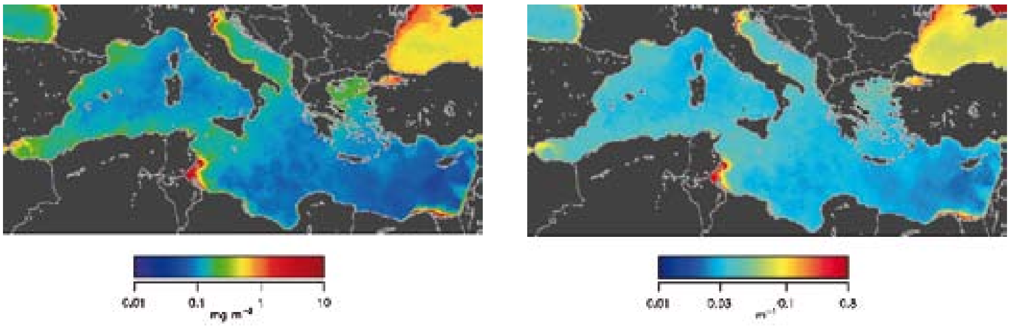
The experience in satellite ocean color techniques and bio-optical oceanography gained from the OCEAN project has been further developed within GEM Unit with the establishment of an integrated data system to process, analyze and archive quality-controlled ocean color data products at various levels of information. The system is fully operational and has been adapted for the processing and applications of SeaWiFS and MODIS data to support scientific studies and management projects in the European Seas, as well as globally. It includes level-1 data collection through GSFC DAAC (Goddard Space Flight Centre Data Active Archive Centre) up to the retrieval of high-resolution geophysical products, re-mapped onto geographical windows of interest and combined in time to yield level-3 time series. An originality of the system has been the development of a combined land/sea algorithm to analyze simultaneously the marine surface optical properties and its optically active components, the aerosol characteristics, and the state of the terrestrial vegetation. This feature and an accurate representation of the interface between the two media, especially in terms of resolution and pixel classification, represent a step forward in the development of an integrated approach to assess the anthropogenic impacts on coastal systems.

2.2.1 The ocean colour archive

European Seas - GEM is maintaining an archive of ocean colour derived products for the European seas, over the geographical domain 40˚W-55˚E, 10˚N-80˚N, covering the European Atlantic sector from the Arctic to the Cape Verde Islands, the North Sea, Baltic Sea, Mediterranean Sea, Black Sea and Caspian Sea.
The time series contains daily, 8-day and monthly maps derived from SeaWiFS and MODIS for the period September 1997 to present. These maps have an approximate resolution of 2-km and are obtained after processing of all top-of-atmosphere full resolution imagery available for the domain. The processor used for the development of the archive is SeaDAS version 4.8.

The archive contains several categories of products:

- aerosol description (optical thickness and Ångström exponent),
- ocean surface apparent optical properties: normalized water leaving radiances *Lwn*, diffuse attenuation coefficient *Kd*,
- concentrations of optically significant constituents: Chlorophyll *a*, total suspended matter,
- inherent optical properties: absorption, backscattering,
- photosynthetically available radiation (*PAR*, for SeaWiFS only).



Various products can be derived from the Lwn spectra, using different types of algorithms. Here are illustrations of derived products for monthly composites (September 2003) of the Mediterranean Sea: (left) chlorophyll concentration (in mg.m^{-3}) from NASA OC4v4 algorithm; (right) Diffuse attenuation coefficient at 490 nm (Kd, in m^{-1}) from the OBPG algorithm.

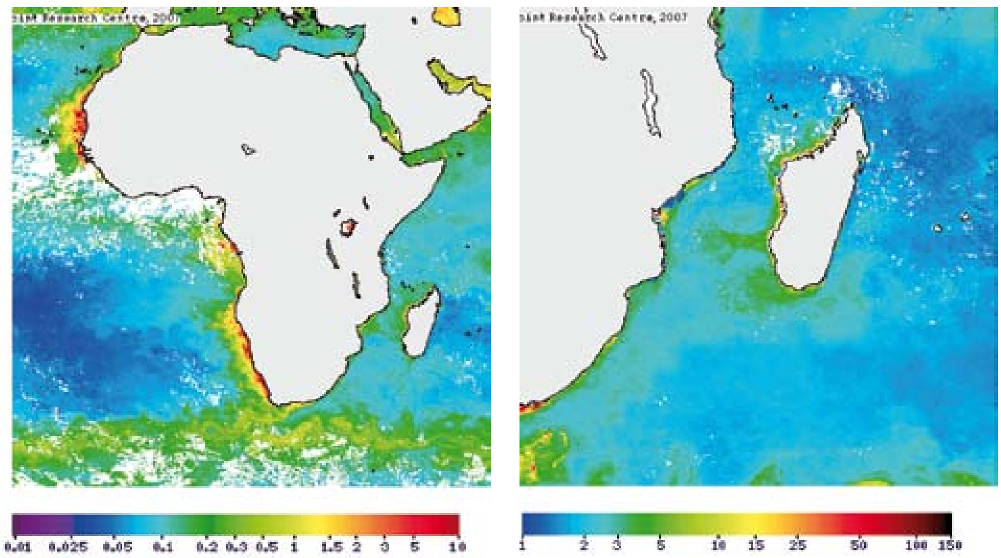
The African Data set - The marine dataset around the African continent (Lat. 40°N – 50°S; long. 60°E – 30°W) is composed of:

- Sea Surface Temperature (in °C),
- Surface chlorophyll concentration (in mg.m^{-3}),
- Diffuse attenuation coefficient (Kd) at 490nm (in m^{-1}),
- Depth integrated primary production (in mg C.m^{-2}.d^{-1}).

Except for primary production, all variables are derived from MODIS-Aqua L3 data monthly composites at 4 km resolution. Primary production has been obtained from SeaWiFS L4 data at 9 km resolution. At present, the time coverage of the archive is from July 2002 to April 2006, and the data are archive in NetCDF format, adopting the Climate and Forecast (CF) Metadata convention.

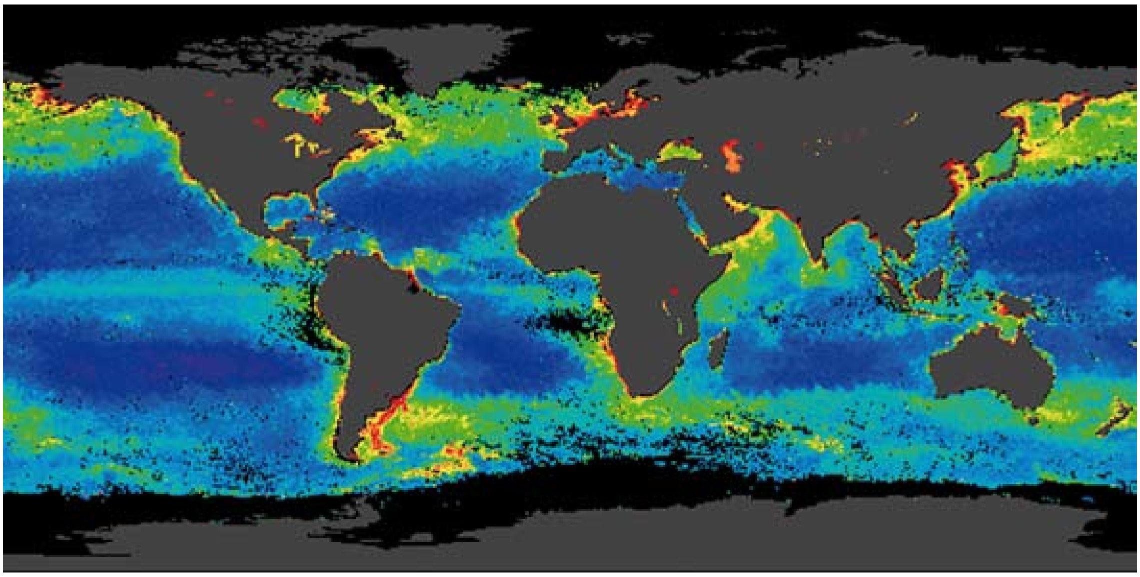
The data set is extracted and downloaded from the NASA OceanColor web portal in HDF format, subsequently converted to netCDF and then stored to the archive maintained within the GEM Unit. Primary Production data files are extracted from the Ocean Colour 9 km global archive.

All images are stored as NetCDF format. They are conveniently read with commonly used software such as IDL. Note that the archive has been specifically developed for use within the African Marine Information System (AMIS) architecture, which makes use of the MapServer technology in order to access, read and display data directly on the web client (see below).



Examples of data products available within the African archive: (left) surface chlorophyll concentration for the entire African window (data from MODIS-A, October 2004); (right) regional extract of primary production estimates in the western part of the Indian Ocean (January 2004).

Global Data set - The GEM Unit also maintains a global archive of ocean colour derived data sets, based on SeaWiFS and MODIS. Emphasis is given for the study of the global oceans with monthly maps of aerosol optical thickness, normalized water leaving radiances, diffuse attenuation coefficient, chlorophyll a concentration and *PAR*. Moreover, chlorophyll a and *PAR* time series are used to compute global primary production with a depth- and wavelength-resolved primary productivity model.



Surface chlorophyll concentration (in mg.m^{-3}) for October 2003

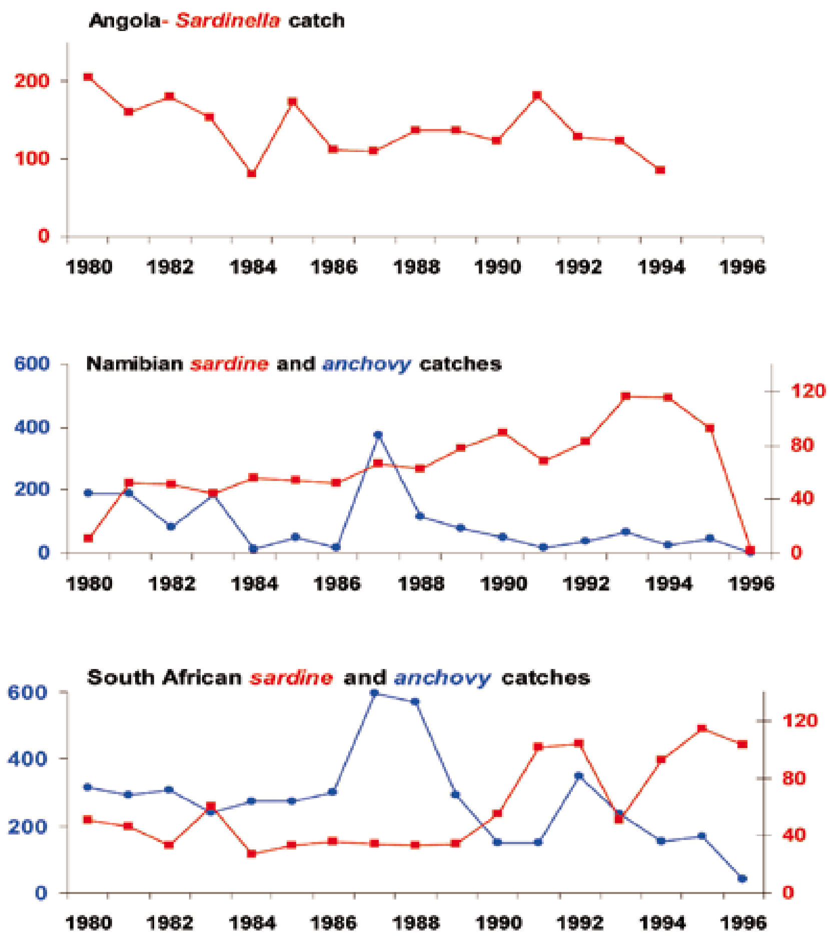
In terms of ocean colour data, the Unit is well positioned to maintain an up to date archive of calibrated data from the most recent satellites due to the historical accumulation of knowledge and experience of ocean colour within the Unit.

3. Examples with special reference to development co-operation

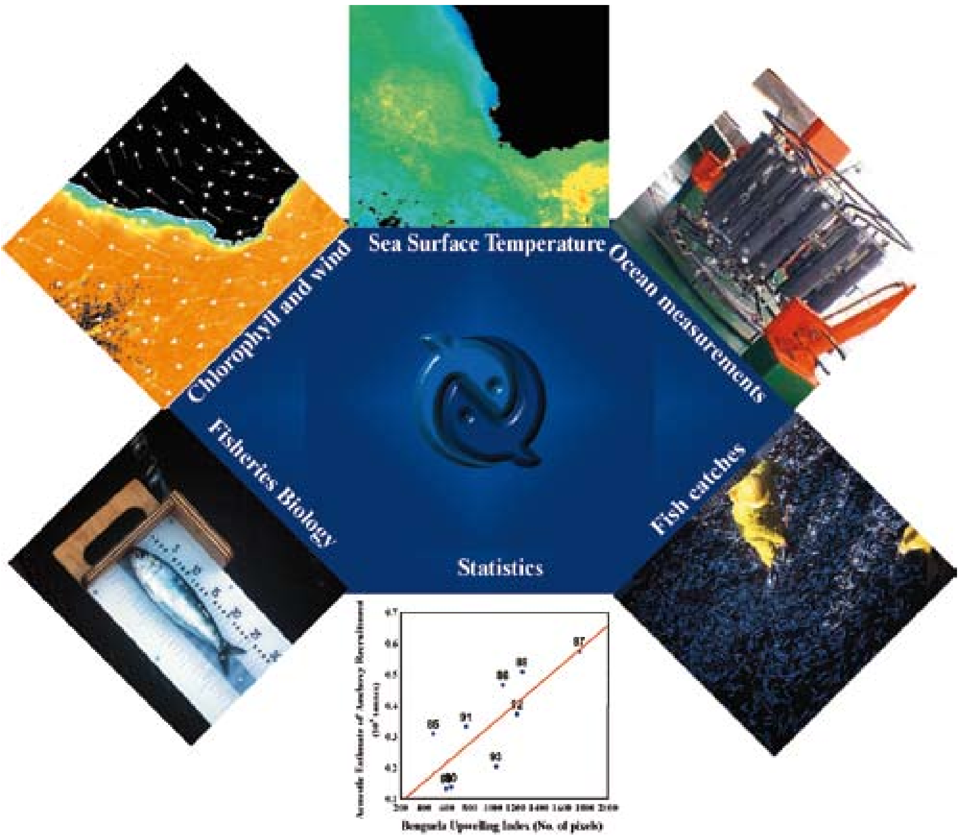
3.1 Envifish

Envifish was a Shared Cost Action in the 4th Framework Programme. It was carried out between 1998 and 2002.

The Benguela and Angolan marine ecosystems support large populations of pelagic and demersal fish of considerable economic importance to South Africa, Namibia and Angola. The catch of small pelagic fish in the region fluctuated greatly after 1980. Most dramatic was the collapse of the Namibian sardine catch where fisheries almost closed down from 1994 to 1996, despite the application of sound management principles. The observed variability was largely due environmental variability and not to fishing activities as frequently seen in other modern fisheries. The short-lived small pelagic fish live in the layer of the ocean where the exchange of energy and momentum with the atmosphere is taking place. One of the key concepts of *Envifish* was therefore to examine surface conditions in the oceans and compare the conditions to the variability in any life stage of the fish. Formally, the main objective of *Envifish* was the identification and quantification of key environmental conditions that influence fluctuations in the recruitment and distribution of small pelagic fish stocks in the Benguela and Angolan systems. *Envifish* was carried out as a retrospective analysis of environmental and fisheries data over the 2 decades from 1980 to 2000. The first activity of *Envifish* was to examine existing data and if necessary construct suitable inventories and summaries of data. A substantial part of the environmental data was composed of satellite derived SST for the period 1982 to 1999. Other environmental data comprised satellite derived chlorophyll-like pigment concentrations and sea surface height. Local meteorological data and oceanographic data were catalogued as well.



Variable catch of small pelagic fish since 1980 in the Benguela region



In Envifish a variety of environmental and fisheries data were compiled and analysed

Inventories of fisheries data for sardine, anchovy and sardinella for the region were produced for the period covered by the environmental data.

The initial analysis concentrated on large-scale studies. Different statistical methods, such as Empirical Orthogonal Function (EOF) Analysis, have been applied to SST data to characterise the spatial and temporal patterns in the area. One such analysis revealed different spatial dynamics between the Western Agulhas Bank and the coastal upwelling areas on the west coast of South Africa.

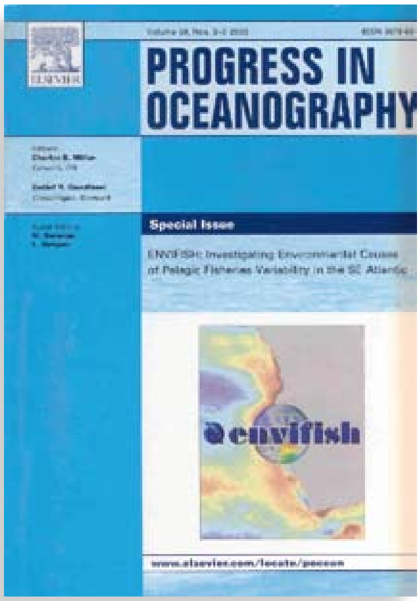
The Triad hypothesis, which identifies 3 major classes of processes that combine to yield a favourable reproductive habitat for small pelagic fish, was used to guide some of the analyses. For instance, an upwelling index as a measure of *enrichment* was extracted from SST data. From this index, the spatial and temporal extent of coastal upwelling wa identified, and anomalies in coastal upwelling were examined. Furthermore, the upwelling index was used to determine the location of the Angola/Benguela front, an important spatial pattern for understanding sardinella populations.

Artificial neural network techniques were developed for characterising SST data in various areas around the west coast of southern Africa. A second application of the neural network identified and classified vertical chlorophyll profiles and predicted their parameters from remotely sensed SST and ocean colour data.

Changes in environmental conditions at decadal time scales were investigated using meteorological data. Combining selected data sets, a Benguela Regime Index (BIX) was proposed. It reflects inter-annual trends in coastal upwelling and related biological consequences. On the decadal scale, the BIX was compared with other globally acting indices such as the North Atlantic Oscillation (NAO), Southern Oscillation Index (SOI) and Pacific North American Oscillation (PNA).

The partnership of *Envifish* consisted of 4 European partners (IMR, Norway; IPIMAR, Portugal; PML, UK and IOW, Germany), 2 international organisations (FAO, Italy and JRC, Italy) and 4 African Institutes (NATMIRC, Namibia; MCM, South Africa; UCT, South Africa and IIP, Angola).

As a result of the project, the use of environmental data is being expanded in order to understand the variability of small pelagic fisheries in an ecosystem context. The scientific results of the project have been collected in a special issue of Progress in Oceanography.



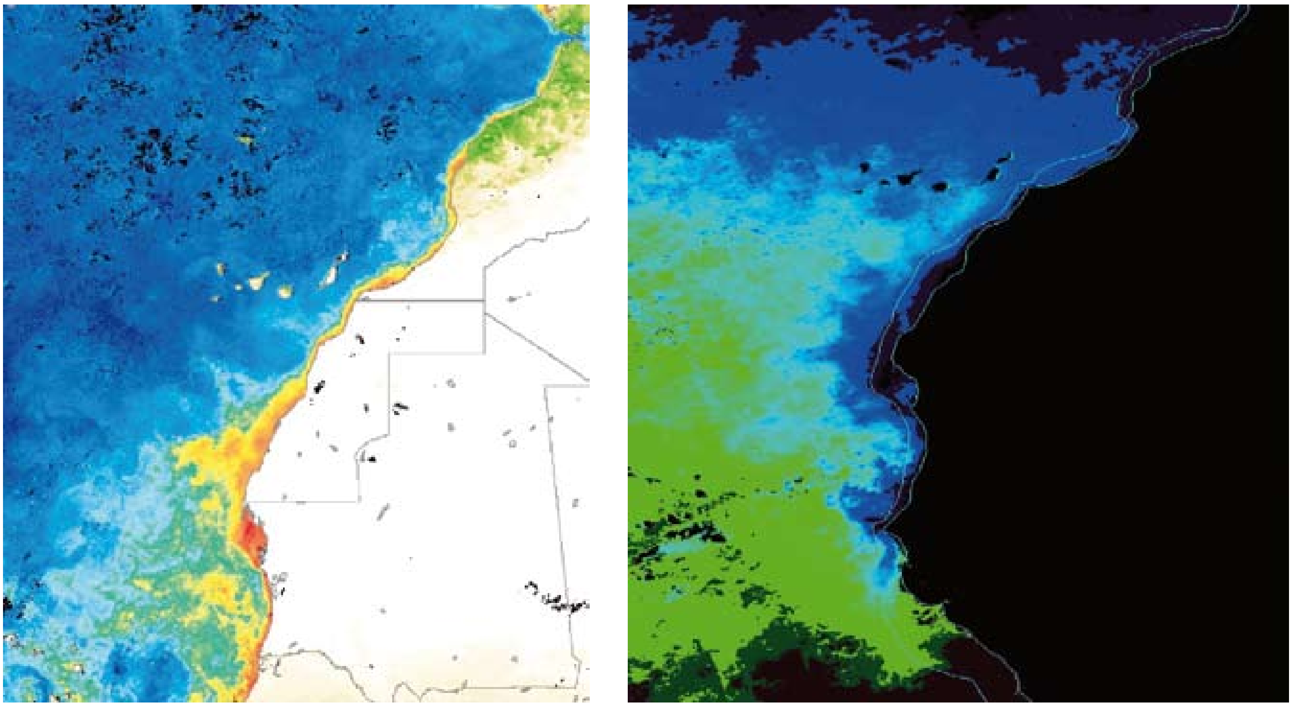
3.2 Nat-fish

Following the outcome of *Envifish* it was natural to perform a similar analysis of the small pelagic fisheries in the North West African upwelling system. Hence a project named NAT-FISH was defined and accepted as a Shared Cost Action in the 5th Framework Program. The project was carried out between 2002 and 2005.

The objective of NAT-FISH was to analyse and quantify the influence of the natural variability of the Northwest African upwelling system on the abundance and distribution of small pelagics. In particular, the project would:

- compile relevant environmental, biological, and fisheries data into a distributed database together with tools for analysing the data
- identify and quantify environmental variability relating to significant changes in abundance and distribution in small pelagic fish stocks
- model different environmental situations and their consequences on key processes influencing successful recruitment and fish distribution
- investigate the potential of using models as a tool for suggesting precautionary measures to be incorporated into responsible fisheries management strategies;
- develop adequate training and capacity building for African scientists and managers to properly understand natural environmental variability and its significance for fisheries management

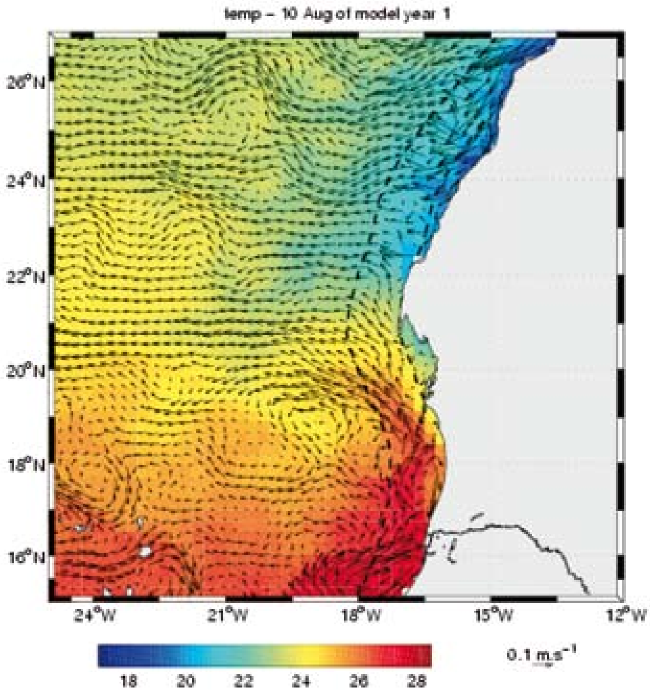
NAT-FISH was carried out as a retrospective analysis of environmental, biological and fisheries data with focus on the decade 1990 to 2000. After having retrieved all relevant data the environmental variability associated with the major changes in pelagic fish populations was documented. A hydrodynamic model was adapted for the area to investigate upper ocean dynamics and to retrieve oceanographic key parameters that would influence the distribution and biology of small pelagics. A selected set of output data from the hydrodynamic model was examined using simple software developed within the project, permitting all partners easy access to a coherent time series of oceanographic data. With the hydrodynamic model it was possible to identify the anomalies in the large scale distribution of water masses, which were believed to be linked to the interannual variability of small pelagics and in particular



Time series of satellite data (chl: left and SST:right) played an important role in understanding environmental variability in NAT-FISH

to the collapse of the sardine population off Southern Morocco in 1996/1997. Finally an evaluation was carried out to what extent some of the environmental changes could effectively be monitored and how their effect on the fishery resources could be forecasted.

NAT-FISH provided data and methodologies that could be used and maintained by the developing countries for practical use in resource management. For the scientists it offered the opportunity to gain insight into a time series of oceanographic variables which so far has never been available for the countries involved. It additionally introduced the scientists to the potential of hydrodynamic modelling and provided hands-on experience on working with model data. The project increased the awareness at the scientific level of considering environmental and/or hydrographic data in the management of living resources. By providing a common data set and associated software for analysing the data set NAT-FISH improved capacity building of African scientists and strengthened human networking and institutional partnership.



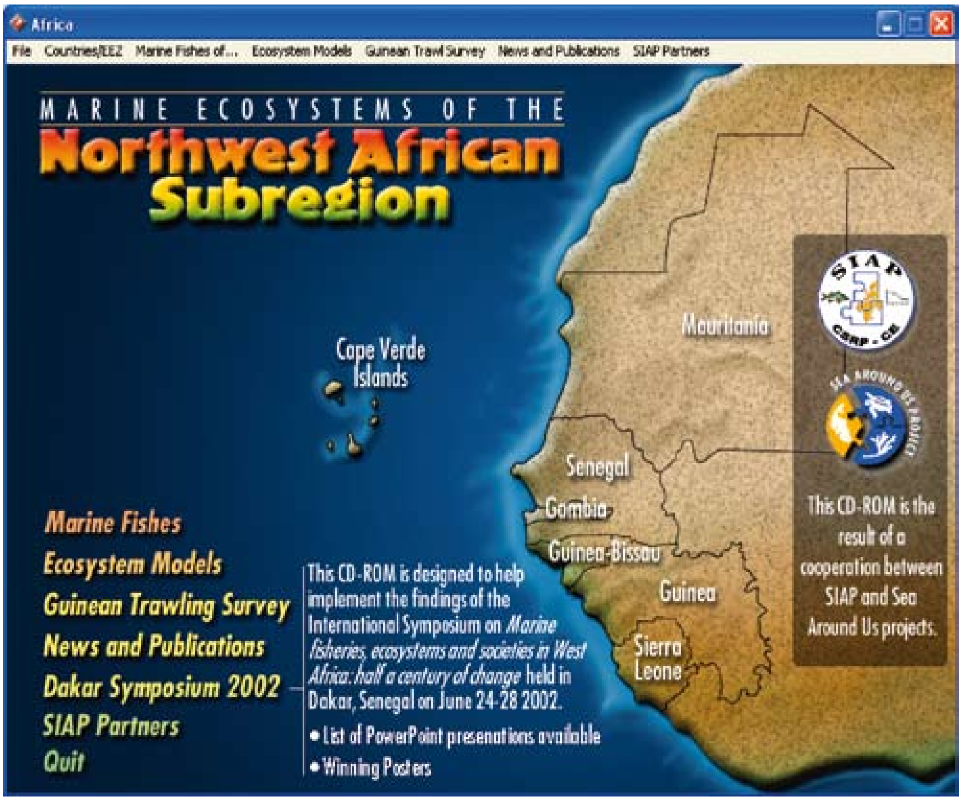
With the hydrodynamic model it became possible to obtain dynamic parameters such as surface velocities displayed here to complement the satellite data

3.3 Fisheries Information and Analysis System

From 1999 to 2002 IES was the implementing agent for an European Development Fund project known as FIAS (Fisheries Information and Analysis System) or the corresponding French acronym SIAP (Système d'Information et d'Analyse des Pêches). The project targeted fisheries and resource management institutions in West Africa from Mauritania to Guinea in a collaborative between 6 institutions in West Africa and 4 institutions in Europe.

The objective of FIAS was to strengthening the capacities for improved resource management in the partner countries in West Africa, both on national and regional level, by making the partner institutions aware of necessary information and tools to assess past and present status of their fisheries and their impact on aquatic ecosystems.
FIAS was split among a number of interlinked modules, which dealt with different aspects of the natural resources:

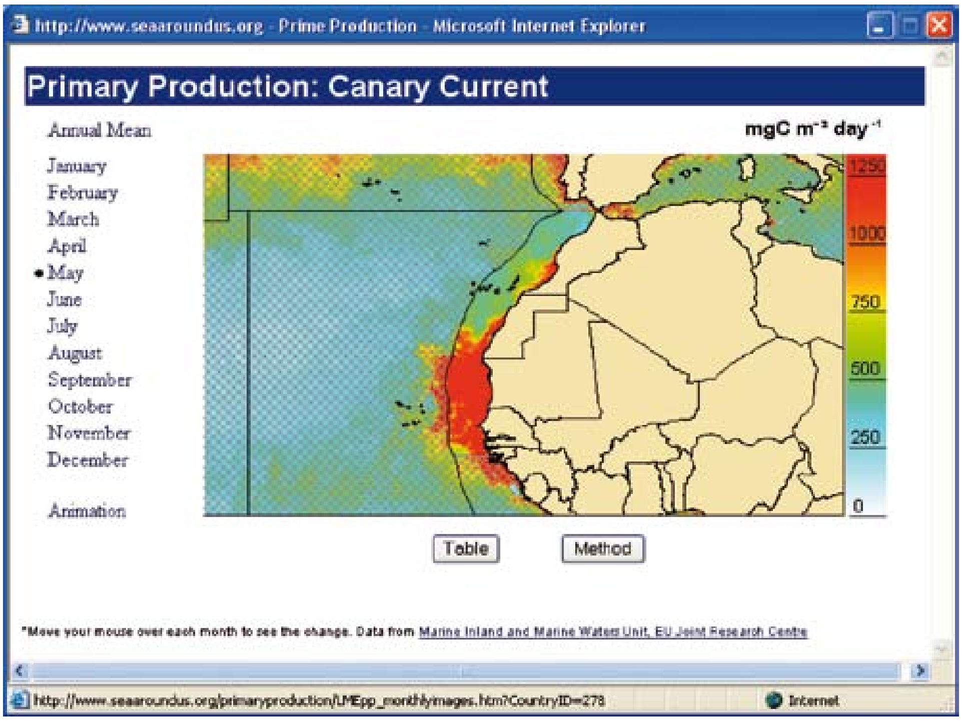
- **Biology and ecology of demersal speciesFishBase**, the electronic encyclopedia on fish, was used as the major tool to verify the completeness of available information of species in the region
- **Assessment of the history of resource exploitation**
  A tool was developed (**TrawlBase**), which captured the demersal survey data in a structured and standardized format and allowed the West African research institutes to assess the history of resource exploitation in their territorial waters.
- **Assessment of the present status of resource exploitation**
  Information on catch and effort related data from the West African fisheries was inserted in a new tool (**TrawlBase**), which improved on already existing data collection schemes in the countries by harmonizing and standardizing available information and adding routines for advanced data analysis.
- **Improved visualization of spatial data**
  Fisheries related data and other data sets (geographic maps, oceanographic data, remote sensing data) were brought together for presentation in Geographic Information Systems (**GIS**) for an improved understanding of spatial processes affecting fisheries.
- **Ecosystem modeling**
  Information compiled by the various modules were combined in an effort to develop both national and regional models of marine ecosystems. This was carried out with the help of the **Ecopath with Ecosim** software. It gave the West African partners a better understanding of the structure and dynamics of their demersal marine resources and it provided them with the tools to evaluate the possible outcome of alternative strategies in fisheries management (changes in fishing effort, establishment of protected areas, etc.).
- **Restitution**
  A continuous and institutionalized exchange between fisheries research and management was a crucial aspect of the project's effort to disseminate the results of the work in the various modules to the beneficiaries of the project. Restitution included "round table" meetings with government and other stakeholders in the fishery sector as well as seminaries and publications, both for the specialists as well as for the general public.



FIAS co-organised a symposium in Dakar 2003 where the main results were presented

3.4 International collaboration using Primary Production

In the frame of international collaboration GEM is contributing to the Sea Around Us project which is implemented by the Fisheries Centre, University British Columbia, Canada and devoted to studying the impact of fisheries on the world's marine ecosystems In Sea Around Us GEM is providing global estimates of primary production which is integrated in a GIS to map global fisheries catches



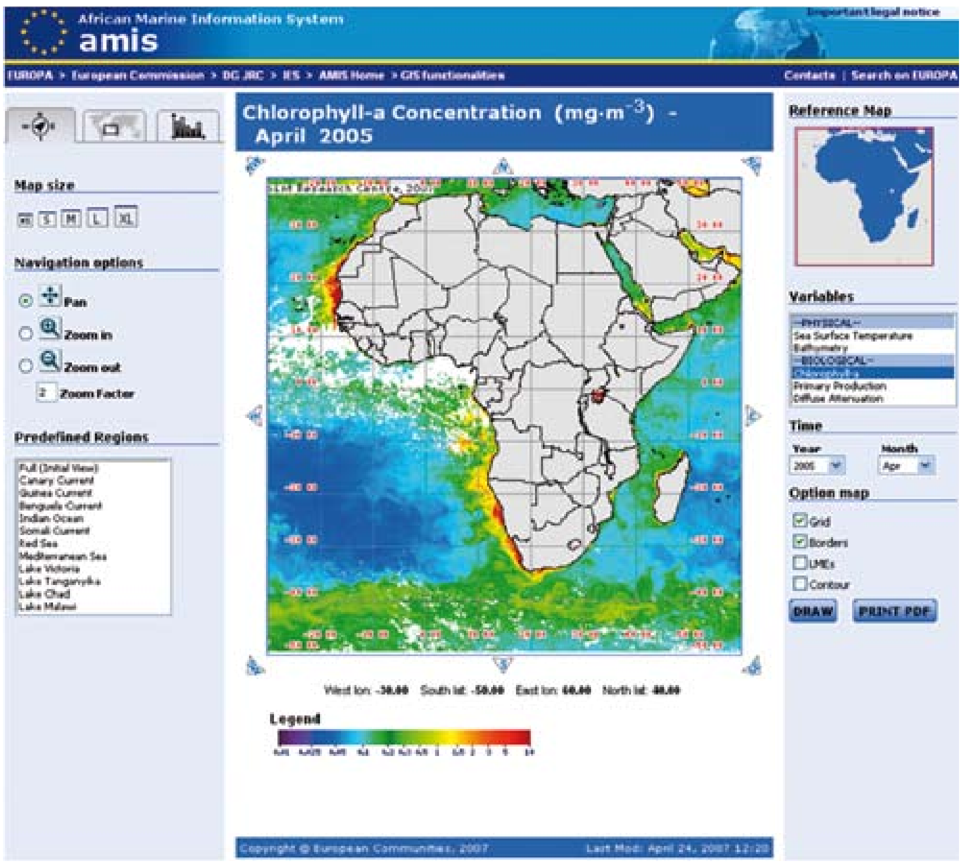
Primary production maps on the Sea Around Us web site from 1950 to the present, under explicit consideration of coral reefs, seamounts, estuaries and other critical habitats of fish, marine invertebrates, marine mammals and other components of marine biodiversity.

The data presented, which are all freely available, are meant to support studies of global fisheries trends and the development of sustainable, ecosystem-based fisheries policies.

3.5 The African Marine Information System (AMIS)

The African Marine Information System (AMIS) has been recently developed to provide the Users with an appropriate set of bio-physical information, of importance to conduct water quality assessment and resource monitoring in the coastal and marine waters. AMIS is a simple and easy-to-use mapping tool application, developed for the publication and dissemination of African marine information via the web. It is a web-based application that allows the provision of scientific information, by way of geo-referenced maps (created in real-time), and supplies the users with basic navigation and interrogation tools.

Geographical sources are mainly raster data, stored in NetCDF files, a machine-independent format for representing scientific data. The African Marine Information System application is written in *PHP* and *Perl,* scripted programming languages for developing server-side applications and dynamic web content and it is based on a *UMN MapServer* engine, an open source environment for building spatially-enabled internet applications. Its functions are written in *C* and its interaction with *PHP* is achieved using *PHP/MapScript*, a dynamically loadable module that makes *MapServer*'s functions and classes available in a PHP environment.



The GIS functionalities of AMIS enable the visualization and analysis of a variable through the following steps: variable selection, map navigation, identification of region of interest and statistical analysis

3.6 Training and capacity building

In development studies and research with an active involvement of developing countries, capacity building and training of local people are always necessary. A proper defined training program may contribute to a sustainable level of self sufficiency and autonomy in use of modern technology and enhance the base of educational level among local staff.
In Envifish, 4 students made their Honors, Master (2) or Doctorate degrees during or immediately following the project. On-the-job training in use of different software packages and satellite images was carried out at 2 occasions. Participations to project relevant summer schools were facilitated using funds from the project. In Nat-fish dedicated on-the-job-training was carried out during one of the scientific cruises and a training workshop on use of model data was organised towards the end of the project. Nat-fish also funded summer schools and the participation of a student from a developing country to follow a M.Sc. course on oceanography in Europe. In FIAS, training was a substantial part of the project and training workshops were organized for all the modules in the project.

Through the scientific networking the GEM is frequently involved in specific training activities as well, is particular through the so-called IOCCG (International Ocean Colour Coordinating Group). GEM has provided lectures and specific training at the Asian Institute of Technology (Bangkok, Thailand, 2-12 Nov., 1999), at the University of Conception (Chile, 21 Oct.-1 Nov., 2002), at the JRC Ispra |Site as part of the JRC Enlargement and Integration Action (3-14 Oct. 2005) and at the Memorial University (St John, Canada, 7-11 May 2007).
Recently, GEM has organized a two-weeks training course (24 Sept. -5 Oct. 2007) in Mombasa (Kenya) to provide the theoretical basis of optical satellite measurements, as well as key applications of ocean colour remote sensing in monitoring and managing the coastal zone, in protecting the marine ecosystems and their resources. The Training Course was attended by 18 participants coming from different countries in Africa and western Indian Ocean Islands, and selected out of 62 applications received. A series of lecture sessions chaired by international experts from Europe and Africa were conducted such as to cover the physical principles of ocean colour measurements from space, as well as various applications addressing important environmental issues in coastal and marine waters. The course also included practical sessions during which participants were trained on various image processing and applications software, such as Envisat-BEAM, BILKO, and SeaDAS. Practical sessions continued in the form of 'mini-projects' where participants conducted a short study applying knowledge recently gained during the lectures and software demonstrations.

Participants in the training course in Mombasa, Kenya, 2007

4. Other data sources

GEM does not maintain databases of other remote sensing data than the SST and ocean colour data described in section 2 and 3. Neither are non-remote sensing data systematically archived, but for use of such data GEM is relying on either access to international and public available data centre or access to local data through the existing network of collaboration. A short description of some of the data types that are frequently used is given here.

4.1 Meteorological data

As the oceans interact continuously with the atmosphere, meteorological data are almost always required in any study of the ocean. At large scale, fortunately, data are available from major meteorological centres. JRC is using the European Centre for Medium-Range Weather Forecast (ECMWF), www.ecmwf.int, or the World Data Center (WDC) for Meteorology, http://www.ncdc.noaa.gov/oa/wdc/index.php. There may be other major data centres, however the 2 mentioned above are good entry points and contain links to sites with more specific datasets. Data access is normally free of charge.

Local meteorological data may be more difficult to obtain especially in developing countries with limited resources available for data collection and archiving. However most countries have a national meteorological service which holds data archives, although quality of data and archiving systems may vary substantially from country to country. Access to data is facilitated through collaboration with national institutes.

4.2 In-situ data

It is well-recognized that combining satellite data with in situ observations in a judicial manner allows i) a better quality of the satellite products through calibration and validation exercises, and ii) an extension of applications to domains inaccessible by either method taken in isolation. In situ data are usually collected by individual scientists within the frame of international or national programmes. Chances to get an easy access to these data through well structured databases decrease with the specificity of the data.

International Data Centers
Global field data, including African marine waters, can be accessible through International Organizations such as UNESCO-IOC (Intergovernmental Oceanographic Commission). The IOC International Oceanographic Data and Information Exchange (IODE) holds a Marine Environmental Data Inventory (MEDI) which provides the users with information describing the selected data holdings and their sources.
A Pan-Africa network of in situ coastal observing stations has been established through the ODINAFRICA project (http://www.odinafrica.net/) to provide a wide variety of products and services related to coastal and marine waters. Within this project, the African marine Atlas provides maps and data on variety of physical, biological and chemical variables extracted from global (WOCE, WMO, FAO) and regional data bases.
The Chlorophyll Global Integrated Network (ChloroGIN, http://www.chlorogin.org/) project aims to promote in situ measurement of chlorophyll in combination with satellite derived estimates.
Finally, GOOS-Africa (http://www.gosic.org/goos/GOOS-AFRICA_program_overview.htm) and ROOFS-Africa http://ioc.unesco.org/GOOS/africa/ROOFS-AFRICA.htm are developing a database with a wide range of oceanographic and meteorological data of importance to detect and forecast climate changes around Africa.

Local data
Local in-situ data are in practice only available through collaboration with national institutes. There is hardly any consistency in data across national borders even for countries sharing important large marine ecosystems. Quality control, data archiving and access can only be verified though collaboration. National data from Africa are not frequently communicated to major world data centres.

4.3 Other remote sensing data

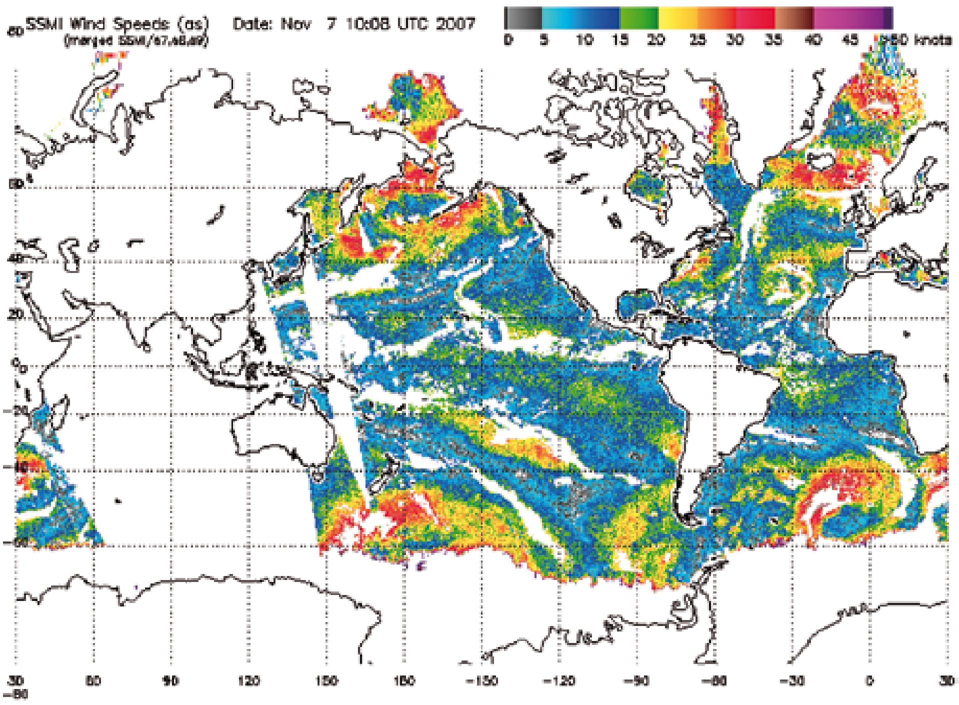
The GEM expertise in remote sensing of the oceans has been focused on SST and ocean colour but there are 2 other parameters that can be measured from space instruments. These 2 parameters are surface roughness (at small length scales) and slope of the sea surface (at longer length scales). From these 2 parameters other geophysical parameters such as surface winds, sea surface height and surface waves can be derived. These parameters can only be derived at medium to low resolution, i.e. 20-100 km, and are therefore of limited use in the near coastal zones. On the contrary they have become essential at global and regional scales where they are used in conjunction with sophisticated models of ocean circulation. For completeness a brief description of the parameters is included here.

Winds

Both active (radar, altimeters)) and passive (radiometer) microwave sensors have been shown capable of determining the ocean surface wind speed, with active microwave instruments being used to derive the wind direction. Recently, radiometer systems have been shown capable of determining the wind direction using polarimetric and multi-look observations. Development and refinement of instrumentation and algorithms for ocean surface wind retrieval is an ongoing process being conducted in both the active and passive areas. Current satellite systems that carry instruments for retrieving ocean surface winds are ERS, Topex/Poseidon, Quickscat and SSM/I.

For daily and long term weather forecasting to global climate studies, knowledge of the energy exchange at air-sea interface is very important. The ocean surface winds are a key parameter influencing the coupling of energy between the ocean and the atmosphere. Thus, global monitoring of the ocean surface winds is of vital importance to the operational and scientific community.

While instruments on buoys and ships do provide measurements of the surface wind vectors, their coverage is insufficient to provide a global wind field map. On the other hand, satellite based sensors can provide global coverage in a reasonable time period. Additionally, sensors operating at microwave frequencies can measure the surface wind vector during nighttime and cloudy conditions, and therefore, greatly increasing the quantity of surface observations.

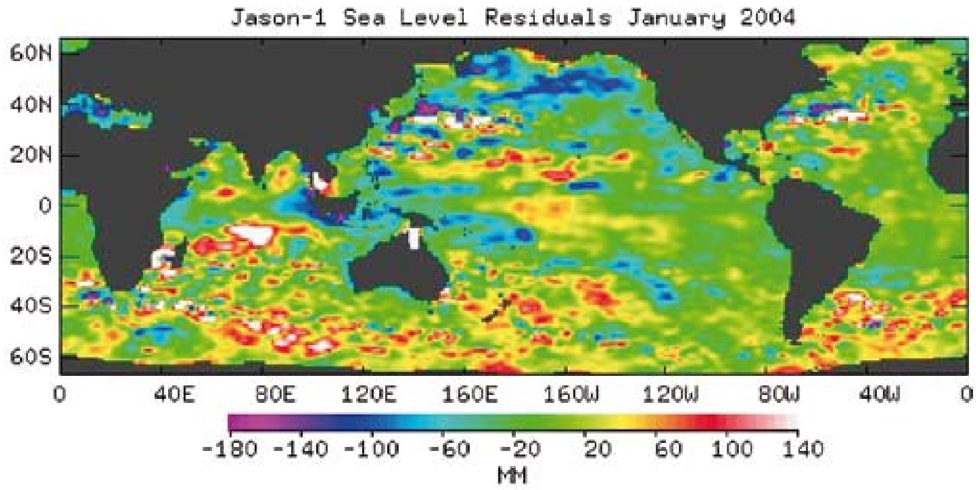


An example of daily wind speeds derived from SSM/I 7 November 2007

The scale or resolution at which ocean winds are derived are typically of the order 25-50 km's which is adequate for large scale studies of ocean features and for ingestion into models, but is not sufficient for near coastal applications. Data are often merged at daily or weekly intervals to provide full global coverage.

Sea surface height

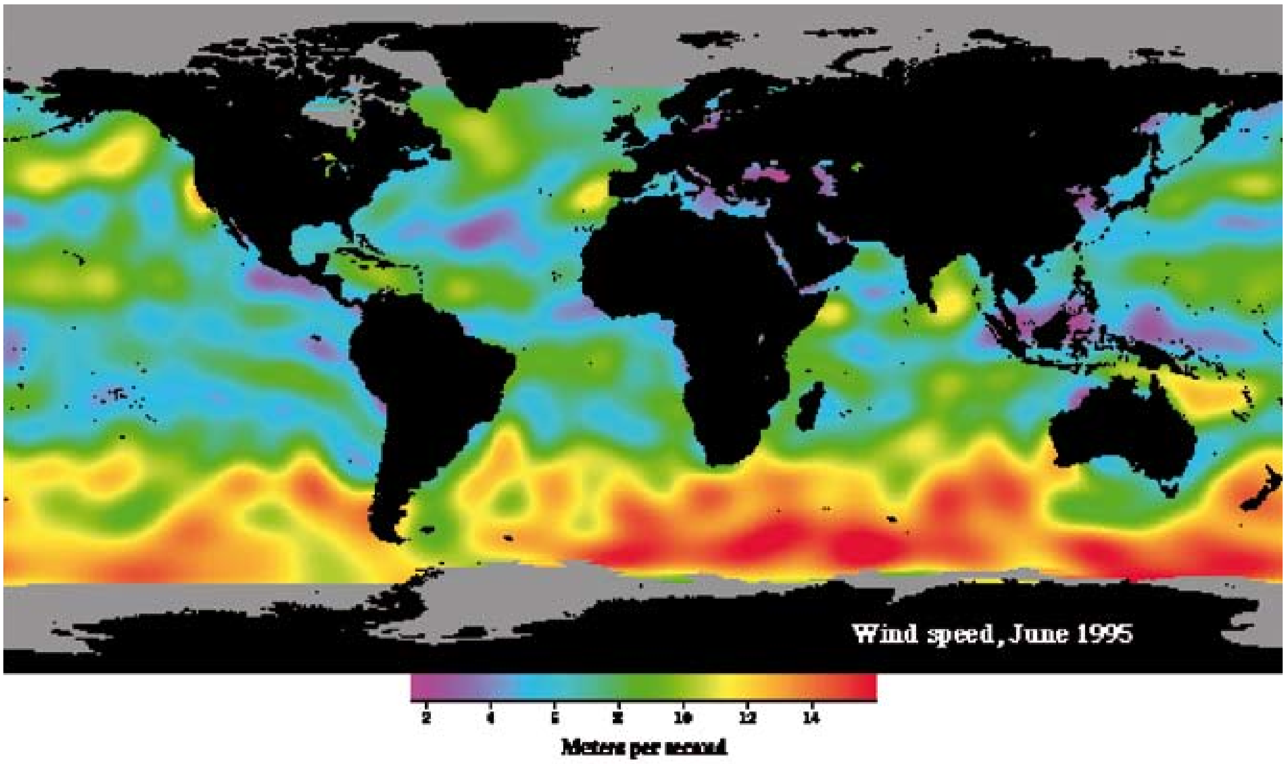
Sea surface height is measured using so-called altimeters. Altimeters are measuring the time delay between emission of a sharp electromagnetic pulse down towards the sea surface and the return of the pulse when reflected from the sea surface. The satellites are TOPEX/Poseidon, ers-1, ers-2, Envisat, Jason-1 and Jason-2 (planned for 2008). With sophisticated processing maps of the mean sea surface height above the geoid and anomalies in sea level rises and falls above the reference level can be derived. Such surface height information is useful in deriving the large scale geostrophic currents of the ocean as well as meso-scale meanders and eddies. The resolution of data is typically of the order 20-100 km and not directly useful for coastal applications, but maps of sea surface topography are now ingested into models of the ocean at regional and global levels for forecasting purposes.

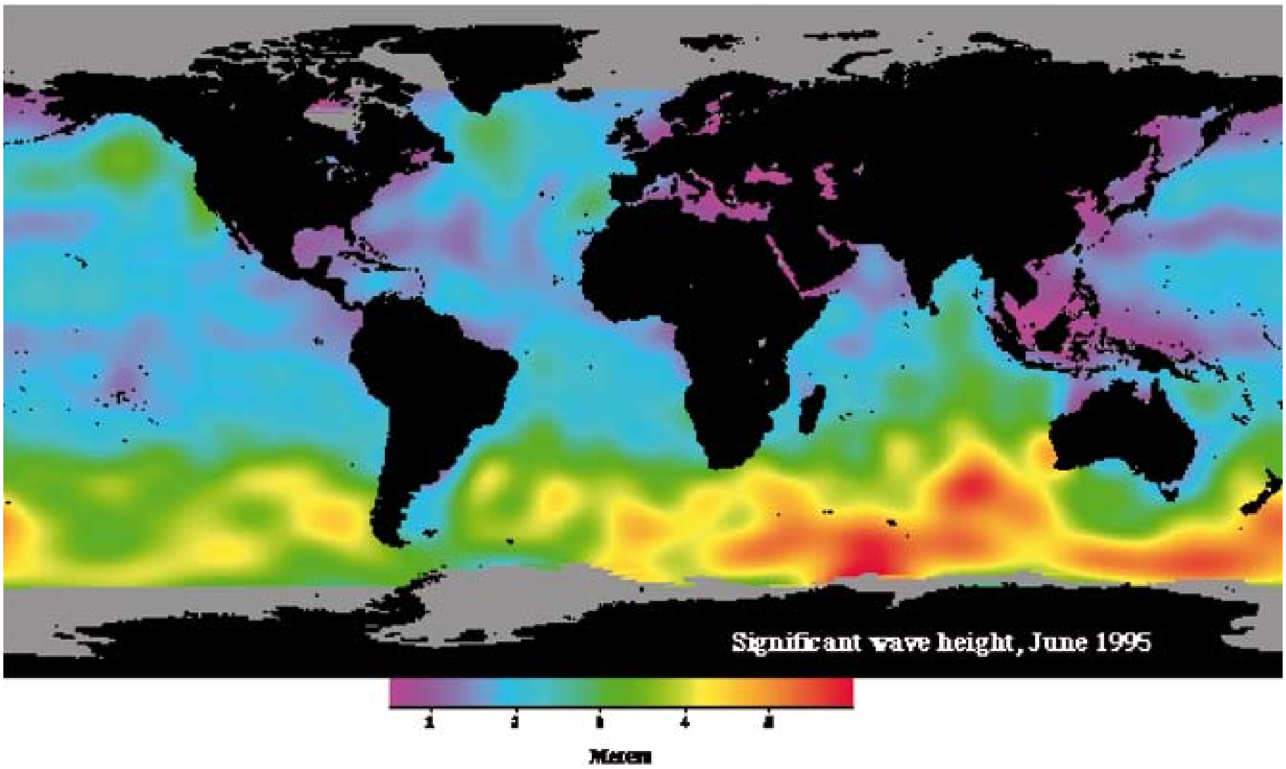


Sea surface height anomaly (millimeters) for January 2004 from altimeter onboard the Jason satellite

Wave height

The satellite altimeters used to estimate sea surface height can also be used to measure wave-height. Our knowledge about the global wave climate has significantly improved compared to the pre-altimeter age, where data were confined to data from buoys and from visual observations. Global climatologies are now available and near-real time data are used in wave forecasting programs.





Wind speed and significant wave height from Topex/Poseidon June 1995

5. Potential application of GEM capacities

Satellite SST measurements are used in many applications as they provide a synoptic view of the dynamic thermal character of the ocean surface. Measurements are fundamentally important to agencies and institutions tasked with the study of climate variability, operational weather and ocean forecasting, military operations, validation and forcing of ocean and atmospheric models, ecosystem assessment, tourism and, fisheries research, amongst many others. SST by itself is a simple indicator of climate change, but is often used in conjunction with numerical models for both weather and climate forecasting. SST is used both in a research and an operational context, depending on the topic addressed.

Ocean chlorophyll and primary pigments are likewise used worldwide in both operational and research contexts ranging form climate change issues to ecosystem assessment. While the application of both data types can be multiple, the following sections mention some of the possibilities that can be further developed in the current GEM setting.

5.1 Climate change and the marine environment

Developing countries and Africa in particular are seen as the most vulnerable regions in the world to the projected changes in climate. Most of the on-going debate is focused on terrestrial effects of climate change, while for the marine part it is often reduced to either flooding or coastal erosion as a consequence of sea level rise. There are other aspects of climate change in the marine environment to which the GEM data can be applied. Here is a list of issues:

- Use historical data from which possible trends and statistics of temperature and biomass variability can be derived. Provide the baseline for current data and future monitoring programs. Near real-time information derived from the data, such as upwelling indices or biomass blooming may become relevant for on-going monitoring programs
- Identify so-called ‘hot spots’ i.e. areas where changes in SST are more pronounced that the average situation. This may be particularly interesting as climate change is not supposed to occur evenly in the world’s oceans
- Ecosystem assessment based on a modelling of scenarios of changes in temperature, stratification and nutrient regimes. Alterations of the ecosystem will modify the composition of marine organisms although the ways of alteration may not be fully understood. The impact on biodiversity may be a key issue.
- Develop better measures and indices of exposure to climate change, particularly incorporating marine-relevant climate change parameters such as sea level rise, sea surface temperatures, storm frequency and intensity, upwelling frequency and intensity

Areas for Community action: climate change, biodiversity, fisheries
Potential users: public services

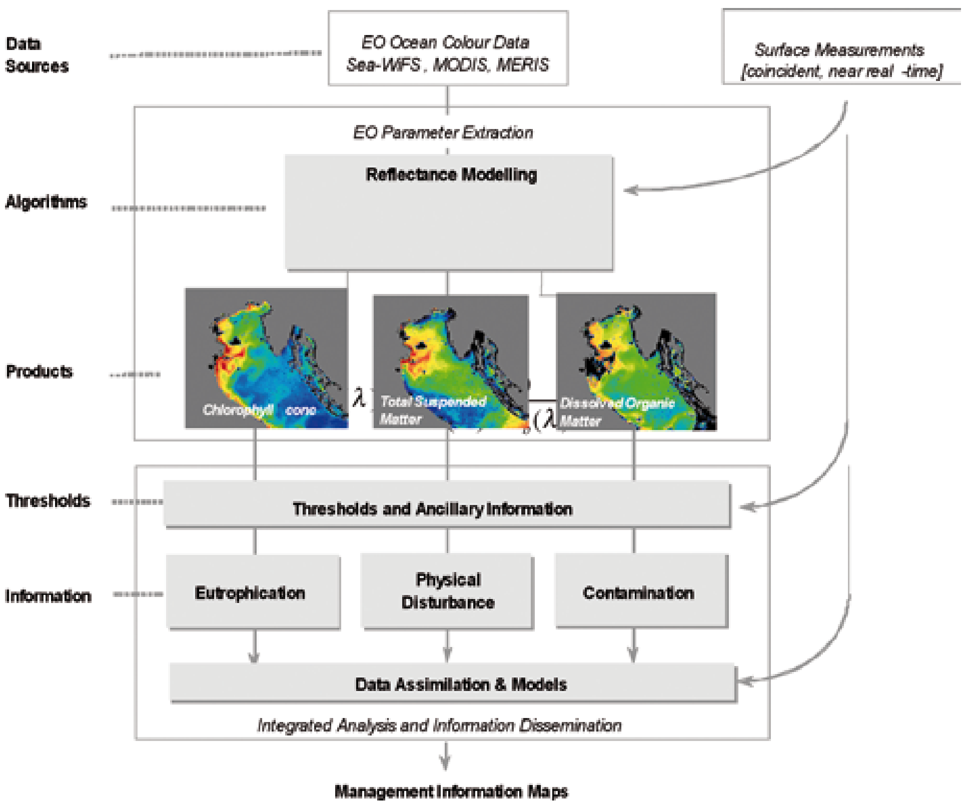
5.2 Integrated coastal zone management

The coastal zones are under increasing pressure from demographic changes and sectoral activities in the near coastal areas with severe coastal degradation as a result. Integrated coastal zone management is one of the tools used for planning and management of the conflicting interests in the coastal zones. Satellite data and derivatives can be integrated in such systems for:

- Establish basemaps of algal blooming, sedimentation and SST along the coast
- Provide cartography of mangroves and reef systems.
- Establish shoreline cartography
- Use models to give dynamic view of coastal currents

At present, downstream estuarine and coastal impacts are often poorly understood and monitored, especially in large or remote ecosystems, because of the difficulty and expense of monitoring marine indicators at appropriate time and space scales. Ocean colour products such as suspended sediments, dissolver organic matter (CDOM), light attenuation and chlorophyll concentration, are key indicators of cause and effect in these systems. There is often concern and uncertainty about the spatial extent of impacts associated with major flood events. Suspended sediment and CDOM concentrations can be used to track plume distribution and dilution, and sedimentation, calibrate or validate dispersion models, and identify interactions with benthic ecosystems (eg coral reefs) or exchanges with offshore waters. Note that indicators such as colour, transparency and chlorophyll biomass are commonly included explicitly in environmental regulations. Direct satellite estimates of the light attenuation at different wavelengths provide information on the depth of penetration of the solar radiation and, therefore, can be related to water transparency and Secchi depth information which represents a major quality parameter for the classification of ecological status of lakes and coastal waters. The differentiation of each optically-active contributor to the water transparency (particulate organic matter, sediment, dissolved organic substances) gives further information on the source of turbidity and allow appropriate mitigation measures to be developed. In addition, chlorophyll concentration provides an index of active organic biomass found in phytoplankton, distinct from the other light absorbing materials that do not contribute to local production.
Rather than to be used in isolation, these products and others need to be merged or combined with other diverse forms of data to develop an analysis environment that will support the rapid and flexible incorporation of statistical and modeling schemes for transformation of these data into operational water quality maps.

Areas for Community action: territorial development, research
Potential users: national public services concerning with physical planning and land management, i.e. ministries, agencies



The sequential process for the use of satellite Ocean Colour data and field measurements into an integrated water quality analysis and monitoring system

5.3 Information for the 'country environment profile'

In the particular case of the programming phase of the EC 'Cycle of Operations' the satellite data and the knowledge inherent to the use of satellite data is of interest for the 'Country Environment Profile'. Satellite data may also be of interest for the analysis of environmental impacts of projects and programmes, and to identify and assess environmental issues to be considered during the preparation of a Country Strategy Paper which will directly or indirectly influence European Union (EU) cooperation activities. The Table below shows how satellite products from multiple sources (e.g. ocean colour and thermal imagery) can be used in an integrated way for water quality classification.

Product Name	Standard and advanced Products requirement	Application
Transparency / Secchi disk depth	Pigments, Total Suspended Matter (TSM), light attenuation coefficient Dissolved organic matter (DOM), Attenuation coefficient	Water quality monitoring
Primary production	Pigments, TSM,DOM, inherent optical properties of water constituents, SST, surface irradiance	Water quality monitoring, ecosystem and habitat assessment
Differential Biomass/ phytoplankton community structure	Pigments, chemotaxonomic equations	Water quality monitoring, ecosystem assessment, hazards
Eutrophication index	Chlorophyll, primary production , nutrients, SST	Water quality monitoring, hazards
Turbidity index	Transparency, phytoplankton biomass	Water quality monitoring
Submerged benthic vegetation index	Pigments, sediment, dissolved organic matter, bathymetry, albedo data base	Aquaculture, water quality monitoring, impact assessment
Bloom/ plume dynamics	Chlorophyll, TSM , DOM	Hazards, ecosystem and habitat assessment

Note that all products / indices in the first column of the table fit to the definition of 'state indicators' as given by OECD, which further stipulates that an indicator could be the expression of a parameter or a pool of environmental parameters. From a country management perspective, these indicators need to be integrated into a more complex information and assessment system tool, such as the *'pressure-state-response'(PSR)* framework or the *'Driver-Pressure-State-Impact-Response' (DPSIR)* framework introduced within the IGBP-LOICZ project and adopted in the European Water Framework Directive.

Areas for Community action: Programming development policy
Potential users: EC services, beneficiary countries, consultants

5.4 Natural resources including fisheries

Data could be applied as in the projects Envifish and Nat-fish where the understanding of the variability of the marine environment is seen as a sound prerequisite for sustainable management of living resources. The approach of managing fisheries in the context of an ecosystem management is now fully established as a most sustainable way of managing living resources.

Fishing communities as a natural resource are increasingly subject to climate change as reduced primary productivity may limit the food available for fish and furthermore fishing populations may move out of their normal habitats due to climate shifts.

The involvement of environmental data in managing natural resources such as fisheries may not be seen as a stand alone activity as most fisheries in developing countries are subject to overexploitation, often caused by unsound management principles and illegal and unreported fishing. Specific applications could be:

- Analyse past environmental changes and relate them to known events of abnormal conditions in fisheries. Key environmental information such as 'upwelling indices' could be extracted for early inclusion in precautionary management.
- Integrate satellite data in fisheries information system in relation to the spatial distribution of fishing grounds, spawning areas, nursery areas. Such an activity is specially relevant for the establishment and monitoring of Marine Protected Areas

Areas for Community action: fisheries, biodiversity, climate change
Potential users: organisations charged with fisheries surveying, monitoring, research and management, normally a ministerial office.

5.5 Training and capacity building

Specific training opportunities such as:

- On-the-job training in use of specific satellite data and relevant software. Such training is often carried out with other institutions through international networking
- General training in use of satellite data for environmental monitoring and assessment

Areas for Community action: research, science and technology
Potential users: all

6. List of acronyms and abbreviations

AMIS	African Marine Information System
AVHRR	Advanced Very High Resolution Radiometer
CHL	Chlorophyll-like pigment
CZCS	Coastal Zone Color Scanner
DOM	Dissolved Organic Matter
EC	European Commission
EOF	Empirical Orthogonal Function
ESA	European Space Agency
EU	European Union
FIAS	Fisheries Information and Analysis System
GEM	Global Environment Monitoring
GHRSST-PP	Global High-Resolution Sea Surface Temperature (SST) Pilot Project
GIS	Geographic Information System
GSFC DAAC	Goddard Space Flight Centre Data Active Archive Centre
HDF	Hierarchical Data Format
IES	Institute for Environment and Sustainability
IGBP	International Geosphere-Biosphere Programme
IOCCG	International Ocean Colour Coordinating Group
JRC	Joint Research Centre
LOICZ	Land-Ocean Interactions in the Coastal Zone
MONDE	Monitoring Natural Resources for Development
NAO	North Atlantic Oscillation
NOAA	National Oceanic and Atmospheric Administration
OCEAN	Ocean Color European Archiving Network
OECD	Organisation for Economic Co-operation and Development
PAR	Photosynthetically Available Radiation
PNA	Pacific North Atlantic Oscillation
PP	Primary production
SOI	Southern Oscillation Index
SIAP	Système d’Information et d’Analyse des Pêches
SST	Sea Surface Temperature
TMI	Tropical Rainfall Measuring Missions (TRMM) Microwave Imager
TSM	Total Suspended Matter

European Commission

EUR 23213 EN – Joint Research Centre – Institute for Environment and Sustainability
Title: **Availability of coastal and marine data and potential applications for development co-operation**
Author(s): L. Nykjaer and N. Hoepffner
Luxembourg: Office for Official Publications of the European Communities
2008 – 32 pp. – 21 x 29,7 cm
EUR – Scientific and Technical Research series – ISSN 1018-5593

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