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Poseidon: A marine environmental monitoring, forecasting and information system for the Greek seas

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Abstract

The scope of this work is twofold: i) to discuss and analyze some principles, issues and problems related to the development and advancement of Operational Oceanography in Greece and ii) to present a real-time monitoring and forecasting system for the Aegean Sea, which is currently under implementation.

Operational Oceanography in Greece has become a necessity today, since it can provide aid to find solutions on problems related to societal, economic, environmental and scientific issues. Most of the Greek coastal regions are under pressure, susceptible to damages due to the increasing tendency of the population to move from the inland to the coast, marine environmental pollution, competitive development of the coastal market sector, etc. Moreover, the complex geomorphology of the coastal areas and the interdependence between natural processes and human activities causes significant alterations in this delicate environment. A rational treatment of these problems can be based on integrated coastal zone management (ICZM). An absolutely necessary means for establishing ICZM is the operation of marine monitoring systems. Such a system ("POSEIDON system") is under implementation by the National Centre for Marine Research. POSEIDON is a comprehensive marine monitoring and forecasting system, that aims to improve environmental surveillance and facilitate sea transport, rescue and safety of life at sea, fishing and aquaculture, protection of the marine ecosystem, etc. POSEIDON is expected to enhance considerably the capabilities to manage, protect and develop the marine resources of the Greek Seas and to promote Greek Operational Oceanography.

Keywords: Operational Oceanography, Marine Monitoring Systems.

Introduction

Operational Oceanography and its status in Greece

General

Although its beginnings can be traced back to classical times, Operational Oceanography is a relatively new activity global in scope. As "classical" Oceanography reaches maturity in the domain of understanding ocean processes and moves fast towards reliable prediction, Operational Oceanography gains special importance and can be considered as the Ocean Science of the 21st century.

Today, the continuous interaction among Operational Oceanography, Ocean Forecasting

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and Marine Technology necessitates the matching of scientific efforts with technological applications. Thus, the twofold character of Operational Oceanography, reflecting the two major components of which it is comprised: **the scientific and the technological,** (SOUKISSIAN, 1998). The scientific component of Operational Oceanography sprung from its continuous interaction with the other marine sciences, such as Physical and Chemical Oceanography, Sea Biology, Ocean and Environmental Engineering, Marine Hydrodynamics, Coastal Engineering, Biochemistry, Marine Geophysics, etc. The goal within the scientific context of Operational Oceanography is the accurate prediction of the state of the sea ([1]) on multiple time and spatial scales ([2]). The core of Ocean Forecasting is the development and use of numerical models, i.e., numerical structures for simulating and predicting the characteristics of oceanic and coastal processes. A numerical model becomes an efficient tool for prediction by assimilating the appropriate real-time oceanographic data, (SOUKISSIAN, 1998).

It is difficult to reach, until now, such a target because of the gap between ocean observations and their analysis and theoretical modeling. Although prediction models do not suffer from serious shortcomings, their integration into an ocean prediction system gives rise to important problems. The three main components of an ocean prediction system are **a marine monitoring network, numerical models** and **data assimilation schemes**, (ROBINSON *et al.,* 1996). Excluding numerical models, the effectiveness of which strongly depends on computer power sufficiency and capabilities and data assimilation schemes, a still remaining problem of Ocean Forecasting is the scarcity of oceanographic observations in time and space.

Accordingly, one of the most important elements of Operational Oceanography is the capability to access real-time oceanographic data. The implementation of sophisticated marine monitoring systems, in conjunction with improved telecommunication systems, is necessary in order to provide precise, detailed and prompt information about the prevailing sea state in a given geographic area or all over the World Ocean. Today, the technological character of Operational Oceanography is emphasized due to the ever more demanding user-needs for inexpensive, high resolution and reliable data and forecast model products. Meeting these requirements relies, to a great extent, on the development and innovations in a variety of fields such as marine communications and computer technology (FLEMMING, 1995, Commitee on Environmental and Natural Resources Research, 1996, International Oceanographic Commission, 1994).

Despite the rapid expansion of the remote sensing techniques, it seems that these alone are not yet capable to cover all the current demands. The combination of in-situ (direct) measurements (by means of integrated monitoring systems, consisting of moored oceanographic buoys, oceanographic vessels, voluntary observing ships etc.) with remotely sensed data has proved to be an efficient tool, for a wide range of marine applications.

Status of Operational Oceanography

The Greek sea environment constitutes a variable, dynamical system subject to rapid changes, being dependent on the atmosphere, coastal ecosystems, the general features of the Mediterranean Sea, human activities, etc. To date, fishing, aquaculture,

([1]) The notion of "sea-state" is used herewith in a broad context: the ensemble of all sea characteristics including physical and dynamic conditions as well as biogeochemical parameters characterizes a sea-state.

([2]) Spatial scales are the local, the regional and the global, while time scales extend from the present (real-time nowcasting) to the next 6-72 hours (short-term prediction), the season (seasonal or mid-term prediction) and the next few decades (long-term prediction).

shipbuilding, marine trade and transportation, tourism and recreation are major activities gaining recognition of their special importance. 30% of the population of Greece is living within a distance of <2-km from the coastline, while more than 40000 people are employed in aquaculture. Greece remains the most important European country in the field of maritime transportation, as it owns almost the 50% of the European commercial vessels and the 16% worldwide. On the other hand, Greek waters receive the wastes from industry, aquaculture and agriculture, while the Aegean Sea, in particular, receives various pollutants, including radioactive disposals, originating from the Black Sea through the Strait of Dardanelles and from the rivers draining the Balkan peninsula and Asia Minor. In spite of the complexity of the Greek coastal system, efficient management and understanding is feasible. A prerequisite for this is the systematic monitoring of all the interesting sea processes and phenomena. Moreover, real-time transmission from remote locations and assimilation of the necessary information into numerical models are of crucial importance for obtaining reliable forecasts in various time and spatial scales.

In particular, the control and anticipation or forecasting of the rapid changes taking place in the coastal areas of the World Ocean has become nowadays of fundamental economic importance. Especially for Greece, due to the increasing tendency of the population to move from the inland to the coasts, new demands for space and other resources, as well as conflicts between various user groups (e.g. industry, agriculture, fisheries, tourism), have highlighted the need for a rational approach to coastal zone management (International Oceanographic Commission, 1994). Today, this gains much more attention due to the revolutionary overall changes taking place in Greece and the forthcoming 2004 Olympic games to be held in Athens.

Operational Oceanography has become a necessity today, since it can provide aid to find solutions on the aforementioned problems. Certain prospects of development are based on the efficient European co-operation in the context of EuroGOOS and MedGOOS, on the high level of marine research performed in Greece and, mainly, on the operation of a marine environmental monitoring, forecasting and information system for the Hellenic waters (POSEIDON System), described in "The POSEIDON system".

Monitoring systems and oceanographic data

Monitoring systems: An integrated, continuously operating network providing meteorological observations (temperature, humidity, wind speed & direction, clouds, etc) is under the administration of the **National Meteorological Service** (NMS). The NMS network consists also of agricultural / meteorological observation stations transferring data to the NMS, operated by the **National Institute of Agricultural Research.** 20 additional agricultural/meteorological stations, the installation of which took place in the framework of the TELEMATICS project, have recently upgraded the NMS network. Furthermore, NMS has recently installed a Land-Earth Station (LES) receiving data from meteorological satellites. This project is in operation since 1995 and was implemented in accordance to the TELEMATICS program. The station is capable of receiving, processing and transferring data obtained by the European geostationary satellites METEOSAT of the EUMETSAT organization and by polar orbiting satellites of the US National Oceanic and Atmospheric Administration (NOAA).

A tide-gauges network providing tide and sea-surface temperature measurements is operating under the responsibility of the **Hellenic Navy Hydrography Service**. The components of the network are mainly

located at harbors.

Finally, networks for monitoring inland waters as well as marine pollution are under the administration of the **Ministry of Environment, Physical Planning and Public Works**, in co-operation with Universities and the Ministry of Agriculture. The in-situ measurements are conducted in areas of specific interest (as e.g., Saronikos and Thermaikos gulfs, highly polluted areas, etc.).

Physical and biogeochemical data: Oceanographic measurements of physical and biogeochemical parameters are conducted by the **National Center for Marine Research** (NCMR), **the Institute of Marine Biology of Crete** (IMBC), the Hellenic Navy Hydrography Service, various research institutes, Universities and governmental authorities all over the country. NCMR is the main public organization for conducting marine research covering the most important aspects of Physical, Geochemical and Biological Oceanography. It owns the research vessel "AEGAEO", the largest of its kind in Greece. Its tasks mainly involve oceanographic, hydrography environmental surveys and support to the understanding of the marine environment mechanisms of the Eastern Mediterranean. Most of its missions are performed in the context of participation in national and European research projects dealing with a variety of current issues from geophysical exploration to environmental monitoring. The vessel is also equipped with a submersible (and an ROV) capable of exploring greater depths (~600 m) of the Eastern Mediterranean. IMBC and the Hydrography Service are also owners of oceanographic research vessels.

The systematisation of the measurements obtained during the last decade resulted in a large, even though scattered in space and time, set of accumulated oceanographic data. These data are archived in the Hellenic National Oceanographic Data Centre (HNODC) developed in NCMR and are available to the scientific and users community, including various public and private organizations, educational and research institutions, single users, marine scientists, etc.

Wave and wind data: Wave and wind data are of crucial importance for operational forecasting purposes. Measured (in-situ) wave data are very sparse, randomly distributed over the Aegean and adjacent seas and of very short duration (of the order of some weeks or months). The corresponding measurements are conducted occasionally either by educational and research institutes or private companies. Visual wave data for the Greek Seas (obtained by observations made from trained personnel on board Voluntary Observing Ships) are purchased from the Meteorological Office, England, further processed and archived in the form of a Wave/Wind Atlas (ATHANASSOULIS, & SKARSOULIS, 1992), within the context of a project funded by the Greek Navy ([3]). Hindcast wave data are available in the form of both time series (of 10 years duration) and frequency tables, from the U.S. National Climatic Data Centre. The hindcasts are derived by means of the Spectral Ocean Wave Model (SOWM), (Naval Oceanography Command Detachment, 1990), with grid points spaced up to 180 nautical miles. However, SOWM is a general purpose and coarse deep-water model not designed to include coastal dynamic effects (refraction, diffraction, shoaling etc.), being thus highly unreliable for the Greek seas ([4]). It is remarkable that, currently, in Greece, **neither private nor public organizations can provide systematic and reliable long-term wave time series**. On the other hand (processed) measured wind data are available by the National Meteorological Service. These data can be obtained in the form of

([3]) These data accumulated over the last 100 years and cover the Greek seas in a resolution of 10x10.

([4]) The highly irregular topography and the presence of many islands characterize Greek seas.

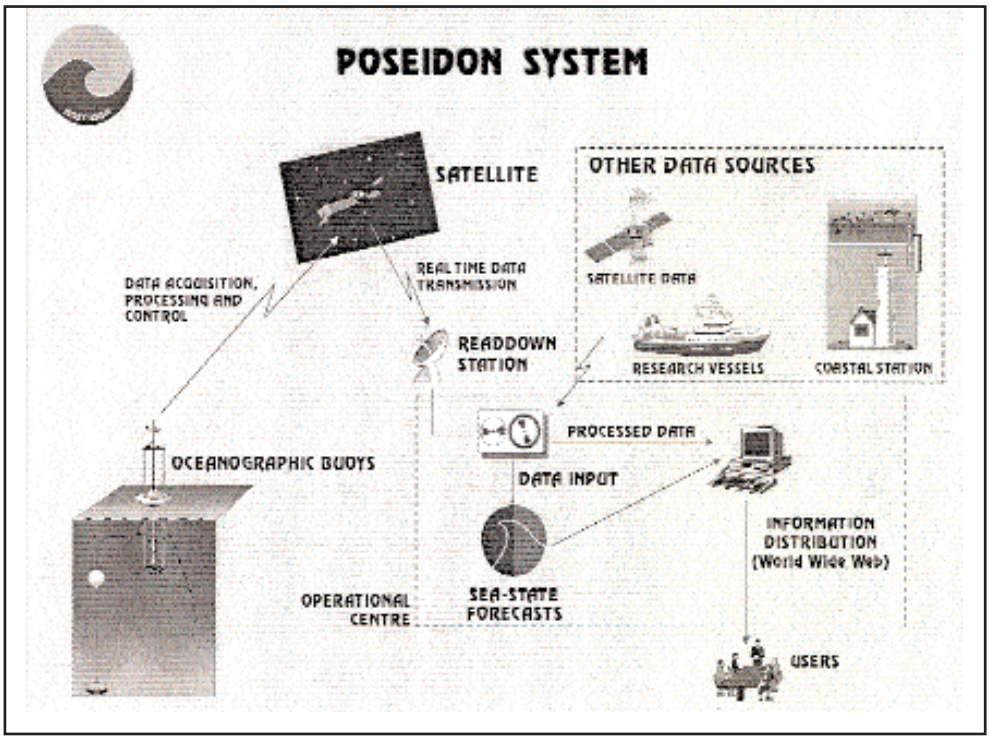

Fig. 1: The POSEIDON system.

time series (with a time step of 3 hours) as well as of mean values (e.g. monthly mean values), thus being suitable for most of research purposes.

The POSEIDON system

Background

To satisfy, apart from monitoring, forecasting requirements as well, a marine monitoring system must be of operational nature. The installation and operation of such a system for the environmental monitoring and forecasting of the Greek waters is undertaken by the National Centre for Marine Research (POSEIDON System). POSEIDON is the first project of this kind in Greece and is jointly funded by the European Financial Mechanism (European Free Trade Association) through the European Investment Bank (85% of the total budget) and the Ministry of National Economy. Completion of the project is expected mid-year 2000.

The mission of the POSEIDON System is multipurpose consisting in:

· Routine monitoring and measurement of parameters of the marine and atmospheric environment,

· Remote transmission of the above data to the Operational Centre of NCMR,

· Processing of the raw data and user-friendly presentation of the results,

· Forecasting of the state of the sea using numerical models,

· Dissemination of the processed data and forecast outputs to the end-users.

Description of the POSEIDON System

POSEIDON is based on the principles of OCEANOR's Sea-watch System, (HANSEN, & STEL, 1997), consisting of separate yet interrelated components. More precisely (Fig. 1):

1. The backbone of POSEIDON is an **integrated network of 10 (+ 2 spare) ocea-**

nographic buoys and 10 wave buoys deployed in Greek territorial waters, equipped with a variety of sensors for the monitoring of the sea environment. The buoys are integrated into a network (**POSEIDON network**). Environmental monitoring is primarily based on oceanographic buoys equipped with sensors for measuring meteorological, environmental and oceanographic parameters. More precisely, oceanographic buoys are equipped with:

· **Sensors** for monitoring wind speed and direction, air pressure and temperature, surface water temperature, sea-surface conductivity, sea-surface current speed and direction, wave height and direction, water temperature and salinity from 0-50 m, sea-surface radioactivity and light attenuation, dissolved oxygen, chlorophyll-□ and nitrates,

· A **computing system** and the related software for the automated measurement, control, storing, pre-processing and preparation of the data for their near real-time remote transmission to the Operational Centre of NCMR,

· Two-way **telecommunication systems** (satellite-□□□ARSAT std. C and/or GSM-cellular phone telecommunication system) for the transmission of the data to the Operational Centre.

2. The control and surveillance of the POSEIDON system is made through the **Operational Centre** located at NCMR's installations. The Centre is equipped with a main frame UNIX computer, PC's and peripheral devices, hardware and software for the remote connection with the POSEIDON network, as well as with all the necessary software for the data processing, storage, quality control, correction, presentation and distribution of the processed data to the end-users.

3. Finally, the **Aegean Operational Forecasting System** (AOFOS) consists of separate, yet interacting, numerical simulation/forecast models adapted for the special environment of the Greek seas and will provide operational forecasts and simulations of the state of the sea. The Forecasting System consists of a **weather prediction model, an open sea wave forecast model, a 3-D hydrodynamic model, a shallow water wave prediction model and a buoyant pollutant transport model** (International Oceanographic Commission, 1993)([5]).

NCMR is the owner of the POSEIDON system. In the very first phase of the POSEIDON project (1996) and within the context of EuroGOOS, an initial market research has been accomplished in order to identify the needs of the potential users of Operational Oceanography services (SOUKISSIAN & TZIAVOS, 1996). This research showed that the users do not form a uniform group of easily classified people. They are spread across various industrial and service sectors (private and public) such as defence, shipbuilding, port operations, civil engineering, marine tourism, fisheries, etc. The required data and products encompass a wide range of ocean parameters, including wave characteristics, sea temperature and salinity, tides and coastal circulation. The results of this research are in concordance with those presented in FLEMMING (1995) and "Coastal Zones. A survey of data requirements of the operational community", (1995). A more detailed, system-oriented market research is under preparation, covering a better-refined field of applications with respect to the possible uses of the POSEIDON system.

In the implementation phase of the system, the buoys are moored in locations suitable for the calibration of the wave-forecasting model (both deep and shallow water wave models). Due to some peculiarities of the Aegean Sea regime (which are not be analysed within this work), all the moorings

([5]) Currently the only operational model is the one concerning every day's weather forecasts run by the National Meteorological Service.

are placed in Greek territorial waters; in the subsequent phases of operation of the system, the mooring sites will be determined solely by user's demands.

The development / implementation of the operational forecasting modules is assigned to research groups from Greek Universities. In the first period of operation, only the weather and the offshore wave prediction model will run in operational mode, providing every day forecasts.

Expected problems and benefits

The development and use of a system such as POSEIDON, is expected to both give rise to problems and to provide benefits. The major expected problem concerns the covering of the operational, maintenance and repair costs of the various elements of the system. The choice of near-shore mooring locations is expected to significantly reduce the maintenance and repair costs. Such costs can be covered only by providing services to users of both the private and the public sector, as well as by participating into EC research projects. As concerns the users-group, there is a high degree of uncertainty on whether they are ready to pay for the services of such a system.

On the other hand, the operation of the POSEIDON System is expected to improve:

· Marine meteorological services, port management, rescue and safety at sea, rational offshore and near shore installation design (reliable design criteria),

· Decision-making in the event of accidents or natural disasters involving environmental damage (as e.g. oil spill contingency planning and action),

· Fishing and fish farming,

· Shipping and sea transport, ship routing,

· Tourist and recreation industry services,

· Protection, sustainable utilization and responds to environmental disasters of the marine ecosystem.

The POSEIDON System should also address planning activities such as:

· Environmental impact studies,

· Integrated coastal zone management.

It is evident that the POSEIDON project is expected to significantly contribute to the establishment of Operational Oceanography in Greece.

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