Mediterranean Operational Oceanography Network (**MOON**):

in support of Sustainable development and Marine State Assessment

Science and Strategy Plan

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PREFACE

In 2002, INGV (IT) and MERCATOR (FR) joined together to establish a 'Mediterranean Operational Oceanography Network' (MOON) in order to elaborate a unique plan for operational oceanography in the Mediterranean Sea and develop an overall science and strategy plan for the expansion of operational oceanography toward environmental predictions and sustainable development of marine and water resources.

In March 2004, a MOON Science Steering Group was established that is composed of representatives from about 20 laboratories in Europe and EU entering/accessing countries around the Mediterranean. The members of the MOON Science Steering Group are listed in section 8 of this document. The MOON Steering group held another meeting in Barcelona, June 12, 2004 in order to revise this document. The latter explains the science and strategy plans for the next five years in order to expand the benefits of operational oceanography to the sustainable development of Mediterranean coastal areas and in support of rational marine state assessment.

We would like to thank the EU V Framework Program, Research Directorate, Energy, Environment and Sustainable development for the continuous support to the development of operational oceanography in the Mediterranean Sea.

EXECUTIVE SUMMARY

Due to the large natural variability and the human induced changes, the Mediterranean Sea water resources and coastal areas sustainable development need to be continuously monitored, analyzed and predicted following the practice of operational oceanography (GOOS, 1996).

Operational oceanography in the Mediterranean Sea is now a reality but it is mainly connected to physical environmental variables. However, it is clear that the practices and methodologies of operational oceanography could be of benefit to sustainable development issues related to marine coastal areas, water and marine resources management. In particular, the practice of real time monitoring and modelling together with field estimation needs to be exported to the other environmental aspects of sustainable development of marine areas.

The availability of a real time, quality controlled stream of complex environmental information coming from the optimal estimation of observations and models could provide an innovative support to policy makers and managers of environmental marine emergencies.

For some of the aspects of environmental monitoring and modelling in real time, basic research still needs to be carried out and new tools have to be developed. It is timely to start these developments coordinating the efforts in the various disciplines with operational oceanography in order to develop them within the concepts of operational science.

MOON tries to undertake the task of consolidating the present Mediterranean operational oceanography network and at the same time using the forecasting system to improve the present state of monitoring the marine environment state of health and the information to be used for the management of water and marine resources in the Mediterranean area. In other words, MOON links operational oceanography to users of environmental information in order to reach the goal of sustainable development of this critical marine area.

The MOON plan is subdivided into six areas of action that are:

1. Ocean hydrodynamics,
2. Water cycle and resources,
3. Biochemical fluxes and cycles,
4. Open ocean and coastal marine pollution,
5. Sedimentary fluxes and coastal erosion,
6. Operational Fisheries

These key action areas are the focus of research, development and demonstration exercises to bridge the gap between operational oceanography and the final end-users of the forecasts, for the practical solution of sustainable development problems. The strategy for development of the different action areas is outlined in five special focus projects that should be developed in the next five years.

1. INTRODUCTION

The GOOS framework, the European effort and the GMES initiative

During the past ten years, monitoring and forecasting of the ocean and its coastal areas has been established by research projects and it is now being done pre-operationally by several research and operational agencies around Europe and in the world. The Unesco/IOC action on the Global Ocean Observing System-GOOS[1] and its Coastal Ocean Observing Panel-COOP[2] is establishing a world-wide network for the exchange in real time of ocean data and the usage of observations into predictive models of the marine environment, from physical fields to marine ecosystem variables.

In Europe, EuroGOOS (EuroGOOS, 1995) has fostered the development of operational oceanography since the middle nineties through an association of operational and research agencies that developed plans and the implementation of prototype systems in the European shelf areas and the global ocean. One of these groups, the Mediterranean Task Team developed the Mediterranean ocean Forecasting System Plan and implemented it in the Mediterranean Sea, as it will be described below. EuroGOOS and the Mediterranean Task Team also fostered the development of MedGOOS (MedGOOS, 1998) to coordinate the developments in the marine sector with different stakeholders and to construct a coherent framework in the Mediterranean Sea.

[1] GOOS: http://ioc.unesco.org/goos

[2] GOOS- Panel-COOP: http://ioc.unesco.org/goos/COOP.htm

The European Commission and its V Framework program for research and development has financed a Cluster in Operational Oceanography that developed and is developing several marine prototype operational systems (in the Arctic Sea and North Atlantic- TOPAZ and in the Mediterranean Sea-MFS) together with capacity building activities (in the Baltic Sea-PAPA, in the Mediterranean Sea-MAMA, in the Black Sea- ARENA). Other national efforts have sponsored the development of operational oceanography in the Atlantic and the global ocean (MERCATOR, France and FOAM, UK).

In line with the European strategy for space developed by the Commission and the European Space Agency (ESA), the EU and ESA Councils have stressed the strategic importance for Europe of global, independent, reliable and ongoing access to information concerning environmental monitoring and management, risk monitoring, and enhance civil protection and safety (e.g. with regard to global change, environmental stress and disasters). This information is critical for the formulation and informed conduct of policies within the EU and for their effective implementation. It is also a vital part of Europe's contribution to issues affecting the global environment and the safety of our planet. This program of development is called Global Monitoring of Environment and Security-GMES.

GMES is an ambitious concept, which reconciles the political needs associated with environment and safety issues with the scientific and technological capacities offered by information society technologies and Earth observation technologies, e.g. observation satellites. Ultimately, the intention is to establish in Europe a recognized entity to which decision-makers and users of this type of information can turn. The multitude of stakeholders and the factors determining the success of such an enterprise necessitate launching the GMES initiative.

Developments and forerunners (resulting in particular from research work) can be used and adapted to respond to the needs of GMES. To ensure the transition to a fully operational phase within this decade, coordination at European level between providers and users and the establishment of an institutional framework ensuring the long-term supply of the services (be they public interest or commercial services) required by the users are essential. GMES involves the European Commission, the European Space Agency, the European Environment Agency (EEA), the space agencies, industry, the national authorities and the scientific community.

For the initial period (2001-2003) nine potential topics have been identified, one of them is the sustainable development of European marine areas. During this phase, The MERSEA- Strand 1[3] project analysed and inter-compared the four operational ocean systems in Europe (FOAM, MERCATOR, MFS, and TOPAZ) and their connection to application modules. The final conclusion was that the four operational systems are providing consistent information and they can be used for practical applications (oil spill and eutrophication modelling) and they are mature to work operationally but they are lacking connections with marine coastal areas management issues and stakeholders. The application modules on the other hands require still research and development work as well as the set up of a real time exchange of high resolution in situ and satellite data.

The European Commission and its VI Framework program is now supporting a further consolidation of monitoring and forecasting of the marine environment in the European area within the GMES initiative[4] and it has launched the MERSEA Integrated Project initiative[5].

The Mediterranean Operational Oceanography Network-MOON initiative tries to bridge this gap between the present day operational oceanography products and environmental monitoring and management in the Mediterranean Sea in a complementary way to MERSEA Integrated Project and focusing to the major environmental problems of the Mediterranean area.

[3] Web page at: http://www.mersea.eu/

[4] GMES:Global Monitoring of Environment and Security. Wb page: http://www.gmes.info/

[5] Web page: http://www.ifremer.fr/mersea/

What are the Mediterranean environmental problems?

The sustainable development of Mediterranean coastal areas, the management of water (surface and underground fresh waters), marine resources (off-shore activities and fisheries) and the overall management of open sea and land derived pollution is a serious concern for the European and non-European States bordering the Mediterranean Sea. Millions of people lives depend upon the continuous assessment of the state of the system so that prevention actions against pollution, overexploitation of fish stocks, loss of water resources and marine ecosystem habitat loss can be organized in a timely fashion, together with adaptation and mitigation measures.

The major Mediterranean Sea environmental problems that are of concern for MOON are:

1. changes in the basin hydrological cycle (also due to man induced changes in the river basins and their runoff), in underground waters and in precipitation events;
2. fate and dispersal of oil and contaminants in the open sea;
3. fate and dispersal of land derived nutrients and contaminants;
4. coastal erosion;
5. fishery activities and aquaculture;
6. algal blooms and adverse effects in coastal areas (anoxia, turbidity, etc.);
7. ecosystem changes, invasive species and long term adverse marine trends.

For the hydrological cycle, it is now evident (Mariotti et al., 2002) that decadal time scales variability of the evaporation and precipitation budgets are acting upon the basin due to teleconnections with Atlantic climate regimes. Furthermore, precipitation regimes have been changing in the past 20 years (Brunetti et al., 2000) with fewer days of heavier rain and increasing number of drought days. The regulated runoff and river basins changes are perhaps the most serious man induced change occurring in the Mediterranean due to the agricultural and industrial usage of fresh water resources (see for example the recent Ebro river changes in discharge rates, Sanchez-Archilla et al., 2002, and the Nile, Hamza, 2003). The water cycle in the Mediterranean Sea is affected by atmospheric air quality and by teleconnections with the larger Northern Hemisphere climate. The water resources in and around the Mediterranean area are vulnerable and under stress since industrial and agricultural development heavily draw on water resources. The coastal areas degradation and change of ecosystem habitats that may result from the vulnerability of fresh water resources need to be studied in detail.

It is recognized that transboundary aquifer systems are important sources of fresh water in the world with most of these systems being important in arid and semi-arid areas. The Mediterranean and in particular the Adriatic basin are characterised by Karstic aquifers, and many are transboundary groundwater systems. It is thought that changes in the sea level and hydrological cycle will change the underground water budget and thus the salt intrusion into the aquifers with consequent dramatic change of this natural but vulnerable resource. It is also possible that the submarine fresh water sources could sustain part of the marine productivity wherever groundwater discharges are present on the continental shelf.

Oil pollution in the open ocean of the Mediterranean Sea is of great concern because 30% of the sea-born trade volume passes through the Mediterranean (Fig.1 and 2) and new maritime traffic developments will create new ‘sea highways’ with higher risks of accidental discharges. Other contaminants could be already affecting the open ocean areas but there is not obvious monitoring of such pollution at the moment and probably it needs to be developed.

The land derived contaminant arrive to the sea through the atmosphere and the rivers, direct sewage system discharges, industrial discharges in the coastal zone, etc. The Mediterranean is in a state of emergency because of the high anthropogenic activity occurring along its coastal boundaries and along the river catchments. The contaminants and nutrient fluxes entering the coastal areas by large Mediterranean cities (hot spots) have to be re-evaluated since the previous assessment (EROS-2000, 1996) is old and they need to be re-assessed in view of the EU Water Framework Directive new rules.

Coastal erosion and the increase of its natural occurrence is a very important concern for several coastal areas in the northern Mediterranean Sea and it derives from coastal urban development, land usage and river sediment fluxes. Coastal currents couple to waves and tides in a complicated way to produce erosion and sediment deposition/transport and the changes in wave regimes have to be carefully monitored, together with currents variability and sediment quality changes.

The biogeochemical fluxes and cycles of the basin are partly regulated by atmospheric inputs (Krom et al, 2004) and river loading (Crispi and Crise, 2002). Half of the Mediterranean coastal areas are connected to open ocean biogeochemical cycles and microbial loop dynamics can be as important as the herbivorous food web dynamics in both coastal and open ocean waters (Legendre and Rassoulzadegan, 1995). Coastal algal blooms, toxic and not, and other concomitant phenomena such as mucilage in the Adriatic and Tyrrhenian Sea can produce anoxic conditions that could induce animal and plants habitat loss and fish kills.

Tertiary production in the Mediterranean is quite separated from actual primary and secondary production since fish stocks are abundant but the Mediterranean is generally an oligotrophic open ocean basin. Other environmental conditions may be important for the conspicuous development of the tertiary production in the basin and they are still to be fully understood. Climate fluctuations in fish stocks imposes the need for continuous monitoring of environmental conditions and fishing effort.

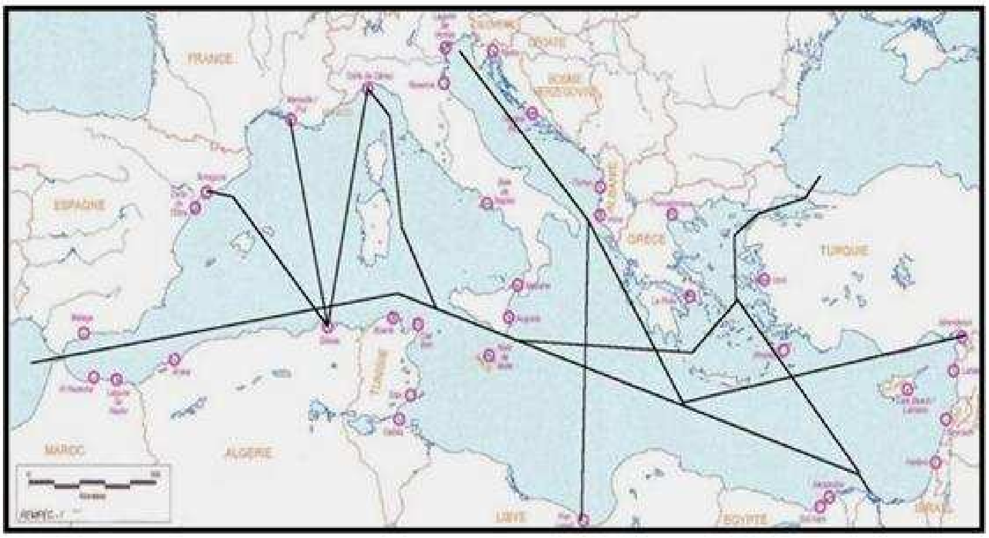

Fig. 1 The main oil routes of the Mediterranean Sea

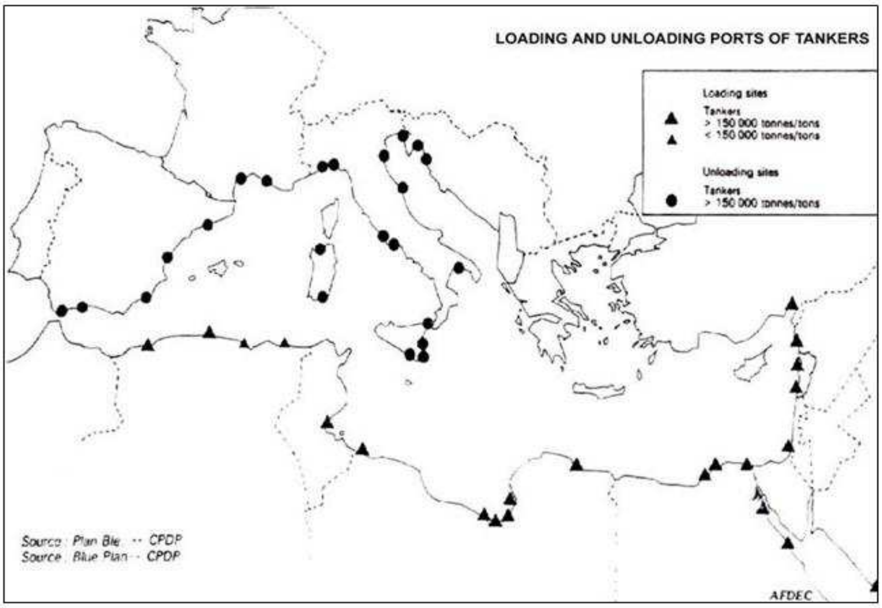

Fig. 2 The loading and unloading ports in the Mediterranean Sea where pollution impact is expected to be important

All these problems require a scientific basis of understanding, monitoring and modelling of the marine environment that is far from being established. The MOON science Plan tries to envisage the research and technology developments necessary to cope with these problems building on a scientific and research based information system that has been developed for operational oceanography and that needs to be developed now for the rest of the marine environmental variables.

Operational oceanography and environmental predictions

Modern research has developed the concept of 'operational science' that tries to understand and model processes not in the laboratory but directly in the field. Meteorology and oceanography are examples of disciplines where such methodological approach is particularly valuable since the complexity of the system requires the collection of data directly in the field. In addition, operational science tries to optimize the usage of theoretical, numerical models and observations to solve practical problems with a basic scientific rigorous approach. The approach is based upon the 'trial and error' method because the complexity of the system can only be tackled by a process of incremental upgrade of knowledge and implementation of the methods. For the ocean, the application of the concepts of operational science has occurred in the framework of the Global Ocean Observing System (GOOS, 1997, Pinardi and Woods, 2002) where in fact the experiments are done in the field directly and the problem to solve is the one of the real time monitoring and forecasting of the ocean state and its associated field state variables. The Mediterranean has implemented such system through the Mediterranean ocean Forecasting System (MFS, Pinardi et al., 2003) and the Mercator initiative (Bahurel P. and the Mercator Project Team, 1999). It is now time to consolidate the operational system and it is necessary to integrate more environmentally oriented research and information into the operational oceanography framework.

In the past ten years, operational ocean forecasting has become a reality in the Mediterranean Sea, as well as in other parts of the world ocean. As in operational meteorology, the present day activities are mainly concerned with wave and current forecasting, the latter including temperature, salinity and sea level. Real time environmental monitoring and predictions considering other marine state variables (biogeochemical fields) is lagging behind the developments of the physical state variables. The physical state variables (temperature, salinity, density, velocity, pressure and sea level) were monitored and forecasted first because the measuring technology has advanced rapidly after the seventies and numerical modelling and data assimilation algorithms have reached maturity. Data assimilation allows to meld the observations with the model numerical solution and reduce the uncertainty in the initial conditions of forecasts. It is indeed true that predictions are limited to first order by the accuracy with which the initial conditions are known for all the predicted state variables (temperature, salinity and velocity fields). In addition, the knowledge of the basic hydrodynamics equations for the ocean and adequate parameterizations for the sub-grid scale processes allow a quite accurate forecast.

For other environmental state variables such as sediments, phytoplankton and bacterial biomass, dissolved nutrients, organic matter and contaminants, the monitoring technology and the numerical modelling tools are much less advanced and require a special effort to be developed in the same way that it was done for the physical state variables. This will allow to develop an '*operational marine environment science*' that will allow the efficient monitoring and assessment the state of the marine system in real time.

A marine environmental prediction system is composed of four methodological blocks (fig. 3): the observing, modelling, data assimilation and information management system that contains Decision Support Systems- DSS that considers software interfaces for policy makers. The synergy between the first three building blocks produces an optimal estimate of the present and near future state of the system that is considered to be the basic information before any decision about prevention or mitigation actions should be taken. The data management system makes this information available in real time to policy makers and environmental agencies responsible for the protection of the marine resources and habitats.

Operational oceanography has developed in the past ten years part of these building blocks, in particular the hydrodynamic monitoring and predictions and MOON now tries to advance such system to the extended marine environmental prediction problem, where biogeochemical state variables are considered and the problems to be solved are related to the general environmental problems described before.

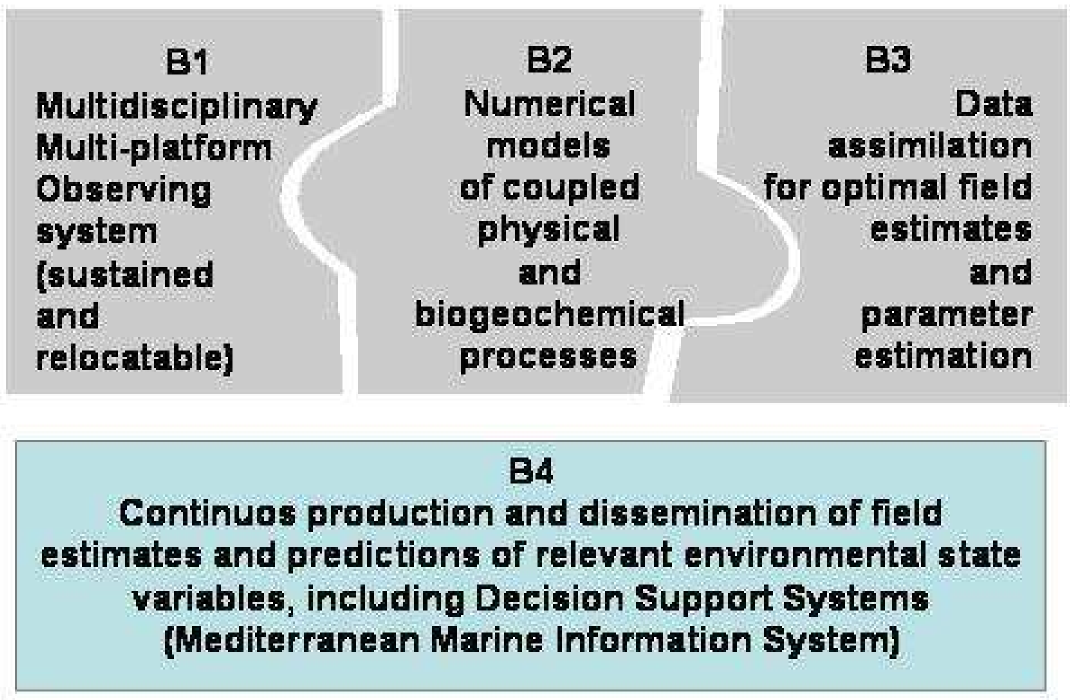

Fig. 3 The marine environmental prediction system methodological blocks

The Mediterranean ocean Forecasting system (1998-2005)

The MFS has been developed and it is continuing to be developed through a sequence of international projects that coordinate government agencies and private companies belonging to the countries bordering the Mediterranean Sea. The projects that have developed and continue to develop MFS are summarized in Table 1.

The general aims of MFS are (Pinardi and Flemming, 1998):

– Scientific

to explore, model and quantify the potential predictability of the marine ecosystem at the level of primary producers from the overall basin to the coastal areas and for the time scale of weeks to months.

–Pre-operational

to demonstrate practical capability of operating a forecasting system at the basin and the shelf scale

The MFS major results are (Pinardi et al., 2004):

1. the continuous monitoring of the basin scale variability through an internationally coordinated large scale observing system composed of Ship Of Opportunity Program-SOOP measurements, satellite data, moored buoys, drifting buoys and unmanned underwater vehicles. All these system components (Fig.4) have been and are being deployed in a fully operational or pre-operational way by the end of 2004.
2. a basin and regional forecasting system that provides short term (3 to 10 days) forecasts of the currents at different level of resolution, asynchronously coupled with a large scale atmospheric forecasting system (ECMWF) and Limited Area Models (LAM) atmospheric forecasts. The forecasts are broadcasted through a Web Bulletin (Fig. 5);
3. a basin and regional coupled physical and biochemical modelling system for the lower trophic environmental variables that can in principle provide short term forecasts of primary producers abundance, bacteria biomass, oxygen, nutrient and particulate organic matter concentrations and other biogeochemical state variables in coastal areas;
4. oil spill and other contaminants predictions in the open ocean coupled to ocean current forecasts and in coastal areas;
5. small pelagic fish stock data collection and the statistical connection to other environmental variables predicted by the current forecast system.

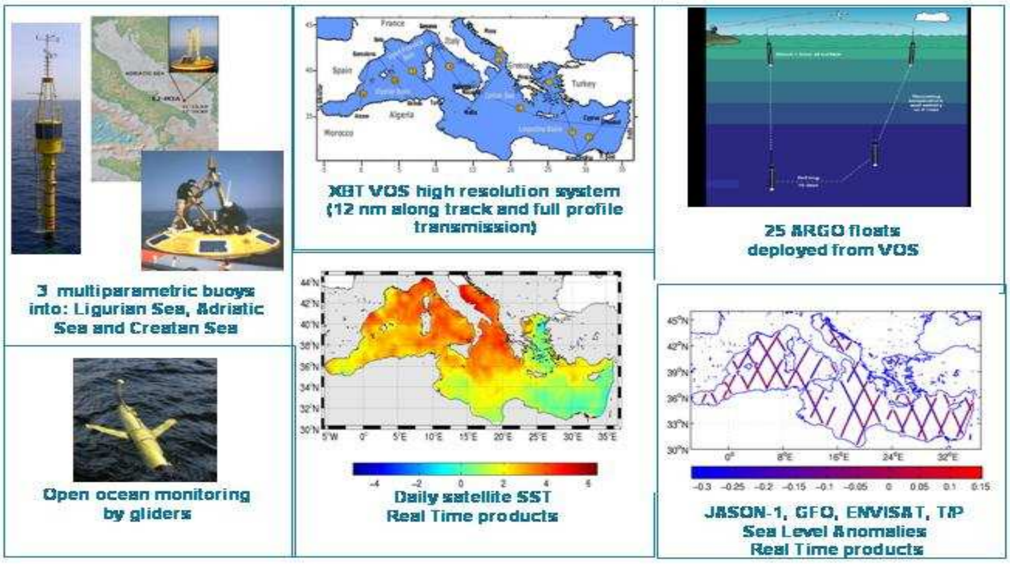

Fig. 4 The MFS Observing system components already operational or pre-operational in the Mediterranean Sea.

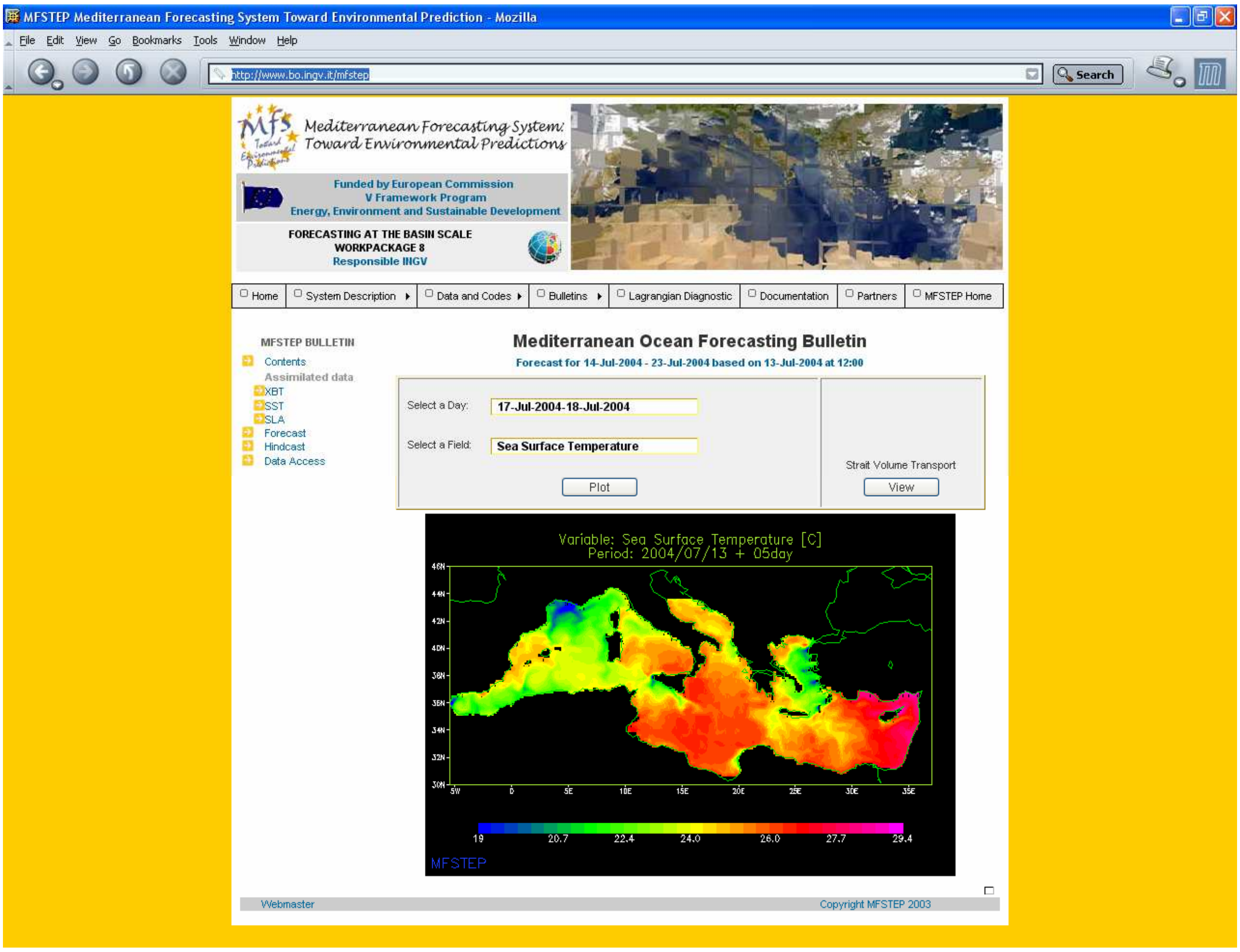

Fig.5 The MFS Web Forecast Bulletin

Project acronym	Project full name	Nations participating or area	Duration	Comments
MFSPP	Mediterranean Forecasting System Pilot Project	Italy France Greece Spain Malta UK Germany Cyprus Egypt Norway Israel	September 1, 1998-March 31, 2002	www.cineca.it/mfspp
ADRICOSM Pilot Project	Adriatic sea integrated coastal areas and river basin management system Pilot Project	Italy France Slovenia Croatia	October 1, 2001- February 28, 2005	www.bo.ingv.it/adricosm
ADRICOSM-EXT	Adriatic sea integrated coastal areas and river basin management system -Extension	Italy Slovenia Croatia Bosnia-Herzegovina Serbia-Montenegro Albania	Autumn 2004-Autumn 2005	
MFSTEP	Mediterranean ocean Forecasting System Toward Environmental Predictions	Italy France Greece Spain Malta UK Germany Cyprus Turkey Czech Republic Israel Slovenia Australia	March 1, 2003-February 28, 2006	www.bo.ingv.it/mfstep
MERSEA-S1	Marine EnviRonment and Security for the European Area	Mediterranean Sea and other European Seas	Jan 1, 2003-June 30, 2004	FP V GMES Strand1 Project
MERSEA-IP	Marine EnviRonment and Security for the European Area	Mediterranean Sea and other European Seas	April 1, 2004-March 31, 2007	FP VI Integrated Project-GMES

Table 1: The projects developing MFS activities in the Mediterranean Sea.

The MERCATOR Ocean Forecasting system in the Mediterranean Sea

MERCATOR Assimilation Centre is based in Toulouse (France), gathering a project team of 35 people. Mercator ocean forecasters have been running basin-scale ocean monitoring and forecasting systems on a real-time and routine basis since January 2001, providing on major ocean basins (North Atlantic & Mediterranean Sea) and Global Ocean (see Table 2) 52 weekly ocean bulletins per year since that day. These various systems are delivering weekly ocean bulletins, composed of ocean nowcasts (3D depiction of ocean present state) and 2-week forecasts. Long term simulations are also available; reanalysis on the [1993 - present time] period being one of the objectives. Real-time outputs (Fig. 6), as well as validation reports, are available at http://www.mercator.eu.org.

Mercator serves today around 150 referenced users.

The Mercator Mediterranean Sea component has been running on an operational basis since January 2003 with an eddy-resolving (1/16°) model dynamically coupled to the North Atlantic whole basin (same model).

Mercator objectives (Bahurel and the Mercator Project Team, 1999) are to:

- simulate the global ocean with a primitive-equation high resolution model, assimilating satellite and in situ data, to provide hindcasts and near-real time nowcasts and forecasts of the global ocean circulation,
- be operated on an operational mode (i.e. routine and near-real-time) to answer (i) research, (ii) national (military and civilian) state application, and (iii) commercial oceanography end-user needs,
- then contribute to the development of a seasonal and climate forecasting system by providing ocean initial conditions for ocean/atmosphere coupled models.

The MERCATOR project was launched in 1995 by the six major French agencies involved in oceanography (CNES, CNRS, IFREMER, IRD, Météo-France and SHOM) to develop a joint operational capacity for global high resolution ocean monitoring and forecasting. They created in 2002 the MERCATOR OCEAN public company to lead this activity, with commitments to prepare an operational centre by 2006.

Mercator is a core member of the international Global Ocean Data Assimilation Experiment (GODAE) for operational oceanography, and partner of the European MERSEA consortium.

In October 2002, Mercator Océan (France) and INGV (Italy) signed a Memorandum of Agreement to joint their effort to develop an operational capacity for Med Sea monitoring and forecasting.

Ocean basins	Status	Operational Mode (starting date)	Horizontal resolution	Vertical levels
North Atlantic #1	Operational	January 2001	1/3° (~ 30 km)	43
Tropical Atlantic	Operational	January 2001	1/3° (~ 30 km)	43
North Atlantic #2	Operational	January 2003	~1/15° (5-7 km)	43
Mediterranean Sea	Operational	January 2003	1/16° (~ 6 km)	43
Global Ocean #1	Operational	July 2003	2° (~200 km)	30
Global Ocean #2	Development	2005	1/4° (~25 km)	46
Global Ocean #3	R&D	2008	~1/12° (~9 km)	

Table 2: Implementation steps of the MERCATOR ocean forecasting system. Status and characteristics of the different components.

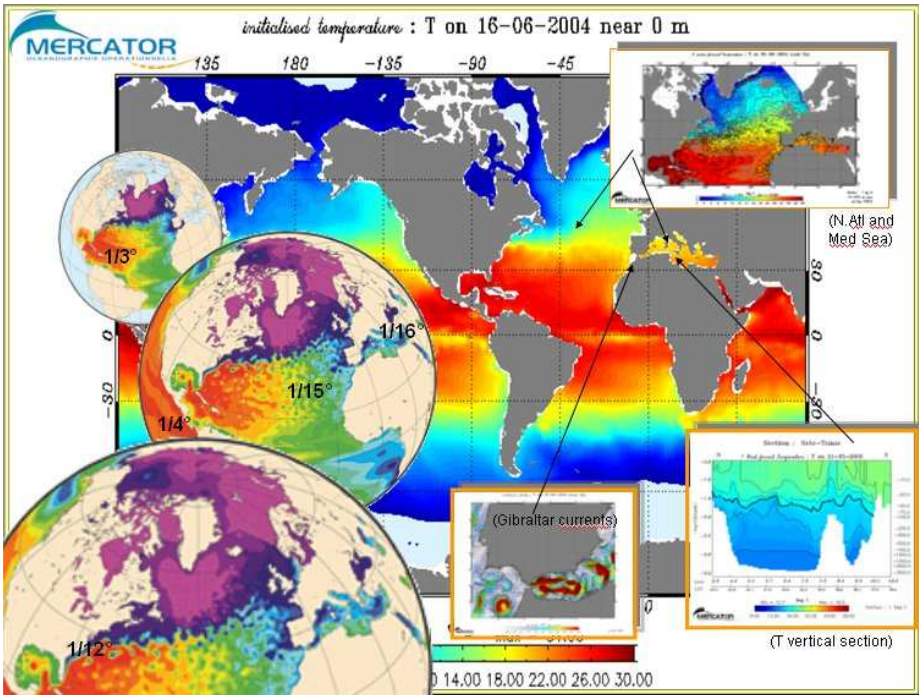

Figure 6: Examples of Mercator Ocean outputs; from global ocean to regional ocean basins.

MERSEA Integrated Project initiative in the Mediterranean Sea

The strategic objective of MERSEA is to provide an integrated service to intermediate users and policy makers in support of safe and efficient off-shore activities, environmental management, security, and sustainable use of marine resources.

MERSEA aims to develop a single European system for global operational monitoring and forecasting of the ocean and a co-ordinated network of regional systems for European waters. The systems will merge and assimilate diverse data from space-borne sensors and in situ measurement networks in order to monitor the ocean physics, bio-geochemistry and ecosystems and to provide forecasts on prediction time scales ranging from days to months. This integrated system will form the ocean component of the future GMES system.

Within MERSEA the MFSTEP system will converge toward the regional component of the European for ocean monitoring and forecasting in the Mediterranean Sea. The scale of integration is at the basin level for the modelling and forecasting part. Elements of the observing system will be continued to be developed such as the M3A buoy network.

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The sub-regional systems

Four major sub-regional systems are being developed and are established to downscale the Mediterranean Sea large scale forecasts to the coastal scales and send-users applications. They are reviewed below

ADRICOSM

The Italian Ministry of Environment and Territory is supporting an international research program for the establishment of forecasting activities in the shelf areas of the Adriatic Sea with the inclusion of river basin modelling and monitoring systems. This project is called ADRICOSM Pilot Project and the project Web site is at: http://www.bo.ingv.it/adricosm .

The Project results are:

1. a basin scale and coastal observing system has been established in the Adriatic Sea. The observations are delivered in real time for both in situ and satellite data. Data collection protocols and quality control procedures have been established for five coastal networks, two in Croatia, one in Slovenia and two in Italy. A new buoy system has been deployed near the Po river outflow.
2. the Adriatic Sea basin scale forecasting system is now working pre-operationally producing every week a 7 days forecast nested within the large scale Mediterranean Sea forecast;
3. a shelf scale forecasting system has been implemented in the Croatian coastal areas nested within the Adriatic Sea forecasting system;
4. an experimental Integrated Coastal Zone Management-ICZM system has been implemented in a part of the Croatian coastlines. The Cetina river flow rates and water quality together with the City of Split sewage water outflows have been systematically measured and simulated. The fresh water outflows, together with their contaminant inputs, have been coupled to a coastal modelling system with approximately 100 m resolution;
5. The ADRICOSM forecast is used and downloaded by several governmental and private companies working in the Adriatic Sea protection and management of coastal areas.

Since 2002 ADRICOSM has become a Type II Sustainable Development initiative in the Theme of ‘Oceans and seas’ (http://webapps01.un.org/dsd/partnerships/se arch/partnerships/134.html) and more projects have been added to the Pilot Project just described. By now all the bordering states of the Adriatic Sea are participating.

CYCOFOS

CYCOFOS, the Cyprus Coastal Ocean Observing and Forecasting System, is a sub-regional operational oceanographic system in the Levantine Basin. CYCOFOS has been developed in Cyprus and has been operational since early 2002. The system is a component of the Global Ocean Observing System (GOOS), and its European (EuroGOOS) and Mediterranean (MedGOOS) modules. CYCOFOS was first developed within the framework of several European Union funded research projects and international activities, which include MFSPP, MFSTEP, MAMA, MERSEA-Strand-1. CYCOFOS at present consists of several operational modules, among them, flow and offshore waves forecasts, satellite remote sensing, coastal and offshore monitoring stations and end-user-derived applications. This sub-regional operational oceanographic system provide regular near-real-time information, both to local and sub-regional end-users throughout the Eastern Mediterranean Levantine Basin.

At present CYCOFOS provides forecasts of sea currents, water temperature, salinity, sea level, significant wave height and direction, but also in-situ observations of sea water temperature, salinity, sea level, and satellite remote sensing of sea surface temperature in the sea areas around Cyprus and in the Levantine Basin.

The near-real-time operational forecasting and observing products from the above CYCOFOS modules, such as daily flow forecasts for the NE Levantine Basin on a weekly basis, 3-hourly sea state forecasts for the Levantine Basin on a 60 hours basis, daily remote sensing sea surface temperature for the Levantine Basin and hourly in-situ sea level, water temperature and salinity at certain coastal and offshore sea stations are available to the end-users at the web page www.ucy.ac.cy/cyocean.

ESEOO

The main objective of the Spanish ESEOO (acronym in Spanish for "Establecimiento de un Sistema Español de Oceanografia Operacional") project is the development and implementation of a Spanish Operational Oceanography system to be used in emergency situations at sea, such us oil spill accidents or tracking of drifting objects. The project is funded by the Spanish National Plan for Research and will be active from 2004 through 2006 with participation of 50 researchers from the main operational oceanography research centres in Spain.

The ESEOO system will consist in several applications based on numerical modelling and analysis of oceanographic data, both historical and real time.

The applications based on numerical models will provide forecast of several physical parameters, such us winds, currents, sea surface temperature, waves and sea level. The models will be operational at three different scales: a) global, generating boundary conditions, b) regional, providing a single high resolution solution for all the Spanish waters and c) local, where the different institutes will create very high resolution applications for different coastal areas. These local models will be able to cover the whole Spanish coastline, either using permanent implementations or by means of relocatable models. Local scale applications will be nested on regional scale ones, and regional on global models. Basic research will be required for the development of the systems, specially on the areas related to data assimilation and model nesting. The applications based on data analysis will provide immediate access to processed information that will be used for decision making during emergency situations.

In order to prepare these applications, new developments will be required in the field of oceanographic data analysis. The results of this project will not be limited to emergency cases, but will boost the knowledge of Spanish coastal waters and the related scientific tools available.

In the Mediterranean, two teams, Puertos del Estado and IMEDEA will be performing the regional ESEOO simulations. The ESEOO domain is established from Gibraltar to Corsica/Sardinia. IMEDEA will use Diecast and HOPS 3d PE models nested to MFSTEP outputs.

POSEIDON

The POSEIDON system is an integrated monitoring, forecasting and information system for the Aegean and Ionian Seas (Eastern Mediterranean) that operates since May 2000 by the Hellenic Centre for Marine Research. Its observing system is based on a network of 10 fixed buoys that collect meteorological (wind speed and direction, air temperature, atmospheric pressure) and upper layer oceanographic parameters (waves, current, temperature, salinity, dissolved oxygen and chlorophyll-a). Data are collected every 1-3 hours and transmitted in real time through the INMARSAT-C satellite system or the GSM network. An upgrade of the buoy network with additional sites in the Ionian Sea and the Eastern Mediterranean and with increased observing capacity in selected areas (measurements in the upper 1000m for hydrological properties and the upper 100m for biochemical parameters) is planned for 2005. The observing system also includes a Ferry Box line that operates in the south Aegean since November 2003 collecting surface physical and biochemical data, while R/S data of sea surface temperature and ocean colour are available on a pre-operational basis mainly for model validation procedures.

The modelling components of the POSEIDON forecasting system follow a downscaling approach and include:

- ✓ An atmospheric modelling system based on the Eta/SKIRON model that provides 72 hours forecasts for the Mediterranean Sea (20 km resolution) and the Aegean/Ionian Seas (10 km resolution).
- ✓ A hydrodynamic modelling system based on POM (Princeton Ocean Model) that provides circulation forecasts for the Eastern Mediterranean (10 km resolution) and the Aegean Sea (5 km resolution).
- ✓ A wave forecasting system based on the WAM model that provides sea state forecasts for the Mediterranean Sea (20 km resolution) and the Aegean Sea (5km resolution).
- ✓ An oil spill weathering and dispersion model that provides forecasts in case of marine pollution accidents.

A high resolution (0.5 nm) nesting of the wave and hydrodynamic models in the Saronikos Gulf is pre-operational since summer 2003 for the needs of the Athens 2004 Olympic Games. Ecosystem forecasting applications are also being developed for selected areas of the North Aegean Sea with problems for local eutrophication and HAB events.

The system products (data and forecasts) are available to the public through the project's web page (www.poseidon.ncmr.gr) and through mobile telephone services (SMS messages and i-mode service). Dedicated internet based services have been developed for selected end users including a live access interface to the oil spill service linked to a real time oil slick detection system based on analysis of satellite (ERS-2) SAR data.

The UNEP/MAP activities and MOON

Mediterranean countries and the European Union have been working together since 1975 through the Mediterranean Action Plan (MAP) first to protect the marine environment and, since 1995, to promote regional sustainable development, biodiversity conservation and integrated management of the coastal areas, all in the framework of the Barcelona Convention and MAP Phase II.

The 21 MAP members, known as Contracting Parties to the Barcelona Convention, decide on the MAP strategies, budget and programme. A rotating Bureau of six Contracting Parties guides and advises the MAP Secretariat.

The Athens-based **MAP Coordinating Unit** (MEDU) is the Secretariat of the Mediterranean Action Plan. It is responsible for the follow-up and implementation of the MAP legal instruments and activities.

UNEP/MAP FIELDS OF ACTIVITY

MAP tackles Mediterranean environmental and sustainable development issues. With the future in mind, it gets different sectors of Mediterranean society involved in preserving the region's rich human and natural resources that have been eroded by rapid development, not always planned with a view on the need for sustainability. In this, MAP mainly focuses on four key fields of activity:
- **Combating land-based pollution**, in particular from areas that feature the heaviest concentration of pollutants from human activities, known as pollution hot spots.
- **Preventing maritime accidents and illegal discharges from ships**: MAP marked a milestone on the path towards achieving maritime safety in the Region through the new Prevention and Emergency Protocol.
- **Safeguarding natural and cultural resources**. Whilst the region's archaeological treasures have been extensively studied and their disintegration in our industrial era is a cause for concern, nature and its evolution have been less of a focus of attention until recently.
- **Managing coastal areas**. With the aim of protecting the Mediterranean coasts from the impact of unrestrained development.
- **Integrating the environment and development**. MAP strives to reverse the current situation in many Mediterranean countries where environmental concern still has too little an impact on development policies.

MOON and UNEP/MAP

MOON initiative should support UNEP/MAP activities introducing the scientific results and operational products developed in the past ten years for the monitoring and forecasting of the Mediterranean Sea.

The practices and methodologies of operational oceanography could be of benefit to sustainable development issues related to marine coastal areas, water and marine resources management. In particular, the practice of real time monitoring and modelling together with field estimation needs to be exported to the other environmental aspects of sustainable development of marine areas.

The availability of a real time, quality controlled stream of environmental information coming from the optimal melding of observations and models could provide an innovative support to policy makers of marine resources and managers of environmental emergencies.

MOON should clearly have a privileged connection with MAP and should try to develop its fields of activities in strict coordination with MAP (Figure 7).

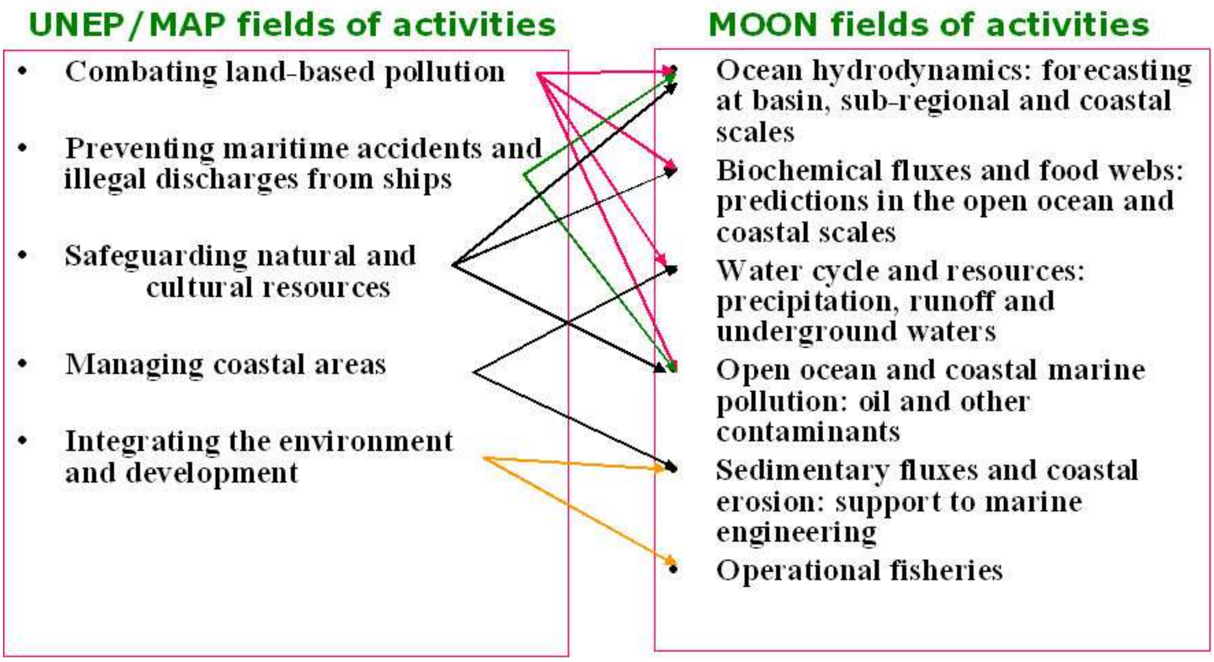

Fig. 7: The strategic MAP-MOON fields of activity coordination

2. OVERALL OBJECTIVES OF MOON

Scientific and operational goals

The overall MOON goals are as follows:

Scientific

to explore, model and quantify the potential predictability of the marine ecosystem from the overall basin to the coastal areas, also integrating the river basin systems and for the time scale of days to months (seasonal)

and

to connect the predicted system variability to anthropogenic forcing that may cause pollution and ecosystem degradation

Operational

to consolidate the operational observational/modelling system in the Mediterranean

and

to demonstrate the usage of the marine environmental prediction system for integrated management of open ocean and coastal marine areas

Outstanding scientific and technological issues

The MOON goals will be achieved only if we will develop a research and technology strategy for each of the four environmental system methodological blocks (see Fig.8):

B1. Monitor in Real Time the hydrodynamics, biochemical fluxes (nutrients and plankton), contaminants levels (oil in the open sea and other contaminants in the coastal areas) and fishery from the basin to the shelf/coastal scale;

B2. Improve the capability to model the hydrodynamics and the biochemical fluxes and food webs (coupled models, downscaling, upscaling, process nesting, ensemble forecasting) from the basin scales to the coastal areas, including the connection with the surface and underground water input to the coastal areas, the contaminants fate and impact on the environment and the connections between fishery and environment

B3. Improve data assimilation tools in order to consider all the relevant real time measurements for the hydrology and biogeochemical parameters;

B4. Develop the information management system for the Mediterranean Sea that will disseminate in real time both observed and model estimates of the state of the system and develop interfaces to make available this information to policy makers

The MOON fields of action

MOON can be subdivided into 6 fields of action that concentrate on the different environmental problems described above. They are:

1. Ocean hydrodynamics,
2. Water cycle and resources,
3. Biochemical fluxes and cycles,
4. Open ocean and coastal marine pollution,
5. Sedimentary fluxes and coastal erosion,
6. Operational Fisheries.

In the following, each field of action will be described separately and in details.

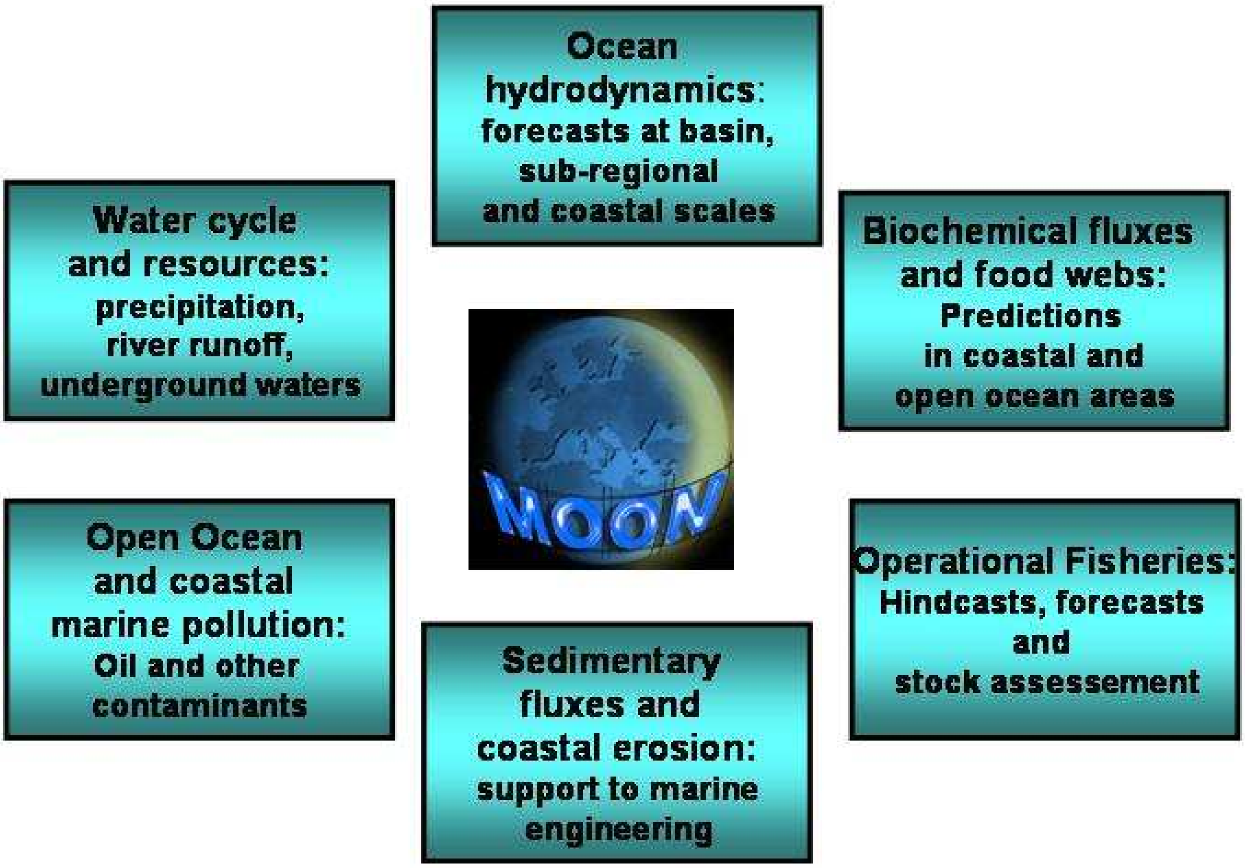

Fig. 8 MOON fields of action

Ocean hydrodynamics

State of the system

Ocean hydrodynamics is the basic action theme for sustainable development of the marine areas since it is the means of transporting contaminants, determine temperature and salinity conditions for the ecosystem to function and the sea surface temperature can determine atmospheric local conditions.

The basin scale, upper thermocline and air-sea interactions monitoring is operational but not sustained. The real time data acquisition system is also interlinked with coastal CTD monitoring stations in the Adriatic Sea. Other automated experimental profilers (open ocean gliders and new profilers from SOOP) are not operational yet.

At present, the real time data information system is composed of a network of centres that releases observations and model data in real time: the delayed mode data is still operated on a basic research mode without consideration for the needs of operational oceanography (shorter term climatologies, quality control procedures, etc.).

The currents are modelled and predicted at 12 km resolution for the basin scales and the forecast activities are carried out at the short time scales, i.e., ten days (Pinardi et al., 2003). The regional sub-systems downscale the basin nowcast/forecast outputs to 1-3 km resolution and they provide short term forecasts, from 3 to 7 days, depending on external forcing considerations (Oddo et al., 2004). The atmospheric forcing is used in an asynchronous way and air-sea interaction fluxes corrections have been developed.

Data assimilation is used at the basin scale but not yet at the regional scale: the scheme used is Optimal Interpolation with a time varying error covariance matrix. The assimilated data in real time are: Sea Level Anomaly-SLA from altimeters, Sea Surface Temperature-SST from radiometric satellite sensors, temperature and salinity profiles from SOOP XBT and ARGO floats.

During the past three years, the forecast has been assessed. The results indicate that the basin scale forecast is better than persistence already after the second day and root mean square error for temperature ranges between 0.5 ^{o}C at the surface and much less below. This analysis pointed out the need for careful evaluation of the effects of assimilation of satellite altimetry in the deep water mass structure together with the improvements in the knowledge of the mean circulation.

State of development of MOON blocks

OCEAN HYDRODYNAMICS	TIME SCALE	SYSTEM COMPONENTS	PRESENT STATE	MOON PRIMARY GOAL
OBSERVING SYSTEM	WEEKLY	Satellite SLA and SST, SOOP-XBT, M3A network MedARGO, Adriatic coastal CTD networks	OPERATIONAL	CONSOLIDATION
	SEASONAL	Long term archiving of M3A data, enlargement of MedATLAS data set with real time data	RESEARCH	DEVELOPMENT
NUMERICAL MODELLING	WEEKLY	Basin scale 6-10 km models, sub-regional 1.5-3-5 km for: North-Western Mediterranean, Sicily Strait, Adriatic Sea, Levantine and Aegean Sea, Cyprus shelf area	OPERATIONAL	CONSOLIDATION
	SEASONAL	Not existent		DEVELOPMENT
DATA ASSIMILATION	WEEKLY	Optimal Interpolation with assimilation of SLA, SST and profiles of Temperature and salinity at basin scales	OPERATIONAL	CONSOLIDATION
	SEASONAL	Not existent		DEVELOPMENT
INFORMATION SYSTEM	REAL TIME	Network of local centers for real time data collection and dissemination, connected to Coriolis	OPERATIONAL	DEVELOPMENT
	DELAYED MODE	MedATLAS	RESEARCH	DEVELOPMENT

Objectives of future work

- Consolidate the operational monitoring, modelling and data assimilation system at the basin and sub-regional scales for the weekly time scales
- Improve the forecasting capability for currents from the 6 km basin scale, to the 3 km sub-basin scale to 1 km shelf scale resolution at the weekly time scales (downscaling of forecast)
- Develop a Real Time regional marine data information system that can freely provide optimal field estimates and forecast results to end-users that will add value to these products for the coastal areas
- Develop the coupling between river basin forecasting and coastal areas hydrodynamic predictions
- Develop the seasonal forecast capabilities with coupled ocean-atmosphere models and explore the limits of predictability for ocean seasonal predictions
- Develop ensemble forecasting to reduce uncertainties due to internal nonlinear dynamics of the system (both coupled and uncoupled ocean-atmosphere systems)
- Develop probabilistic forecasts to ensure an efficient use of the short term forecast for policy issues
- Start the consistent analysis of long term trends in the basin hydrodynamics connecting it to a-biotic indices of change

for the past 50 years (Warming of intermediate and deep waters, changes in salinity due to water management, changes in general sub-basin circulation/exchanges)

Science questions

1. how long and how well can we forecast the Mediterranean basin and shelf scales and why;
2. what are the minimum observing system requirements to reduce the forecast uncertainties at the large and coastal scales;

R&D methods and activities

B1

- Improve the technology of the basin scale monitoring for hydrodynamics to increase cost/benefit ratio;
- Start real time coastal monitoring system, based upon present day activities and enlarge them to other coastal areas
- Activate the network for basin runoff monitoring and dissemination of data;
- Develop a generic scheme for the regional monitoring considering minimum requirements for the sampling scheme and platforms,
- Develop new satellite sensors real time high resolution analyses for SLA and SST

B2

- Further develop the downscaling techniques to allow the to consider shelf/coastal important processes such as tides and barometric pressure effects that may not be present in the coarser resolution models
- Develop the coupling between river basins fresh water flows and the marine coastal areas and try to ‘upscale’ the river influence into the coarser resolution models.
- Develop single and multi-model ensemble forecasts for short range predictions (10 days)
- Develop probabilistic forecasts to interface with policy makers
- Develop ocean-atmosphere coupling for seasonal forecasts
- Produce re-analysis data sets for the past ten years (1993-onward) or longer (assimilation of Medatlas) for assessment studies

B3

- Further develop the assimilation in coastal models

B4

- Link the basin scale observing system with the coastal scale observing systems through a regional information system that defines standards of data collection and dissemination (add the Med GLOSS stations, coastal networks, etc.)

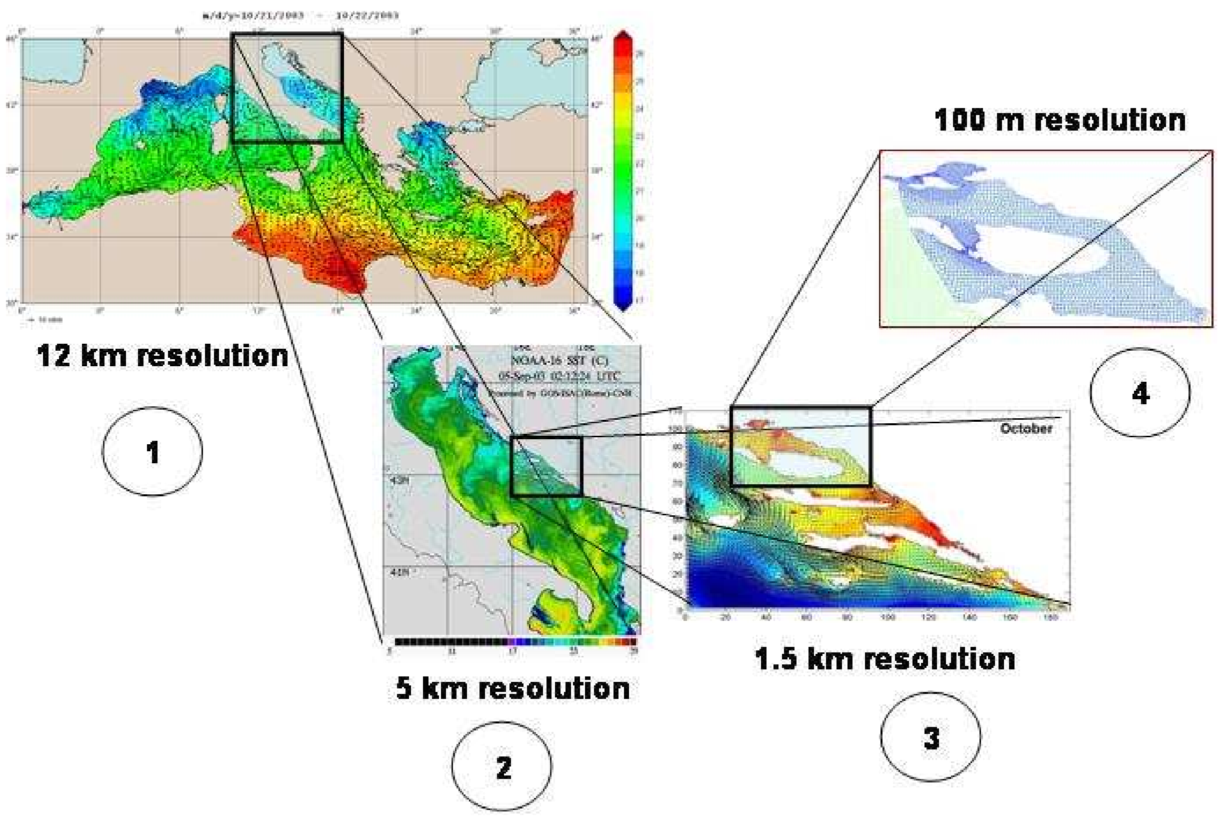

Fig. 9 The present day downscaling to coastal area prototype system developed in ADRICOSM

Water cycle and resources

State of the system

The water cycle, containing evaporation from land and sea, precipitation and land surface waters, is a key theme of sustainable development in the Mediterranean area since water resources are scarce and human impact on them is large.

The Mediterranean Sea is undergoing changes in water resources due both to anthropogenic forcings (fresh water usage by agriculture, industrial activities, radiative forcing by air pollution, etc.) and natural climate variability, such as the North Atlantic Oscillation-NAO, that produces inter-decadal changes in the precipitation regimes (Mariotti et al., 2002) and thus in the Mediterranean energy cycle.

The coastal areas of the basin are strongly forced by river runoff that is forced by precipitation which in turn depends on evaporation, air moisture and cloud physics. Little progress had been done up to now trying to model and forecast the complete water cycle, comprehensive of the surface and subsurface waters in the river basin catchments. The Mediterranean rivers runoff is shown in Fig.10: the north-south asymmetry is evident that is consistent with a north-south productivity gradient in satellite chlorophyll images. The present day atmospheric models completely resolve the whole area but they do not describe the river catchment and the runoff.

In the past twenty years, several global atmospheric general circulation models have continuously improved their ability to reproduce and forecast the atmospheric flow and precipitation regimes over the Mediterranean area, in particular increasing the resolution and describing the complicated topography of the mountain ranges around the sea. The required resolution ranges between 5 and 10 km and it is achieved by Limited Area Models-LAM for the whole Mediterranean Sea. The latter are working operationally and several ocean sub-regional models use this forcing for the marine forecasts. The limit of predictability for LAMs is 3-5 days (shorter than for the global atmospheric models that can forecast one week): after such time in fact the boundary conditions start to affect the interior of the domain, thus limiting the quality of the simulation or forecast. Precipitation forecast is still the lowest quality predicted state variable and improvements are required.

The seasonal time scale which we have chosen as relevant for our study, is not modelled at the moment. Regional coupled ocean-atmosphere models are being developed but the quality of the forecast is still to be assessed. Coupling with high resolution SST derived from the ocean forecasting models or satellite high resolution fields could improve the skill but most of the development still remains to be done.

It is well known by now that the Mediterranean heat budget is greatly affected by aerosols and dust over the Mediterranean Sea (ADIOS Project[6]). Atmospheric pollution has first of all the effect of changing the radiative properties of the atmosphere and it supplies the marine areas of nutrients (mainly nitrogen compounds) that can greatly affect the primary productivity of the open ocean areas as well as the coastal ones. Iron enrichment by Saharan dust deposition can affect the primary productivity in a complicated way, for example shifting the system toward higher phosphorous limitation and increase the importance of the bacterial food web (Krom, personal communication).

There are only few attempts to use chemical-transport models coupled to

[6] Web page at http://adios.univ-perp.fr/Accueil.html

regional dynamical models in order to simulate the effects of pollutants on clouds, precipitation and the hydrological cycle. The present state is to use air quality and dust transport models that have one-way feedback from the physical models to the transport-active chemical models but not vice versa. In US, LAMs are used to provide air quality predictions (Vaughan et al., 2004) but the experience in the Mediterranean Sea is still very limited. In addition, the deposition of chemical species in the marine areas is not modelled yet.

State of development of MOON blocks

WATER CYCLE AND RESOURCES	TIME SCALE	SYSTEM COMPONENTS	PRESENT STATE	MOON PRIMARY GOAL
OBSERVING SYSTEM	daily	Meteorological and dust measurements at buoy stations and on SOOP tracks	PRE-OPERATIONAL	DEVELOPMENT
	daily	river runoff monitoring	OPERATIONAL	CONSOLIDATION
	daily	Satellite data for atmospheric chemical contaminants and dust	RESEARCH	DEVELOPMENT
NUMERICAL MODELLING	daily	Global atmospheric analyses and forecasts, LAMs, one-way coupling of dust transport and air quality models	OPERATIONAL	DEVELOPMENT
	daily	Hydrological modeling coupled with atmospheric modelling	RESEARCH	
	seasonal	Coupled ocean-atmosphere regional models, one-way coupled physical and chemical models	RESEARCH	
DATA ASSIMILATION	daily	Variational assimilation schemes in global atmospheric models and LAMs	OPERATIONAL	DEVELOPMENT
	seasonal	Not existent	RESEARCH	
INFORMATION SYSTEM	daily	ftp dissemination of 6 hours and hourly data from global atmospheric models and LAMs	RESEARCH	DEVELOPMENT

Objectives of future work

- Monitor the atmospheric input of contaminants and dust from the atmosphere (satellite data and buoys);
- Improve the predictability of water cycle and its components such as precipitation over the Mediterranean area
- Improve the river basin modelling and runoff forecasting by coupling hydrological models for major catchments to atmospheric models
- Model and understand the air quality effects on the water cycle

Science questions

1. What are the ocean-atmosphere feedbacks that control the regional precipitation regimes?
2. What is the perturbation of the energy budget due to aerosols?
3. What are the levels of atmospheric contaminant inputs to the sea?
4. What is the predictability of river runoff in different catchment basins?

R&D methods and activities

B1

- Develop the atmospheric monitoring from SOOP;
- Extend the M3A network and add new stations to measure atmospheric input of contaminants and dust in the sea
- Develop satellite monitoring for dust, aerosols and precipitation over the Mediterranean area in real time

B2

- Develop coupled hydrology-atmosphere models with LAM capacity
- Develop 'upscaling' concepts and methods for atmospheric models (especially for hydrology)
- Develop regional coupled ocean-atmosphere models
- Develop regional atmospheric models two-way coupled to chemistry-transport models to model atmospheric pollutants effects on cloud physics and radiation
- Carry out medium to long term predictions with coupled models

B4

- Develop the dissemination network of atmospheric analyses and forecasts for the ocean forecasting community

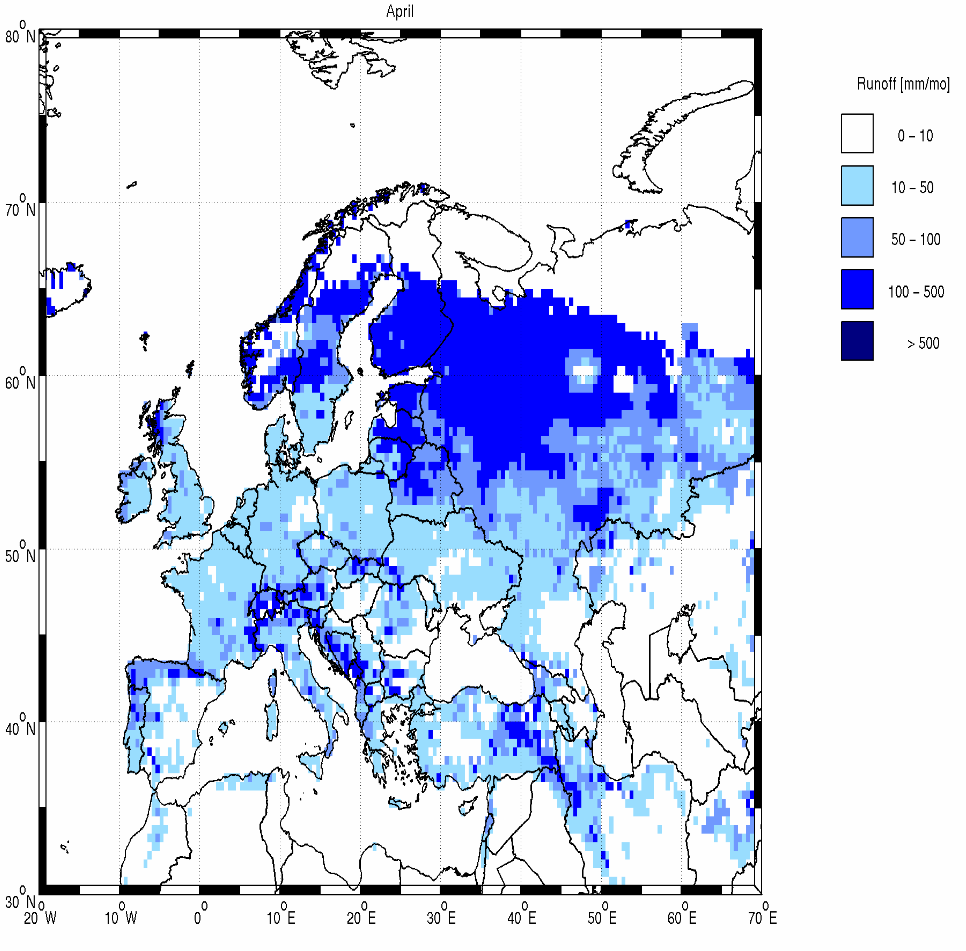

Fig.10 The basin runoff for April computed with hydrological models of the major catchment areas (units mm mo^{-1}). Figure is taken from http://www.grdc.sr.unh.edu

Biochemical fluxes and food webs

State of the system

Sustainable development of Mediterranean coastal areas is connected to questions of coastal eutrophication, harmful algal blooms, anoxic events, loss of habitats due to pollution and invasive species. Only the latter is out of the scope of the present investigations. Here the ecosystem models are considered to be mainly devoted to the primary producers, bacterial components with some closure hypothesis on the zooplankton and fish. This key area of development should be connected to the present day activities in ocean forecasting and it should rapidly be developed with automatic monitoring of ecosystem state variables and assimilation of data into the ecosystem models.

The basin scale ecosystem functioning has been classified and modelled in the past ten years by major international efforts that carried out observational and modelling programs to study the primary and bacterial production, the particulate and dissolved matter fluxes and the ecosystem functioning in the Mediterranean open ocean and coastal areas (MATER special volume[7], 2002, CYCLOPS[8] experiment). Multivourous food webs (herbivorous versus microbial, Fig. 11 develop both in open ocean and coastal areas and they could be connected to the seasonal cycle but also to the presence of land inputs. Many coastal areas are affected by nutrient upwelling from the open ocean as well as the local land inputs. In addition nutrient inputs by the atmosphere could be important, shifting the system toward a higher level of phosphorous limitation. Saharan dust iron fertilization might have a complicated effect on the food webs (ADIOS project[9]).

Monitoring at the basin scale is nowadays based upon ocean colour and buoy stations (M3A and others) collecting biochemical measurements. This part needs to be expanded, new optical instruments are needed for the monitoring at the buoy locations and we need to develop the SOOP based multidisciplinary measurements. In MFSTEP a new expandable instruments is being developed that considers florescence and temperature profiling in real time. The other instrument is a tethered sliding vehicle that could in principle measure the euphotic zone nutrients, oxygen and chlorophyll. The coastal ecosystems in the Regions Of Fresh Water Influence-ROFIs require monitoring of the nutrient loads as well as sediments.

One and three dimensional fully coupled physical and biogeochemical flux models have been and are being developed for the overall basin scale and various sub-regional systems (Adriatic Sea. Levantine-Aegean Sea). These models are based upon the functional group representation of the ecosystem complexity and they express the functional groups in terms of biomass. Data assimilation tools are being developed for ocean colour but there is a substantial need for in situ profiles of biochemical state variables in order to improve and assess the data assimilation capabilities. Models have shown skill to reproduce the major features of the ecosystem seasonal cycle (Triantafyllou et al, 2003, Allen et al., 2003) as well as non homogenous distribution of primary producers properties (Zavatarelli et al., 2000).

The important concept to be developed and tested in this phase is the 'process nesting' methodology where the open ocean

[7] Web reference: http://www.uib.no/jgofs/Publications/Special_Issues/JMS_33-34.pdf

[8] Web page http://www.earth.leeds.ac.uk/cyclops/

[9] Web page http://adios.univ-perp.fr/Accueil.html

ecosystem is downscaled to coastal areas in terms of resolution but it is upscaled in terms of description and/or number of processes considered. An example of this are the pelagic-benthic coupled processes that in the open ocean occur on much slower time scales than in the coastal systems: thus the ecosystem model could consider a different parameterization of the benthic-pelagic coupling in the slow open ocean with respect to the fast recycling time scale of the coastal environment.

State of development of MOON blocks

BIOCHEMICAL FLUXES AND FOOD WEBS	TIME SCALE	SYSTEM COMPONENTS	PRESENT STATE	MOON PRIMARY GOAL
OBSERVING SYSTEM	daily	Ocean colour from satellite sensors, M3A biochemical measurements	OPERATIONAL	DEVELOPMENT
	daily	New multidisciplinary sensors from SOOP network, new optical measurements from M3A	RESEARCH	DEVELOPMENT
NUMERICAL MODELLING	daily	One dimensional biochemical flux models, three dimensional coupled physical and biogeochemical flux models in subregions	RESEARCH	DEVELOPMENT
	seasonal	three dimensional coupled physical and biogeochemical flux models in subregions		
DATA ASSIMILATION	daily	M3A data assimilated into 1-D biochemical flux models	RESEARCH	DEVELOPMENT
	seasonal	Ocean colour assimilated into ecosystem models		
INFORMATION SYSTEM	Real time	M3A data distribution	RESEARCH	DEVELOPMENT

Objectives of future work

- Assessment of the current hypothesis on the marine ecosystem functioning to be able to model them at the basin and coastal scales
- Further develop the real time monitoring at the basin scale based on M3A, SOOP, ARGO and gliders for chlorophyll, nutrients, oxygen and fluxes of particulate material
- Design and implement a ‘Mediterranean biochemical flux large scale experiment’ (MOON-BIOFLUX)
- Further develop the ecosystem three dimensional modelling from the basin scales to the coastal areas applying the concept of ‘process nesting’
- Model and predict HABs in coastal areas
- Model and predict anoxic events in the coastal areas and deeper water bodies
- Monitor Coccolithophorid populations in the open ocean
- Model the dust inputs to the marine ecosystem

Science questions

1. demonstrate/assess the forecasting potential of current hypotheses on marine ecosystem functioning

2. understand regulatory mechanisms of N/P ratio (river versus atmospheric inputs, new and re-generated production) in the open ocean and coastal areas
3. how can we describe the systematic 'process nesting' methodology in the predictive models?

R&D methods and activities

B1

- Add biochemical measurements for chlorophyll nutrients and oxygen to the existing Real Time basin monitoring components (M3A,SOOP, ARGO, gliders)
- Develop satellite colour analysis for Chlorophyll, yellow substances and suspended matter for new sensors
- Develop the large scale nutrient and plankton monitoring system along trans-Mediterranean routes as part of a 'Mediterranean biochemical flux large scale experiment'
- Develop the biochemical monitoring system of the Gibraltar Strait and the Sicily Strait for long time series

B2

- Develop short term forecasting up to primary producers from the basin scales to the shelf areas
- Develop the process nesting methodology for the downscaling to coastal areas
- Develop modelling of HABS in the framework of the three dimensional models

B3

- Develop the assimilation of ocean colour data and Real Time biochemical measurements (nutrient data, chlorophyll, oxygen and other biochemical field state variables)

B4

- Develop the data information system consisting of the quality control and data collection protocols for biochemical measurements at the basin scales

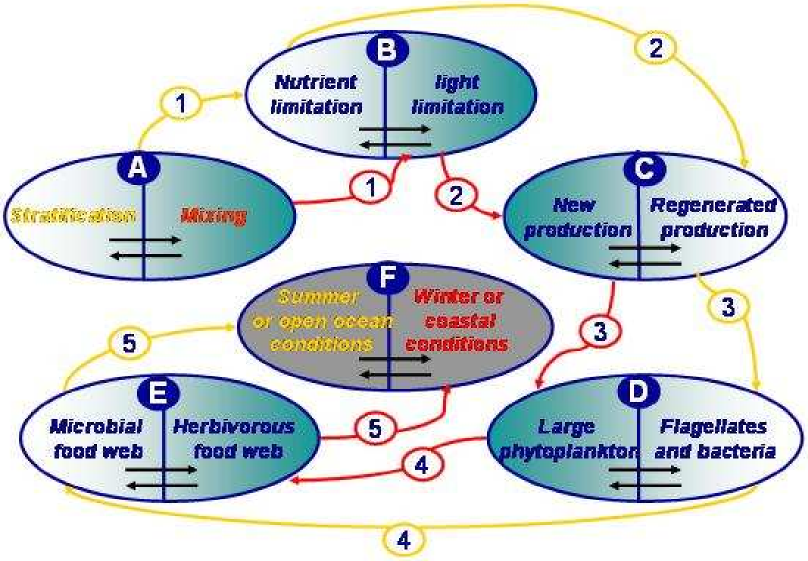

Fig. 11 The hypothesis on the ecosystem functioning between summer/winter and open ocean/coastal conditions (modified after Legendre and Rassoulzadegan, 1995)

Open Ocean and coastal marine pollution

This action will be described by differentiating between the open ocean and coastal ocean marine pollution themes.

OPEN OCEAN

State of the system

The open ocean pollution in the Mediterranean Sea is mainly associated to the illegal and continuous oil spill releases from commercial shipping (Fig. 12). In addition, sustainable development calls for setting up a system capable of dealing with accidental oil releases. The large accidental oil release of the Haven disaster in 1991 produced the dispersal of 140000 tons of oil in few days.

In the past years, several oil spill detection systems from satellites were developed and systems constructed to make the detection of the oil spill available in the shortest time from the collection by the satellite to the user community (RAMSES project[10]). Recent developments concentrate on the combined usage of multisensors Earth Observation data from new satellite platforms (ENVISAT/ASAR, ENVISAT/MERIS, RADARSAT, MODIS) to optimise the oil spill detection algorithms (CLEOPATRA[11]).

However, the problem of satellite repeat time in the single area of the accident (several days in the best of cases) hampers the capability of such system to be really helpful for monitoring. The launch of COSMOSkyMed (COnstellation of small Satellites for Mediterranean basin Observation) will help to have a daily coverage of the entire Mediterranean Sea at unprecedented resolution.

The integration of oil spill detection from satellite sensors with ocean forecasting products and meteorological forcing has not been fully successful yet because of the scarcity of oil spill observations. In addition, the coupling with oil spill advection/diffusion and transformation models with ocean current forecasts is complicated by the resolution required to account for surface processes that can affect the oil dispersal and that are not contained in the current hydrodynamic forecasting models. Thus the coupling algorithms between hydrodynamic complex conditions as well as waves and other meteorological variables and oil spill models still require a research and development activity.

[10] Web page at http://ramses.esrin.esa.it/

[11] Web page at http://www.eurimage.com/cleopatra

State of development of MOON blocks

OPEN OCEAN POLLUTION	TIME SCALE	SYSTEM COMPONENTS	PRESENT STATE	MOON PRIMARY GOAL
OBSERVING SYSTEM	Weekly to monthly	Satellite SAR data	OPERATIONAL	CONSOLIDATION
NUMERICAL MODELLING	daily	Coupled oil spill models to ocean forecasting systems	RESEARCH	CONSOLIDATION
INFORMATION SYSTEM	Real time	SAR data (images) release in real time and geophysical parameters	Pre-OPERATIONAL	CONSOLIDATION

Objectives of future work

- Set up a monitoring and emergency response system for oil spills in the Mediterranean Sea coupled with the hydrodynamic ocean forecasts

Science questions

1. Can we detect oil spills from satellites with enough accuracy to be used for modelling purposes?
2. How can we efficiently couple oil spill models to ocean current forecasting products?

R&D methods and activities

B1

- Use new satellite generations as CosmoSkyMed to better detect illegal oil spills
- Combine radiometric measurements (optical sensors) with SAR observations to optimise detection of oils spills

B2

- Inter-compare different oil spill models and evaluate skill
- Develop a rapid response management system to oil spill emergencies requiring multiply connected modelling domains in critical areas.
- Further develop the relocatable modelling systems for REA- Rapid Environment Assessment and emergencies management

B3

- Develop inverse modelling to provide initial conditions for oil spill models

B4

- Develop a Decision Support System for oil spill detection, prevention and management of emergencies connected to authorities

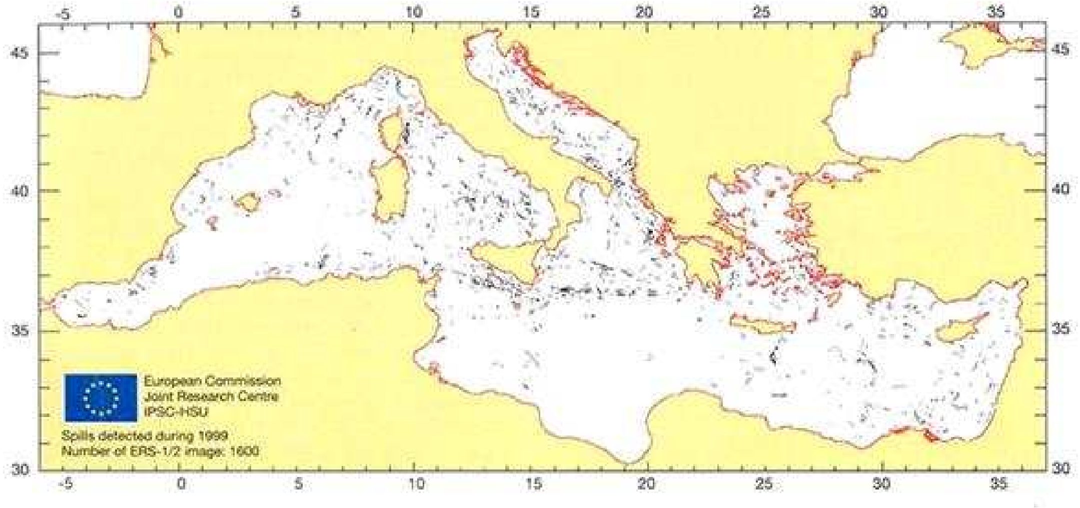

Fig. 12 Detected oil spills in the Mediterranean Sea from satellite monitoring in 1999

COASTAL AREAS

State of the system

The marine pollution deriving from contaminants entering the marine environment through fresh water discharges and sewage waters from coastal cities is debated in the EU Water Framework directive of October 2000. The aim is to prevent the deterioration of the aquatic ecosystems by progressively reducing the discharges of hazardous substances. Due to its semi-enclosed nature and the consequent slow renewal time, the Mediterranean Sea has little capacity to recycle or disperse the contaminants that are introduced and bioaccumulation could occur at a high rate. Thus the monitoring and modelling of the contaminant discharges in the coastal areas is at the basis of Integrated Coastal Zone Management (ICZM) issues for the Mediterranean.

Major oil loading and unloading ports already give an idea of the contaminant sources but other contamination comes from the medium and large size cities present along the coastlines. The European Water Framework Directive establishes a list of 32 substances that should be monitored and that consider metals and organic-metals, volatile substances, PAH, pesticides, POPs, etc. These substances will be more abundant in ROFI areas and at the sewage outflows of the large cities along the coasts. It is then mandatory to concentrate on these areas.

The development of contaminant monitoring protocols and measurements are out of the scope of this program since we expect that other projects/programs will develop them: the measurement techniques and data collection protocols are mainly connected to instrument development for better water quality monitoring and the implementation of new methodologies for new contaminants. In the following, the monitoring of the contaminant abundance and species will be called 'water quality monitoring' as a whole and it will not be further specified.

MOON tries to concentrate on the predictive modelling of the dispersal of any of such substances given that we can monitor them at their entrance in fresh and marine waters. This is already a challenge due to the complexity of the processes affecting the hydrodynamics at these scales and the interactions with the point source of discharges (sewage and waste water outflows). MOON focuses also on the monitoring of the physical state variables that could calibrate/validate the hydrodynamic models at this scale. ICZM needs to be based on a sound modelling framework that will consider horizontal scales of few tens of meters, vertical stratification at river months and the dispersal of the contaminants in the marine water body that is complicated by nonlinearities creating vortices and local recirculation. If such modelling framework will be established, management scenarios could be devised in order to promote the safest discharge locations and policy decisions could be taken on the basis of a sound scientific framework.

In ADRICOSM we realised for the first time a four folding nesting of models (Fig. 9) with simulation of the dispersal of contaminants from a sewage outflow. In this project we also realised a coastal marine and river basin observing system that could in principle be used for calibration/validation of the models. Water quality measurements were done in combination with hydrodynamic measurements. MOON should try to expand/further develop and test these activities to other key areas around the Mediterranean coastlines for different contaminants inputs and hydrodynamic conditions.

On a purely research side we should try to develop the ecosystem modelling at the ICZM scale. The ecosystem modelling should be coupled with water quality modelling and the effects of contamination on different components of the trophic food chain should be studied and simulated.

State of development of MOON blocks

COASTAL POLLUTION	TIME SCALE	SYSTEM COMPONENTS	PRESENT STATE	MOON PRIMARY GOAL
OBSERVING SYSTEM	daily	Coastal networks, river runoff, traditional contaminant water quality measurements	OPERATIONAL	DEVELOPMENT
NUMERICAL MODELLING	daily	Coupled river basin - coastal models with advection/diffusion of contaminants	RESEARCH	DEVELOPMENT
DATA ASSIMILATION		Not existent yet	RESEARCH	DEVELOPMENT
INFORMATION SYSTEM	Real time	Not existent yet	RESEARCH	DEVELOPMENT

Objectives of future work

- Comply with indications given by the MEDICIS[12] project for contaminants monitoring in the coastal areas
- Develop ICZM modelling prototypes for several test sites:
  - Catalan shelf (Ebro),
  - Liguro Provençal shelf (Rhône) ,
  - Adriatic shelf areas (Po and/or other major rivers),
  - North Aegean Sea shelves comprehensive of Dardanelles,
  - Nile littoral cell (Nile river and Suez Canal),
  - Latakia basin with Gulf of Iskenderun (NE Med)
- Intercompare the different implementations/solutions
- Develop a DSS to distribute information to policy makers (UNEP/MAP and national agencies)

[12] MEDICIS is a proposal submitted to the VI Framework program for the ‘Assessment of chemical contamination in the Western Mediterranean’. Information should be asked to Dr. Axel Romana, IFREMER, Brest.

Science questions

1. Can we forecast the coupled river basin and coastal system and for how long?
2. Can we predict the fate and dispersal of ‘passive’ contaminants in the coupled river basin-coastal system?

R&D methods and activities

B1

- Develop monitoring of different contaminant inputs coupled to hydrodynamic monitoring for the very near coastal and river basin areas
- Consolidate the coupled monitoring of water quality, water level and coastal hydrodynamics in a prototype system

B2

- Develop coupled river basin and coastal models for land derived contaminant fate and dispersal predictions
- Develop the connection between the basin/shelf scale forecasting activities and the ICZM modelling

B4

- Develop the DSS containing scenario simulations of discharges for policy makers

Sediment fluxes and coastal erosion

State of the system

Sediment accumulation and erosion in Mediterranean coastal areas is of particular concern since tourism is a large part of the nation's GNPs. The key problem here is that sediment supply from rivers or natural return from offshore beds (500 meters to several kilometres outward from the beaches) are greatly affected by agricultural practices and benthic flora and fauna that in turn is affected by a change in sediment supply. The scale of these processes is few tens of meters in horizontal and it involves the coupling between the different components of the transport field, the wave and wind induced currents and the tidal motion. The latter modulates the boundary between the fresh and salt water at the river mouth where nepheloid layers can form and greatly affect the sediment transport out of the river mouths. Sediment composition and concentration greatly affects the optical properties of the coastal waters and the knowledge of the general characteristics of the sediment distribution and abundance is necessary for coastal ecosystem models and satellite optical images interpretation.

In order to model the sediment deposition and re-suspension processes, several process oriented studies have been carried out in different Mediterranean coastal areas (Wang and Pinardi, 2002; Kourafalou et al., 2004). Sediment deposition/resuspension models can deal now with different sediment composition, different sediment bed structures, they can consider sediment loads and the combined effects of waves, wind currents and tides in the re-suspension/deposition process. The transport of these sediments can go as far as several hundred kilometres from the river mouth in extended shelf areas or can remain constrained near the river mouth mainly depending on the settling velocity of particles which is another important parameters of the sediment re-suspension/deposition model.

Engineering constructions along the coasts and near the beaches will require such models to be run for different scenarios of sediment deposition/re-suspension regimes. The novel approach here is that the local models will be nested within the operational oceanography current estimates at the open ocean boundary of the area of interest and they will be able to downscale to 10-100 meters in the beach areas, keeping however into consideration the large scale flow field.

Last but not least, model development should consider cohesive sediments and their capability to aggregate contaminants or organic compounds. The models should be developed to reproduce also the subsequent release of these constituents in dissolved form by the re-suspension/deposition cycles. The effects of flocculation and/or cohesive sediments on the ecosystem functioning of the very near coastal areas has never being considered properly in a numerical simulation framework. The cohesive sediments can be a source of dissolved nutrients far more superior than the present day consideration of the slow diffusion of recycled nutrients from the pore waters. Thus the sediment models could be coupled with the ecosystem modelling done at the appropriate scale and assess the cohesive sediment effects on the marine ecosystem.

State of development of MOON blocks

SEDIMENT FLUXES AND COASTAL EROSION	TIME SCALE	SYSTEM COMPONENTS	PRESENT STATE	MOON PRIMARY GOAL
OBSERVING SYSTEM	Daily	Sediment composition and concentration, river flow rates	RESEARCH	DEVELOPMENT
NUMERICAL MODELLING	Daily	Coupled wave-tide and current sediment resuspension/deposition models	RESEARCH	DEVELOPMENT
DATA ASSIMILATION		Not existent	RESEARCH	DEVELOPMENT
INFORMATION SYSTEM		Not existent	RESEARCH	DEVELOPMENT

Objectives of the future work

- Develop sediment transport models in the nested framework to evaluate causes of coastal erosion in different areas
- Couple sediment re-suspension/deposition models with ecosystem models
- Couple the sediment re-suspension/deposition models with ICZM modelling for pollution purposes

Scientific questions

1. What is the fate of sediments in different coastal areas of the Mediterranean Sea for the daily to seasonal time scales
2. What is the effect of sediment transport on contaminants fate and dispersal from the source to the coastal waters
3. What is the effect of cohesive sediments on the ecosystem functioning at the coastal scale

R&D methods and activities

B1

- Monitor the sediment quality and concentration at river mouths and river flow rates to estimate inputs into the sediment transport models

B2

- Implement very high resolution fully coupled wave, wind circulation, tides models with sediment re-suspension/deposition models
- Develop the modelling system at pilot locations, ideally river affected littoral zone with human pressure
- Develop the process description of cohesive sediments into the ecosystem models and analyse effects on primary productivity of these regions
- Develop the process description of the contaminant binding into sediments and analyse fate and dispersal of such contaminants considering the sediment re-suspension/deposition process

Operational fisheries

State of the system

During MFSTEP, a new observing system for small pelagic fish has been developed, the so-called Fishery Observing System-FOS (http://www.ucy.ac.cy/~mfstep/english/ADRIATIC(User7).html) This system uses the commercial fishing fleet from several ports to monitor in real time the fish catch, abundance and size for selected commercial species (anchovies and sardines). The system is being developed in the Adriatic Sea and four fishing vessels have been equipped with this innovative electronic log book system that gives a three dimensional description of fish catch at unprecedented resolution. This resolution will allow to couple the physical environmental state variables to the fish catch obtaining statistically relevant correlations between fish abundance and physical state variable structure. The system needs to be expanded to more fishing fleets and other Mediterranean areas in order to test the generality of the observing and modelling system.

State of development of Blocks

OPERATIONAL FISHERIES	TIME SCALES	SYSTEM COMPONENTS	PRESENT STATE	MOON PRIMARY GOAL
OBSERVING SYSTEM	daily	Fishery Observing System in the Adriatic Sea	RESEARCH	DEVELOPMENT
NUMERICAL MODELLING	daily	Statistical combination of forecast products and FOS data	RESEARCH	DEVELOPMENT
INFORMATION SYSTEM	Real Time	FOS data base with numerical model output on a GIS based system	RESEARCH	DEVELOPMENT

Objectives of future work

- Expand the Fishery Observing System-FOS to relevant shelf areas where small pelagic fish is an important resource
- Model the correlation between environmental variables and FOS data
- Use the FOS data in stock assessment models

Science questions

1. can the FOS data be coupled with other biological information (age and size correlation, etc.) to be used in population analysis models;
2. can we build credible stock assessment models from the combined use of hydrodynamics, biochemistry and fishery data?
3. Which data on recruitment do we need to arrive to fish stocks forecasts?

R&D methods and activities

1. Extend the FOS to many ports/areas in the Mediterranean Sea and other commercial species in order to improve the generality of the coupling between FOS data and environmental predictions
2. Develop the information system for rapid dissemination of data and statistical analysis of the physical and fishery data taken from the FOS

3. BENEFITS OF MOON

MOON tries to envisage the strategy to connect operational oceanography products at different scales to applications that will give reliable, scientifically controlled information to policy makers to decide the prevention/adaptation/mitigation actions against the deterioration of the Mediterranean Sea environmental problems.

Most of the environmental problems in the Mediterranean Sea open ocean and coastal areas are connected to fresh water resource management issues and MOON tries to develop the science necessary to develop the link between fresh waters and marine waters. In doing so, it capitalises on the existing operational oceanography system being set up and run in the Mediterranean Sea. It is timely now to start the process of interfacing operational oceanography with applications for the partial solution of the environmental problems on the short to medium time scales (days to months).

The coastal zone is a unique environment where terrestrial, oceanic, atmospheric and human inputs of energy and matter all converge. It also supports the greatest concentration of living resources and people in the planet. As the number of people living, working and playing in coastal ecosystems increases, the demands on these systems to provide commerce, recreation, and resources and receive, process and dilute the effluents of human society will increase. The resulting conflicts between commerce, recreation, development, utilisation of natural resources, and conservation will become increasingly contentious, politically charged and expensive.

Resolving these conflicts in an informed, timely and cost-effective fashion requires a significant increase in our ability to monitor, nowcast (i.e. produce an optimal estimate of the state of the system at one instant) and forecast the marine environment. MOON advances the capability of interfacing the operational forecasting of ocean currents with modules that will make possible to better find the solution to conflicting issues, by supplying the scientifically correct information to policy makers.

Last but not least, it will support the scientific understanding of climate variability and change by increasing the availability of long time series of quality controlled data. The project only gives a basis for climate monitoring and modelling without pretending to be unique or exhaustive on this issue. However, it is believed that a climate observing system could benefit from the long-term operations of relevant monitoring activities in the field of ocean forecasting.

MOON is also preparing the Mediterranean component of the monitoring and forecasting system in support of the European Union GMES[13] action that is now undergoing the second phase of implementation. During the first phase the Mediterranean operational oceanography system was evaluated and the conclusions and recommendations from this phase have been considered into the shaping of MOON.

MOON is also being developed with an overall participatory approach and with an open consultation of all interested parties in the Mediterranean region.

[13] GMES-Global Monitoring of Environment and Security. Web pages:

4. ECONOMIC AND SOCIAL IMPACTS OF MOON

The Global Ocean Observing System (GOOS) is an international programme (coordinated by UNESCO-IOC) preparing the permanent global framework of ocean observations, modelling and analysis needed to support ocean services wherever they are needed around the world.

A regional approach is an essential component of GOOS and in fact GOOS is being re-organised in Regional Alliances that allow to build the intergovernmental support for the sustained monitoring and forecasting of different regions.

MOON capitalizes on the past advancements that established operational oceanography in the Mediterranean Sea and it advances toward Global Marine Assessment-GMA objectives that were requested by the Johannesburg Conference in 2002:

1) <u>Environment and Mediterranean policy:</u>

The development of an operational forecasting system for regional and shelf areas of the Mediterranean Sea with the consideration of environmental aspects such as pollution, ecosystem health and marine resource management will contribute to the implementation of European policies concerning the protection of the marine environment. MOON will provide a scientifically based, real time and ecosystem based approach to regional policy makers for the implementation of the EU Water Framework directive and the regulations foreseen by the Mediterranean Action Plan-MAP of UNEP.

2) <u>Fisheries Policies</u>:

MOON will consistently contribute to a better management and sustainable exploitation of marine bio-resources. This important marine resource is threatened by climate change and exploitation, a combination which has had already disastrous effects on the Atlantic ecosystem.

3) <u>Integrated Coastal Zone Management Policies (ICZM):</u>

The broad interdisciplinary aspect of MOON and strong focus on coastal areas will provide useful scientific elements for the development of ICZM policies, an effort that is currently undertaken by the European Parliament and MAP.

4) <u>Small and Medium Enterprises (SME's) policy</u>:

The implementation of operational ocean forecasting requires improved systems for robust monitoring, and the provision of new marine services. Presently Europe leads in the implementation of GOOS, this favours European small/medium firms with the opening of new markets and the strengthening of their global competitiveness

5. STRATEGIC PLANNING

The strategic development of MOON activities can be subdivided in two phases:

PHASE 1 (2004-2006) CONSOLIDATION AND EXPANSION

In 2005 a MoU should be signed with all the Institutes participating to MOON to establish the agreements for the observing and modelling system consolidation.

In the meantime, three major pilot projects could be considered and submitted for funding

P1- MOON Consolidation Pilot Project (2005-2008)

This project should:

- Define the 'MOON' basic monitoring network (VOS, ARGO, M3A, SST, SSH and COLOUR)
- Carry out technological improvements to the basic network
- Development of new coastal networks coupled with large scale networks
- Animate the river runoff data dissemination system for the basin
- Development of the Information system for observations and models
- Long training courses on the usage of model forecasts, observing system and data management in operational oceanography
- Draft the regional MoU to sustain the monitoring network in connection with MedGOOS and Regional Alliances

P2- Integrated Coastal Zone Management test sites project

This project should:

- Generally a project to implement the EU Water Framework directive
- The project should show the unique value of coupled shelf scale forecasting and ICZM modelling
- The project test sites:
- Catalan shelf (Ebro),
- Liguro Provençal shelf (Rhône) ,
- Adriatic shelf areas (Po and/or other major rivers),
- North Aegean Sea shelves comprehensive of Dardanelles,
- Nile littoral cell (Nile river and Suez Canal),
- Latakia basin with Gulf of Iskenderun (NE Med)
- Monitoring of contaminant levels in coastal areas
- The project should include aspects of integrated river basin and coastal zone, marine pollution, ocean hydrodynamics, coastal erosion and water resources management;
- Design and production of a DSS;

P3- Mediterranean ocean-atmosphere coupled models for assessment of water cycle changes and water resources

This project should:

- Design and implement a regional coupled ocean-atmosphere model with chemistry representation for air quality, aerosols and dust;

- Introduce coupling between atmospheric and hydrological modelling at the level of major river basin catchment areas

In this period two workshops should be held to design the P4 and P5 projects foreseen in the second phase of MOON

Second Phase (2006-2009): Operational marine ecosystem assessment

In this phase, two projects should be launched, that are:

P4- Mediterranean extension of Fishery Observing System toward fish stock assessment

P5- Mediterranean biochemical flux and food webs Experiment

8.The MOON Steering Group

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