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ENVIRONMENTAL MONITORING/  
REMOTE SENSING/POLLUTION CONTROL



# The Cyprus Coastal Ocean Forecasting and Observing System

*CYCOFOS is a Key Component in the Growing Network of European Ocean Observing Systems*

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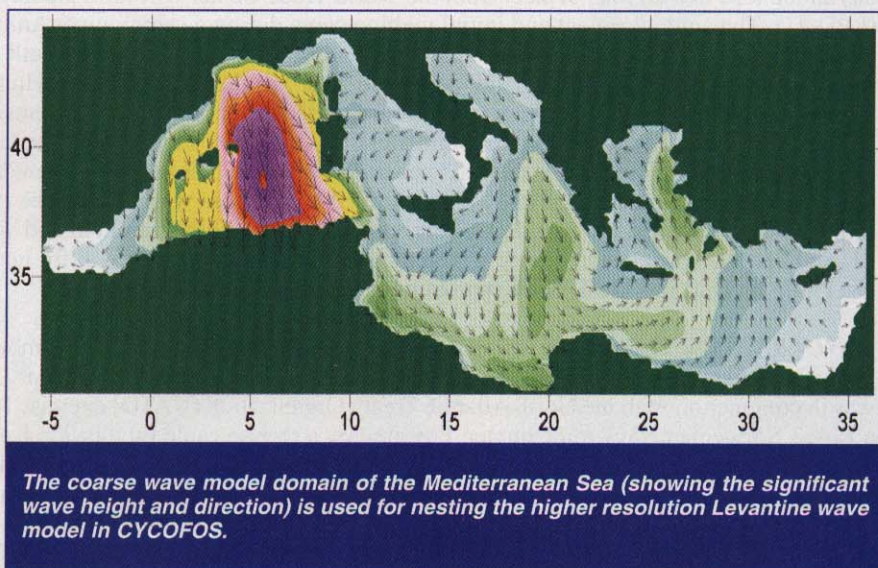
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The countries surrounding the Mediterranean Sea have joined together in several multi-national initiatives to conduct long-term, integrated, operational oceanographic observations and modelling of this important region. A complete operational oceanographic forecasting and observing system has been developed in Cyprus, and has been operational since early 2002. The system is called the Cyprus Coastal Ocean Forecasting and Observing System (CYCOFOS) and is a component of the Global Ocean Observing System (GOOS), and its European (EuroGOOS) and Mediterranean (MedGOOS) modules. CYCOFOS is the result of several years of research activities all carried out within the framework of European Union-funded projects. At present, CYCOFOS consists of several opera-



The coarse wave model domain of the Mediterranean Sea (showing the significant wave height and direction) is used for nesting the higher resolution Levantine wave model in CYCOFOS.

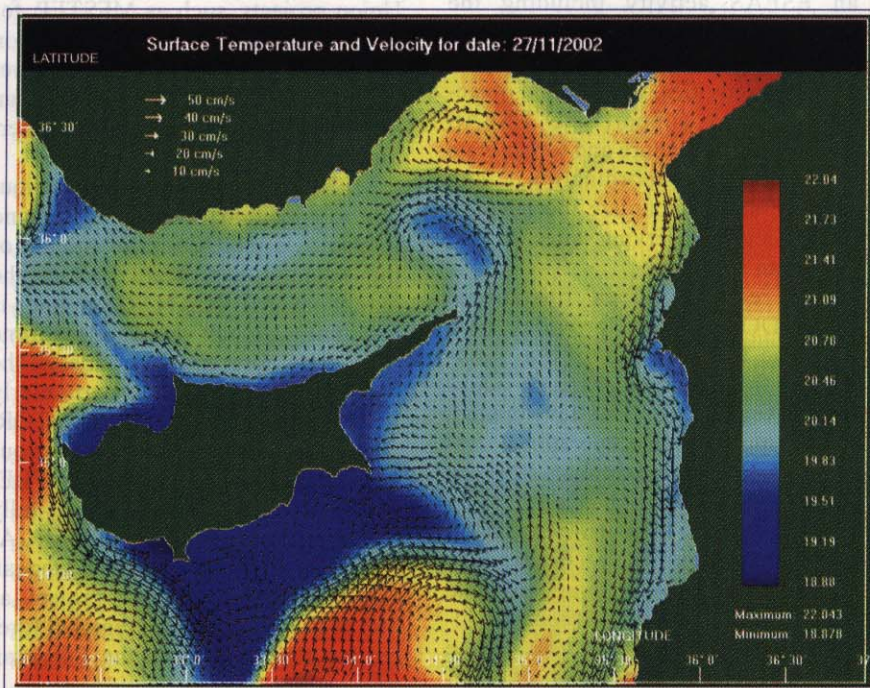
tional modules, among them flow and offshore wave forecasts, satellite remote sensing, coastal monitoring stations and end-user-derived applications. All of these operational modules provide regular near real-time information, both to local and sub-regional end users throughout the Eastern Mediterranean Levantine Basin.

## GOOS, EuroGOOS and MedGOOS

Sustainable development of the coastal and offshore regions of the Mediterranean and the region's marine economic activities depend crucially on the scientific knowledge of the marine system variability, particularly on the capability to monitor and forecast at the relevant space and time scales in near real-time. These challenges have been addressed in several international fora. In Agenda 21 of the United Nations Conference on Environment and Development (1992), GOOS was established. Responsibility

for the design, promotion and implementation of GOOS worldwide was assigned to the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational Scientific and Cultural Organization (UNESCO). Marine monitoring and forecasting systems on global, regional (e.g., European) and local (e.g., Cyprus) scales will play key roles in balancing the relationship between development and the environment. The development of an operational oceanographic monitoring and forecasting system will certainly support better management of the marine environment, reducing environmental problems that arise from the various economic activities in the marine sector. The research and development of these systems will enable continued sustainable improvement, potentially helping to mitigate the effects of industrial accidents, thus further benefiting the economy.





(Above) Typical output of the CYCOFOS high-resolution flow model available in near real-time.

(Right) CYCOFOS Observatory based on the MCS Ocean Net System.

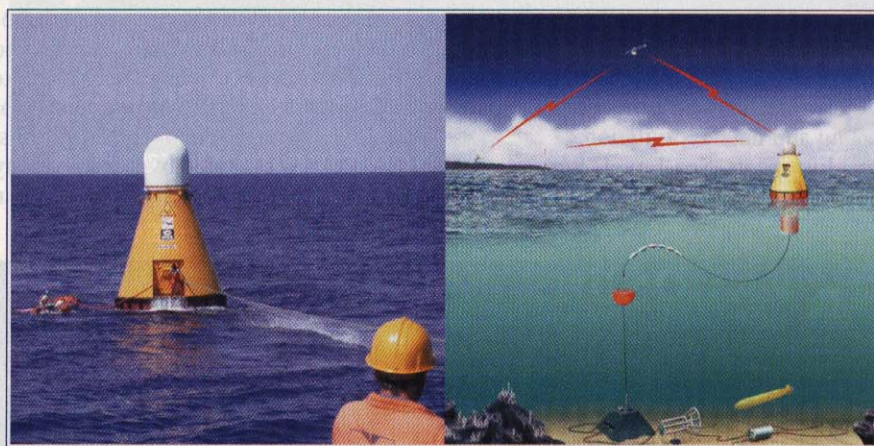
GOOS consists of the following main operational modules:

- a network of remote sensing (both *in-situ* and satellite) oceanographic systems
- an integrated set of oceanographic models to provide coastal and ocean forecasts

- a data network that connects the monitoring systems and the models, and provides updated information to oceanographic databases and to end users.

Following the GOOS initiation, the EuroGOOS and MedGOOS initiatives were established in 1994 and 1999, respectively. EuroGOOS supports the objectives of GOOS at the European level. In EuroGOOS there is a strong emphasis on the development and application of both new and existing technology, which will allow a more efficient use of forecasting, observing and other related tools, with minimal cost and human resources.

Similarly, the objectives of MedGOOS are to link existing operational systems in the Mediterranean and to extend the area of operational oceanographic systems to the entire region. The development of a regional operational forecasting and observing system for the Mediterranean will benefit



local users in all aspects of the marine sector. In MedGOOS there are 16 participating institutions, representing thirteen countries: Bosnia and Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Malta, Morocco, Slovenia, Spain and Turkey.

### A Multi-National System

The development and promotion of the operational coastal/ocean monitoring and forecasting activities in the Mediterranean and European seas is carried out in the framework of several European Union-funded research projects.

The Mediterranean Forecasting System Pilot Project (MFSP) is a EuroGOOS activity aiming to model and quantify the potential predictability of ecosystem fluctuations at the level of primary producers from the overall basin scale to the coastal/shelf areas, through the development and

implementation of an operational monitoring and forecasting system. The modules of this project include *in-situ* monitoring from volunteer observing ships and multi-variable buoy stations, remote sensing, data assimilation tools, a basin general-circulation model, several intermediate and shelf/coastal models, as well as ecosystem models.

The Mediterranean Network to Assess and Upgrade Monitoring and Forecasts Activities in the Region (MAMA) is a MedGOOS-concerted action to promote the coastal monitoring and forecasting in all the Mediterranean countries, following MFSP and the Mediterranean Forecasting System Towards Environmental Predictions (MFSTEP) achievements. The general scope of MAMA includes: aiming to establish a regional network to identify the gaps in existing capacity for systematic

monitoring and forecasting activities, upgrading the competencies of personnel in less developed regions at technical and scientific levels, preparatory design of the initial observing and forecasting network covering the entire Mediterranean basin, and dissemination of knowledge on the importance of oceanographic monitoring and forecasting to policy makers to promote national and international action for the Mediterranean.

(MFSTEP) is a EuroGOOS activity aiming, among other objectives, at the further development of an operational forecasting and observing system in the Mediterranean following the MFSP. Additionally, MFSTEP is intended to demonstrate to end users the usefulness and benefits of the operational oceanographic forecasting products. MFSTEP benefits from its 48 participating institutions, represent-



ing countries such as Belgium, Cyprus, the Czech Republic, France, Germany, Greece, Israel, Italy, Malta, the Netherlands, Slovenia, Spain, Turkey, and Ukraine. Since 1999, the Mediterranean Forecasting System (including both MFSP and MFSTEP) has been providing weekly forecasts of currents, sea temperature, salinity and sea level throughout the Mediterranean Sea. To produce these near real-time forecasts, a tremendous amount of data is collected and assimilated from *in-situ* observations, buoys, XBTs and remote sensing.

Marine Environment and Security for the European Area Strand-1 (MERSEA Strand-1) is a Global Monitoring for Environment and Security (GMES) activity which ultimately aims to develop a pan-European capacity for operational monitoring and forecasting of ocean physics, biogeochemistry and ecosystems on global and regional scales. The objective of MERSEA strand 1 is to integrate existing satellite observations with data from *in-situ* monitoring networks and perform ocean modelling and data assimilation.

European Sea-Level Service Research Infrastructure (ESEAS-RI) is

an ESEAS activity including the Mediterranean Network of Global Sea-Level Observing System (MedGLOSS) activities, whose main objectives are to support the ESEAS research infrastructure and to facilitate pan-European coordination, and upgrade and standardize the network of sea-level observing sites in the European sea areas.

The regional Greek operational POSEIDON system provides near real-time forecasts and *in-situ* observations from 11 multi-variable buoys in the Aegean Sea. The development of this multi-module operational system was completed in late 1999 by Greece and Norway and is presently operated by the National Centre for Marine Research of Greece.

SKIRON is a weather and sea state forecasting system in Greece providing near real-time forecasts in the entire Mediterranean and other European areas. Recently, SKIRON was expanded to also provide oceanographic forecasts in the Aegean and Eastern Mediterranean seas. Unlike POSEIDON, SKIRON does not provide *in-situ* ocean observations. SKIRON is operated by the University of Athens within several European

Union projects, such as MFSTEP, for which it is tasked to provide operation surface atmospheric boundary layer variables for various operational ocean modelling applications in the Mediterranean Sea.

MERCATOR is France's contribution to operational oceanography, and is also a EuroGOOS pilot project of the Atlantic task team. While the extent of MERCATOR's range is essentially global, the near real-time operational forecasts it provides of the Mediterranean Sea are particularly germane to this effort. MERCATOR, whose mission was defined by various French organisations such as IFREMER and Météo-France, became fully operational in January 2001. MERCATOR participates in the European Union MERSEA Strand-1 project, as one of the project's four regional forecasting flow models in the European seas and the North Atlantic.

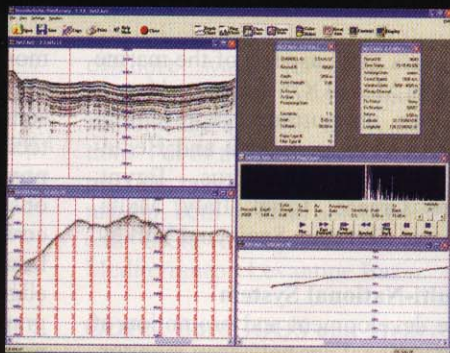
The Forecasting Ocean Assimilation Model (FOAM) is a near real-time forecasting system operated by the United Kingdom's MetOffice. While its major focus is the North Atlantic and Arctic oceans, FOAM also provides forecasts in the Mediterranean Sea. FOAM, together with MFSTEP and MERCATOR, participates in the European Union MERSEA Strand-1 project in order to provide near real-time ocean forecasts for all the European seas.

The Adriatic Sea Integrated Coastal Areas and River Basin Management System Pilot Project (ADRICOSM) is a multi-national sub-regional forecasting and observing system involving relevant agencies from Italy, Croatia, Slovenia and France. The aim of ADRICOSM is to demonstrate the feasibility of near real-time shelf current forecasts and to develop the integration of the river system modelling with the shelf scale current forecasting in the Adriatic Sea. The activities of ADRICOSM include modelling and implementation of *in-situ* and remote sensing monitoring. The ADRICOSM flow modelling is nested within the operational model of the MFSP and MFSTEP.

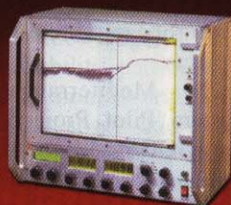
ISRAMAR is an Israel Oceanographic and Limnological Research Institute forecasting system that provides operational offshore sea state forecasts for the entire Mediterranean and the Eastern Mediterranean, using the wind fields from the previously mentioned SKIRON weather forecasting system. Moreover, near

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real-time coastal sea-level monitoring and other related parameters are provided within the frame of the MedGLOOS activities at selected coastal stations in Israel.

## CYCOFOS

The Cyprus Coastal Ocean Forecasting and Observing System (CYCOFOS) was developed within the framework of the previously mentioned European Union research projects, to promote operational oceanography in the Eastern Mediterranean Levantine Basin and the sea area around Cyprus. At present, CYCOFOS provides near real-time operational forecasts of sea currents, water temperature, salinity, sea level, significant wave height and direction, as well as operational *in-situ* observations of sea water temperature, sea level and satellite remote sensing of sea surface temperature. CYCOFOS consists of forecasting (flow and sea state), observing (*in-situ* and remote sensing) and the end-users modules that follow.

**MFS Cyprus Near Real-Time Ocean Forecasts.** CYCOFOS uses CYCOM, a high-resolution flow model based on the Princeton Ocean Model (POM) for climatological and operational coastal and regional flow simulations. It has two open boundaries and is nested operationally into the coarse grid of the MFSP Mediterranean model. The CYCOFOS flow model provides a weekly forecast for the forthcoming week and daily forecasts of currents, sea temperature, salinity and sea level. Within the framework of the MFSTEP project, the CYCOFOS flow forecasting module will be upgraded, and its resolution will be increased from three kilometers to 1.5 kilometers, providing more detailed information that is of particular value to the coastal end users.

**Cyprus Offshore Wave Forecasts in the Levantine Basin.** CYCOFOS uses the CYWAM wave model, which is a version of the WAM-wave model, for offshore wave forecasts of the entire Levantine Basin. The fine-resolution Levantine WAM model is nested entirely in a coarse Mediterranean WAM model. CYWAM provides operationally high-resolution forecasts of significant wave height and wave direction. The CYWAM model initially used the ECMWF wind forcing, while at present it uses the three-hourly winds from the 72-hour SKIRON weather forecasting system.

**The MedGLOSS Paphos Station.** Within the framework of MedGLOSS, a sea-level station was set up September 2001 at Paphos Harbor, on the western coast of Cyprus. The station's primary aim is to collect long-term systematic measurements, monitoring the sea-level rise, which may be caused by melting of polar ice as a result of global warming. The equipment for the Paphos MedGLOSS station was provided by the International Commission for the Scientific Exploration for the Mediterranean Sea

(CIESM), and its installation was conducted by Israel's Oceanographic and Limnological Research Institute (IOLR), who coordinate the MedGLOOS activities. Expansion of the Cyprus MedGLOSS in the near future will include similar stations on the south and east coasts of Cyprus.

## Satellite Ocean Remote Sensing

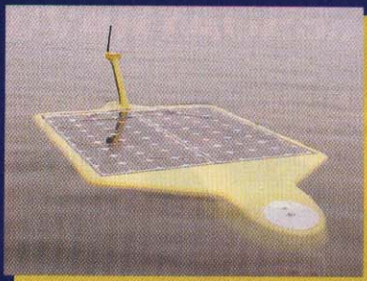
The CYCOFOS satellite ground receiving station has been providing regular (almost daily depending on the cloud cover) remote sensing sea sur-

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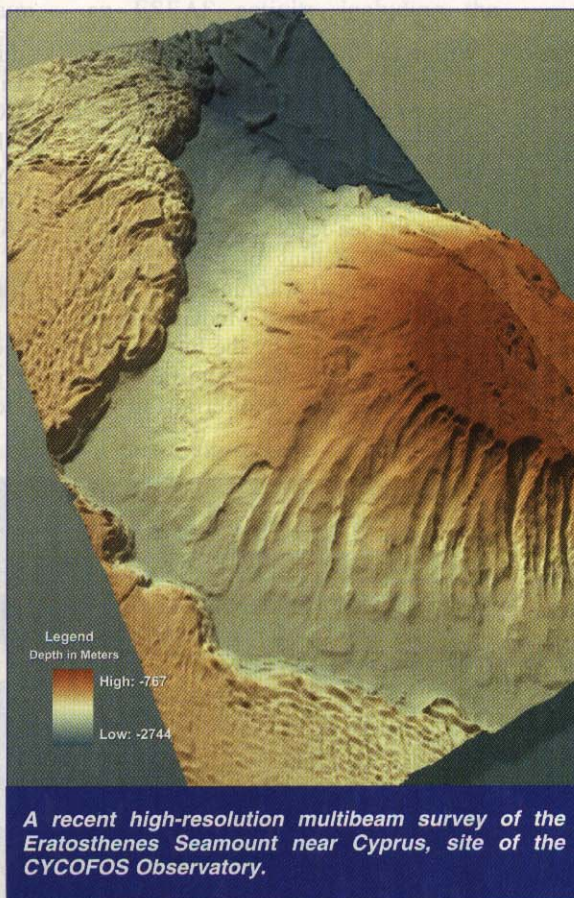




face temperature images of the Levantine Basin since 2001. A high-resolution picture transmission (H RTP) SmartTech Professional Researcher model engine is operated by the CYCOFOS team. Depending upon the satellite's orbit, it is capable of covering in a single capture the Eastern Mediterranean and Black Seas two to three times per day, with a spatial resolution of about one kilometer.

### CYCOFOS Ocean Observatory

As part of the European Union MAMA/MedGOOS initiative, and to promote deep sea operational *in-situ* data collection and transmission in the Levantine Basin, the CYCOFOS Ocean Observatory is currently under preparation for deployment in the Eastern Mediterranean, near the Eratosthenes Seamount off the southern coast of Cyprus. The CYCOFOS Ocean Observatory is scheduled for deployment jointly with Harris Maritime Communication Services (MCS), USA, which developed this buoy-based observing system. A similar Ocean Observatory was previously deployed in the western Mediterranean, off the coast of Sardinia jointly by International Marine Centre and Harris MCS. The sampling strategy of the CYCOFOS Ocean Observatory includes data on sea water temperatures, salinity, pressure, oxygen and currents from selected depths, as well air temperature, wind speed and direction. Fiber optic cables connect a network of seafloor sensors. The system's satellite com-



**A recent high-resolution multibeam survey of the Eratosthenes Seamount near Cyprus, site of the CYCOFOS Observatory.**

munication system and substantial onboard power generation provide continuous transmission of real-time data at high sampling rates.

### End-User-Derived Applications

Among the environmental issues affecting the eastern Mediterranean Levantine Basin are marine pollution, eutrophication and other algae-growth-related phenomena. Commercial activities in the Levantine Basin

such as growth in oil transfer, exploration and production, pelagic fisheries, shipping and yachting, and coastal tourism in particular are all on the increase.

To provide the scientific basis for any user-derived application that tries to manage either the exploitation or the protection of the marine environment, it is necessary to offer an efficient and quality-controlled estimate of marine state variables. A prerequisite for such an effective operational response is the ability to conduct accurate predictions of the sea's characteristics. Similarly, the same information is useful for other marine activities. Among the potential end users of the CYCOFOS's products are the national and sub-regional contingency plans for preparedness and response to major pollution incidents in the eastern Mediterranean Levantine Basin, between Cyprus, Israel and Egypt, in cases of oil spill emergency in the open sea; search and rescue centres, port authorities and marine police;

local and offshore consortiums from the fisheries sector; fish farmers from the marine aquaculture industry; desalination plants, telecommunications cable laying, oil and gas industry, and environmental agencies from the coastal and open sea engineering sector; commercial shipping, recreational boating and the navigation safety sector; marine tourism industry; and international policy organizations, research centers, etc.

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***"CYCOFOS provides near real-time operational forecasts of sea currents, water temperature, salinity, sea level, [and] significant wave height and direction."***

#### **CYCOFOS Internet Products**

The near real-time operational forecasting and observing products from the CYCOFOS modules, such as daily flow forecasts for the northeast Levantine Basin on a weekly basis, three-hourly sea state forecasts for the Levantine Basin on a 60-hour basis, daily remote sensing sea surface temperature for the Levantine Basin, and hourly *in-situ* sea level and water temperature at certain coastal sea stations are available to end users at [www.ucy.ac.cy/cyoccean](http://www.ucy.ac.cy/cyoccean).

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