Global Ocean Observing System

Intergovernmental Oceanographic Commission

Black Sea GOOS Strategic Action and Implementation Plan

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Preface

The present Black Sea GOOS Strategic Action and Implementation plan was adopted in principle by Black Sea GOOS Member States at the second Black Sea GOOS workshop (Poti, Georgia, 22-25 May, 2001; GOOS Report No. 109*;* http://ioc.unesco.org/goos/docs/GOOS_109_BlackSea2.pdf). Following the Poti meeting an editing group was set up to finalise the plan, and the finalised version was subsequently approved at the Black Sea GOOS Steering Committee meeting (Ankara, Turkey, 16 October, 2002) by all Black Sea GOOS Member States.

Members of the editing committee were:

Kakhabez Bilashvili (Georgia)
Elena Cordoneanu (Romania)
Gennady Korotaev (Ukraine)
Alexander Kubryakov (Ukraine, committee secretary)
Alexandre Postnov (Russia)
Ilkay Salihoglu (Turkey)
Hristo Slabakov (Bulgaria)

Thorkild Aarup (IOC Secretariat)

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Abstract

This document sets out a Strategic Plan for the development of a Regional Ocean and Coastal Observing System in the Black Sea. This system will be a regional component of the Global Ocean Observing System (GOOS). Its implementation will be the responsibility of the Black Sea GOOS Steering Committee.

(SC-2003/WS/76)

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EXECUTIVE SUMMARY

Surrounded by six countries (Bulgaria, Georgia, Romania, Russia, Turkey and Ukraine), the Black Sea has a very complex structure; significant fractions of the populations of these countries live in the coastal area or have easy access to the sea. Historically, their societies have been forged by marine industries, fishing, shipping and shipbuilding. In recent years, recreation for tourists from all of Europe has become an increasingly important business.

The potential effects of long-term natural variability and climate change are to aggravate current environmental problems of the Black Sea by adding another dimension to the complexity of the causes, rates, and timing of various types of variability. The Black Sea deserves increased vigilance and effective environmental management. Therefore future environmental changes in the Black Sea must be predicted adequately, so that options and funding requirements for solutions can be analysed and identified. The capability to predict and monitor changes in the ecosystems of the basin will bring extensive benefits to the management of the marine environment and protection of public health and safety. In sum, it will contribute to the sustainable development of the Black Sea.

An operational oceanographic service will benefit the marine industry in the Black Sea region and will contribute to and improve the efficiency of marine operations, reduce the risk of accidents, optimise the monitoring of the marine environment, improve the assessment of fish stocks and improve the foundation of public marine management. An operational oceanographic service supporting these activities should be focused primarily on observations, analysis and model predictions for sea level, waves, currents, temperature, salinity, sea ice, dissolved oxygen, nutrients, algae and chlorophyll.

Operational oceanography includes the routine collection, interpretation and presentation of data from the ocean and atmosphere to:

- Give a reliable description of the marine conditions including the living resources
- Provide prognoses of the future marine conditions
- Establish marine databases from which time-series can be obtained and statistical analysis carried out to detect trends and marine environmental changes, including the impact on living conditions of the Black Sea

The Black Sea Global Ocean Observing System (Black Sea GOOS) will constitute close co-operation between national governmental agencies, mainly oceanographic and hydrometeorological institutions and other relevant institutions of the Black Sea countries responsible for the observational data collection on which operational models and forecasts, services and information for the marine industry, the general public and other end users will be based. To this end, Black Sea countries signed a Memorandum of Understanding under which they agreed to co-operate in promoting GOOS in the Black Sea basin (See Annex IV in GOOS Report No. 109). To assess the economic and social benefits from operational oceanography, the Black Sea GOOS activities will foster operational oceanography in the basin, so as to maximize the benefits from/to ongoing activities of GOOS. The marine research institutes and hydrometeorological institutes of all Black Sea countries are already fruitfully collaborating with the Black Sea Environment Programme (BSEP) and Black Sea Commission (BSC). Black Sea GOOS will extend this collaboration to the other relevant multinational agencies, organizations and initiatives, such as Global International Water

Assessment (GIWA), Large Marine Ecosystems (LME), and the EU's Phare and Tacis programmes, etc.

This document presents a plan for a research and technological development programme to promote the prediction and the monitoring of the state of the ecosystem and circulation in the Black Sea on a permanent basis. This plan defines the scientific and technological research issues to be considered and the strategies to be adopted for developing a Black Sea Global Ocean Observing System for the entire basin.

1. BACKGROUND

In ancient Greek myths, the Black Sea—on the fringe of the Mediterranean world — was named *Pontus Axeinus*, meaning "*Inhospitable Sea*". Later explorations made the region more familiar and, as colonies were established along its shores (Fig. 1), its name was changed to *Pontus Euxinus,* which has the opposite meaning. It was across its waters that *Jason* and the *Argonauts* went, according to legend, to find the *Golden Fleece* in the land of *Colchis*, a kingdom at the sea's eastern tip (now *Georgia*). The Turks, when they came to control the lands beyond the sea's southern shores, encountered the sudden storms whipped up on its waters and reverted to a designation reflecting the inhospitable aspect of what they now termed the *Karadeniz,* or the *Black Sea*.

About 9,000 years ago the general warming of climate and the sea-level rise in the world ocean led to the penetration of the Mediterranean water into the Black Sea through the Bosporus. This event led to the surfacing of deep new-euxinic waters, rich in biogenic elements, into the euphotic zone, and increased primary production considerably in the basin. The concurrent development of density stratification had strongly restricted the rate of vertical exchange, including oxygen penetration into the deep layers. As a result, about 7,000 to 8,000 years ago an anaerobic zone evolved at depth, which, following a suite of transformations, has reached the contemporary physical–chemical state.

Figure 1. *The ancient town of Hersones, Sevastopol, Crimea*

The coastal and shelf zones of the Black Sea are a mosaic of complex, interacting ecosystems of immense economic significance, rich natural resources and ecological communities, and concentrated human activities. They contain biologically productive, diverse ecosystems that provide a vital habitat for many commercial and endangered species. Until recently, it supported fisheries almost five times richer than those of the neighbouring Mediterranean. The Black Sea is of global interest on several levels. First of all, it has experienced the worst environmental degradation of all of the world’s major seas.

The environmental situation has recently become so severe that it has affected the health, well-being, and standard of living of the people living in the immediate area. The coastal zone is densely populated, containing a permanent population of approximately 16 million, with another 4 million visitors during the summer tourist season. The longest and most densely populated Black Sea coastal zones are in Turkey and the Ukraine (Figure 2). Although international agreements, strategic plans, and national environmental programmes are in place, severe economic problems of the Black Sea countries have significantly slowed implementation of environmental monitoring, remediation and restoration.

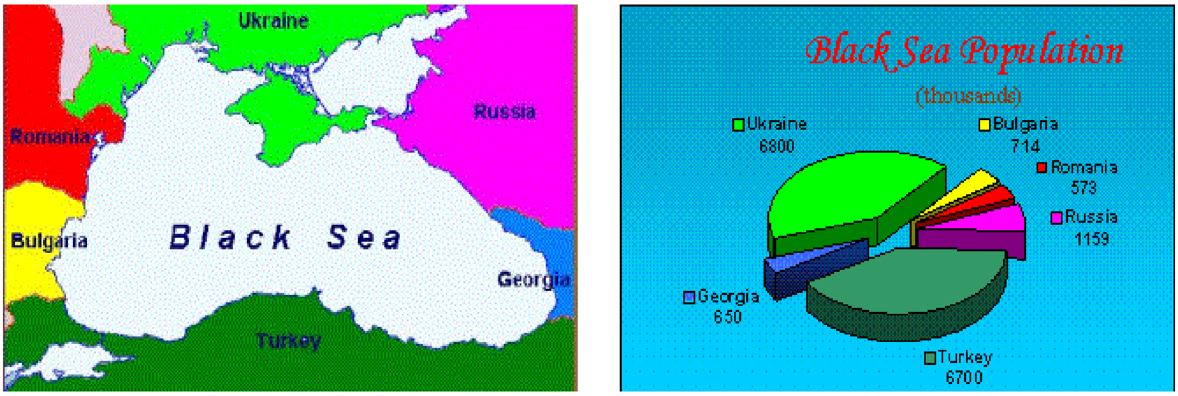

Figure 2. *The riparian countries and their coastal population.*

The map in Figure 3 shows the geographical location of the Black Sea region, its six coastal countries and catchment basin. The Black Sea has a surface area of 423,000 km^2, one-fifth of the surface area of the Mediterranean, a total volume of 547,000 km^3, and a maximum depth of around 2,200 m. The north-western shelf (NWS), less than 200 m deep and occupying ~25% of the total area, receives discharges of three of Europe's largest rivers: Danube, Dniepr and Don, as well as the Dniestr and Kuban Rivers.

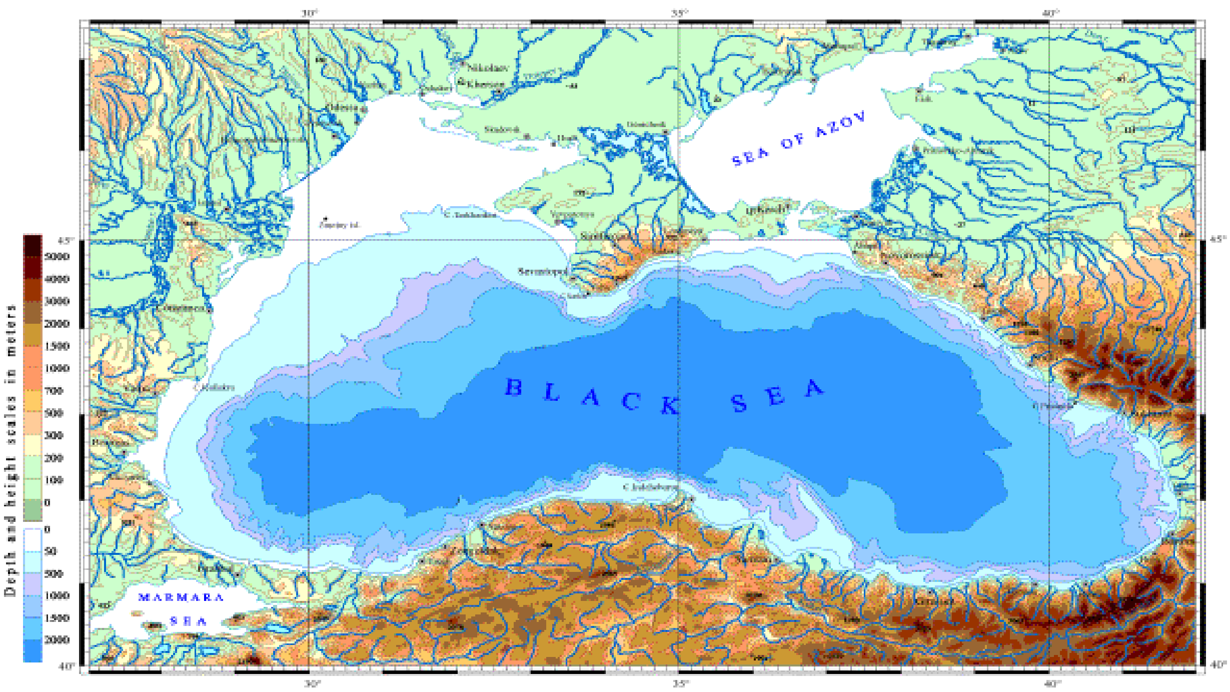

Figure 3. *Map of the Black Sea*

The Black Sea is very deep (about 2 km), and the only outlet is through the narrow, shallow (<75 m deep) Bosporus Strait. In the north, it is connected to the shallow Sea of Azov by the Kerch Strait, which has a surface area of 40,000 km^2, and an average depth of 8 m. The Black Sea has a two-layer stratification of the water column with a thin layer (~100 m) of fresher (~18 salinity) and lighter water overlying denser water (with ~22 salinity, σ_t~17.0 kg/m^3) at depth. The layers are separated by a strong pycnocline at a depth of about 100 m. The difference in density prevents mixing and subsequent ventilation of the sub-pycnocline waters from the surface. Over the years, organic matter has been sinking and decomposing and has given rise to a permanent anoxia below a depth of 100–150 m. This means that more than 90% of its water mass is devoid of oxygen, making it the largest body of anoxic water on Earth. Since dissolved oxygen is not sufficient, organic-matter degradation uses oxygen bound in nitrates and, especially, in sulphates which generate hydrogen sulphide.

The catchment area of the Black Sea (Fig. 4) is over 2 million km^2, entirely or partially covering 23 countries in Europe and Asia Minor. Whereas every square metre of the world ocean receives water from 0.4 square metres of land, in the Black Sea this value is 4.4 square metres. About 162 million people live in the catchment area of the Black Sea basin (Mee, 1992; Unluata *et al.*, 1993), of which 80 million people live in the Danube River basin.

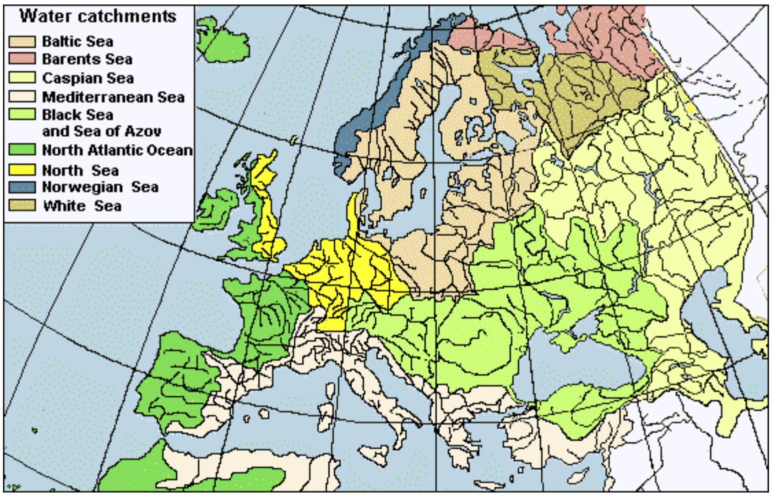

Figure 4. *The Catchment area of the Black Sea*

Until recently, the primary ecological problem in the Black Sea was the massive influx of nutrients and pollutants, coupled with the poor ventilation of the deep water. From the early 1970s till the 1990s, a reduction in the Danube water discharge due to river management was accompanied by an increase in the nitrogen and phosphorus delivery to the north-western Black Sea by factors of 3 and 10, respectively. This was due to the widespread use of phosphate detergents and intensive agriculture, which used fertilisers and thus caused nutrient leaching from the soil.

Atmospheric deposition seems to contribute a relatively minor amount of nitrogen and phosphorus, 19% and 8%, respectively. Agriculture and domestic wastewater contributed the largest shares. The Danube is the single largest source, introducing about 60,000 tons of total phosphorus per year (which is about 66%). The share of inorganic nitrogen in the Danube discharge amounts to about 340,000 tons per year (53%), which is more than double the load from the Rhine. At the same time, silica decreased significantly (about 4 times), owing to the reduced solid flow, which all together resulted in a modified N:P:Si balance of inorganic nutrients. Other rivers of the Black Sea basin have also been seriously contaminated with industrial and mining wastes. Besides river discharge of contaminants, many coastal industries discharge unknown quantities directly to the sea with little or no treatment. Chemical contamination has been coupled with other forms of pollution (organic contaminants, such as pesticides and herbicides, DDT, heavy metals and radionuclides, microbial pathogens, toxic waste, oil). As a result, the major part of the Black Sea, particularly its north-western region, has become critically eutrophic, and hypoxic because of the considerable decrease in the bottom oxygen concentrations (Zaitsev and Mamaev, 1997). Introduction of a ctenophore *Mnemiopsis leidyi*, uncontrolled sewage discharge, dumping of wastes (including radioactive substances, and solid wastes) into the sea, and accidental and operational releases of oil have all added to the problem. The exploitation of the Black Sea's resources during the last few decades has therefore been unsustainable.

Oil pollution continues to threaten Black Sea coastal ecosystems. The current level of oil pollution in the open waters of the Black Sea is not at a critical state, but is nevertheless unacceptable in many coastal areas. It enters the environment as a result of accidental and operational discharges from vessels, as well as from land-based sources. An estimated 30,000 tons of oil enter the sea from domestic sewage plants, 15,000 tons from industry, and 53,000 tons via the Danube River every year, implying some 100,000 tons of unrecoverable oil discharge into the sea annually. The threat from accidental oil spills is growing as a result of increased tanker traffic associated with new oil terminals. Such spills would have disastrous impacts on sensitive marine and coastal areas.

The environmental crisis in the Black Sea due to the impact of human activities, accompanied by natural variability and climatic changes, is manifested by dramatic changes in its ecosystem and resources. The fishery yields have declined dramatically, with an 80% reduction in total catch in recent years; moreover, only six out of the 26 species of commercially valuable fish available during the 1960s remain in exploitable quantities (Fig. 5).

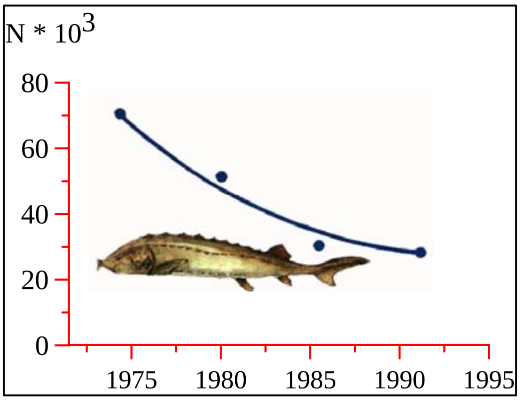

Figure 5. *Decline in the total number of sturgeons in the Georgian sector of the Black Sea (Georgian National Report, 1995)*

Many experts regard eutrophication as the most significant cause of the Black Sea's environmental decline since the 1960s. Eutrophication causes an extraordinary increase in phytoplankton, which grows in all surface waters where there is enough light and nutrients. Consequently, a substantial modification of the phytoplankton community structure and succession, as well as an increase in the intensity, frequency and expansion of microalgal blooms during the last twenty years has been observed. The total phytoplankton biomass in the period 1971–1988 increased from 720 mg/m^3 to 4,780 mg/m^3 along the Romanian coast and about ten-fold along the Bulgarian coast. The ratio Bacillariophyta:Dinophyta has shifted from 10:7 to 7:10; the number of species observed to bloom has increased from 5–8 to 14–18, and the number of blooms has increased more than three times with a ten-fold extension of their area coverage (Aubrey *et al.,* 1996).

Though the frequency of blooms and the number of blooming species have increased, individual blooms have been documented as becoming more and more monospecific. The natural phytoplankton annual cycle with spring and autumn maxima has been replaced by a pattern characteristic of eutrophic waters, identified by several exceptional maxima, the summer one being the most pronounced.

Dramatic alterations have also occurred in the zooplankton community. The total biomass of zooplanktonic fodder species decreased by a factor of 4.7, the abundance of opportunistic species (*Noctiluca*, *Pleurobrachia*, the jellyfish *Aurelia*, and the ctenophore *Mnemiopsis*) reached 99% of the total zooplankton wet weight. The invading ctenophore *Mnemiopsis leidyi*, which is a dead-end species of the food web in the Black Sea, increased to 4.6 kg/m^2 or 3,000 individuals/m^2 (Vinogradov *et al.*, 1992). In the Danube delta, a concentration of 500 g/m^3 of *Noctiluca scintillans* has been measured (Zaitsev, 1993). *Mnemiopsis* was accidentally introduced into the Black Sea, probably from the east coast of the United States in the ballast waters of tankers. *Mnemiopsis* may grow up to 15 cm in length and consume almost any of the zooplankton groups, which are an essential link in the marine food web. Because it had no predators in the Black Sea, the *Mnemiopsis* community quickly dominated the entire ecosystem and changed its structure, becoming a major cause of the collapse of the Black Sea fishery. Recently, there have been some indications that the *Mnemiopsis* community is declining, and that the ecosystem is showing some degree of recovery. But they are still present in large numbers and remain a critical factor in the functioning of the Black Sea ecosystem.

There is evidence that the environmental changes due to eutrophication, including algal blooms and the outbreak of the *mnemiopsis* population, lie behind the dramatic reduction in fish stocks and falling recruitment. The number of species of commercial importance has declined from 21 in the early 1960s to only 6 at present. The *Sprattus sprattus* stock decreased from 200,000 tons (1978–1980) to 40,000 tons (1988–1990) along the Bulgarian coast (Prodanov and Daskalov, 1992).

Environmental monitoring during the last several years has, however, indicated a perceptible and gradual improvement in the state of some biotic components of the ecosystem in the western coastal waters. One of the most noticeable improvements was the reduction in the nutrient input into the region, even though nitrate in particular and phosphates to a lesser extent are still high compared to their concentration during the 1960s (i.e. prior to eutrophication). These improvements are reflected in the changes in frequency and intensity of algal blooms. For example, Romanian coastal water had 16 blooms during 1991–1996 of which only 3 were high-amplitude events, compared to 49 events during the 1980s, of which 15 were of very high amplitude (Petranu *et al*., 1999). During 1995 and 1996, the mesozooplankton biomass was also seen to be relatively higher than in the previous years, which also reflects a gradual improvement in the ecosystem. The effects of the high zooplankton mortality in the past decades are, however, still maintained in the benthos. The consolidation of the gradual improvement in environmental conditions, indicated by fewer red tides and reduced mortality, will depend on further decrease in the riverine nutrient input. A significant reduction in eutrophication will not, however, be possible without the joint effort of all the coastal countries of the Black Sea and a similar effort by the countries bordering and discharging their waste into the Danube.

Although industrial and agricultural discharges seem to contribute fewer chemical contaminants today than two decades ago, pollution due to metals and organic chemicals introduced into the Black Sea is still a considerable problem. The worst chemical contamination occurs in coastal-zone sediments. It is especially troublesome because contaminants tend to settle rapidly, accumulating in sediments close to river discharges. Contamination can be severe and long-lasting in such areas because the toxic chemicals are not generally dissipated. Plant and animal life in these areas can accumulate contaminants from sediments and, in some cases, experience adverse effects. Faecal contamination is another potential problem; it is possibly due to the presence of disease-causing bacteria and viruses in the coastal zone of the Black Sea. Improperly sited or badly maintained sewage and septic systems, sewage-treatment-plant malfunctions and combined sewer outflows/untreated waste discharges all have the potential to introduce faecal matter into nearby waters.

As mentioned above, the health and well-being of 162 million people are affected by the environmental degradation of the Black Sea. Consequently, adequate prediction of the environmental variability in the Black Sea is needed to identify, analyse and determine the costs of solutions for better management of the marine environment and marine operations and activities aimed at sustainable development of the Black Sea resources. Chapter 17, Programme Area A, of Agenda 21, the Programme of Action for Sustainable Development, adopted at the United Nations Conference on Environment and Development (UNCED, Rio de Janeiro, 1992) called for the establishment of the GOOS Global Ocean Observing System. GOOS provides an important tool for the preservation and enhancement of the quality of the environment and the sustainable use of marine resources. These requirements foster a regional activity, which is the Black Sea GOOS.

2. THE "BLACK SEA GOOS" CONCEPT

This concept has been developed in accordance with the GOOS basic documents, "Towards Operational Oceanography: the Global Ocean Observing System (GOOS)" (document IOC/INF-1028, available at www.unesco.org/ioc/goos) and "Strategic Plan and Principles for the Global Ocean Observing System (GOOS)" (GOOS Report No 41, IOC/INF-1091, available at www.unesco.org/ioc/goos). The Black Sea GOOS will be an evolving permanent system able to acquire, integrate and distribute data collected by the ocean-observing mechanisms, and to generate analyses, forecasts and other useful products for all interested parties. Black Sea GOOS has addressed the following aspects:

- Motivation: Why is the Black Sea GOOS is necessary;
- Goals and objectives of the Black Sea GOOS;
- What is essential in the Black Sea GOOS?
- Black Sea characteristics;
- Black Sea GOOS modules;
- Assessment of the Black Sea users' needs and requirements for data and products;
- Strategic plan;
- Scientific plan;
- Implementation plan;
- Resources for the Black Sea GOOS.

3. BLACK SEA GOOS GOALS AND APPROACH

The present plan defines the scientific and technological research issues to be considered and the strategies to be adopted for developing a Black Sea component of the Global Ocean Observing System (Black Sea GOOS).

Black Sea GOOS activities will be designed to foster operational oceanography in the Black Sea basin and to promote the integration of these activities within the framework of GOOS.

The main objective of the Black Sea GOOS is to observe and predict the variability of the Black Sea, on the overall basin scale down to the coastal/shelf area time-scale, extending from days to weeks to months, through the development and implementation of a forecasting and observation system. Black Sea GOOS will provide:

- Marine data and products to the Black Sea community for the efficient, safe, rational use and protection of the marine environment, as well as for climate prediction and coastal management;
- A reliable international observing network that will enable the co-ordination and sharing of data and products in the Black Sea area;
- Co-ordination and unification of scientific research that addresses the most crucial problems of the Black Sea environment.

The specific objectives of the Black Sea GOOS are:

- To specify in terms of space, time, quality and other relevant factors, the marine observational data needed on a continuing basis to meet the common and identifiable requirements of the Black Sea user community;
- To develop and implement an internationally co-ordinated strategy for acquisition of marine observational data, and the archiving and synthesis of these data for common use and practical applications;
- To facilitate, encourage and widen the application of these data to the sustainable use and protection of the Black Sea marine environment;
- To establish new services or improve existing ones to meet the requirements of environmental and maritime user groups;
- To co-ordinate, improve and harmonise observation and information systems, where necessary;
- To increase the quality and reliability of user-oriented operational products;
- To decrease the costs of public products and services by international co-operation;
- To co-operate with EuroGOOS and other relevant bodies to avoid duplication of work and to maximize mutual assistance;
- To identify new customers for operational oceanographic products;
- To further develop the market for operational oceanographic products;
- To develop Black Sea GOOS following the GOOS principles;
- To provide the high-quality data and long time-series required, by advancing the scientific understanding of the Black Sea.

3.1 WHAT IS ESSENTIAL IN THE BLACK SEA GOOS?

In conformity with GOOS principles, the Black Sea GOOS observations should be:

- **Long-term**; i.e. measurements once begun should continue, with improvement of their quality and with more effective methods as they become available;
- **Systematic**; i.e. measurements should be made in a rational fashion, with the spatial and temporal sampling as well as the precision and accuracy tuned to

address specific aspects of GOOS;

- **Relevant to the overall objectives**; i.e. measurements should be made with a view to producing user-oriented end-products;
- **Cost-effective**; i.e. effort should be made to maximize the return on available resources (financial and manpower) by applying observational methods that are economical and efficient;
- **Routine**; i.e. the observations should be conducted regularly to allow periodical dissemination of the products.

The elements of the Black Sea GOOS need to be closely linked with ocean and/or coupled ocean–atmosphere models. The Black Sea GOOS intends to utilize remote sensing of the marine environment from satellites (some satellite observations are already available in all national meteorological centres in the area) and *in situ* measurements using ship-borne observations, towed and anchored instrument systems, drifting buoys and subsurface floats.

The Black Sea GOOS data and analysis products must be efficiently disseminated to the public for information, advice and prediction within a few hours or days.

Much of the data collected for local, national or regional interests in the Black Sea will not form part of the Black Sea GOOS. Data will only be acceptable for Black Sea GOOS if they are provided in accordance with the GOOS data policy and standards, are long-term, systematic, and relevant to the overall objectives of GOOS.

3.2 GUIDING PRINCIPLES

The services derived from operational oceanography must be aimed at identified user groups. There must be a continuing dialogue with potential users of operational marine data and forecasts. All operations, data gathering, modelling and forecasting should be carried out with optimum planning of installation and services, so that participating states and agencies share responsibilities without duplication.

The full benefit of operational oceanography can only be obtained when observations and modelling are integrated at scales from global to regional to local. The Black Sea countries have global interests in the development of GOOS and intend to collaborate with the participants in EuroGOOS.

3.3 COMPONENTS OF THE STRATEGY

The following action items are of strategic importance:

- Identification of users, customers and beneficiaries, and of their requirements for data and products;
- Study of the actual and potential economic efficiency of the Black Sea GOOS;
- Development of the scientific basis of Black Sea GOOS;
- Design of the technological basis of Black Sea GOOS;
- Design and development of the observing system;
- Design and development of information exchange and distribution system;
- Development of numerical modelling, data assimilation and forecasting;

- Product development for customers;
- Capacity-building to help customers to understand the benefits of Black Sea GOOS and to apply GOOS products better;
- Interface with EuroGOOS and other GOOS organizations.

3.4 ASSESSMENT OF THE BLACK SEA USERS' REQUIREMENTS FOR DATA AND PRODUCTS

The assessment of the Black Sea users' needs and requirements for data and products should be achieved by a step-by-step "GOOS marketing" strategy. The successful assessment needs very strong interactions between oceanographers and end-users, since the end-users may not be aware of what could be the real benefit of GOOS, and the oceanographers may not be familiar with the end-users' needs.

Oceanographic research is not yet able to provide data and products in the short term before the infrastructure of the Black Sea GOOS is created. On the other hand, the establishment of a full infrastructure (operational observations, including an open-sea information system to exchange and distribute data and products, and a modelling and prediction system) requires big financial investment, effort and time.

Therefore it is important to demonstrate the eventual effectiveness and benefits of the Black Sea GOOS as soon as possible. Data products should be generated as the Black Sea GOOS develops. "Early" products could be primarily based on single variables or types of observations, such as wave conditions, sea-surface temperature, sea ice or thermocline depth. Today, although some "early" products are available, they are not used properly by the end-users, because not all of these users are well informed and prepared. Such a flow of products will demonstrate in every country of the Black Sea area early and continuing economic and social benefits, as applications and interpretations can be made for local and national planning and decision-making purposes.

The first step in the assessment of users' needs could be the identification of services already being provided in the Black Sea region, such as wind and wave forecasts for maritime transport, ports, etc., environmental and meteorological data bulletins for the tourist resorts, specialized forecasts for the oil platforms, storm warnings for all marine industries, etc., and the dissemination of the operational creation and the distribution of these products to the end-users in the Black Sea countries. Later a public demonstration with discussions should be organized in all Black Sea countries to show and inform the decision-makers in the marine fields of activity, and the general public, what are and what could be the Black Sea GOOS benefits. The discussion should become the basis for the next step, which is the user-needs assessment. The full list of potential Black Sea GOOS data and products is presented in Annex VIII of Black Sea GOOS Report No. 1 (Albena, Bulgaria 11–15 October 1999).

3.5 CUSTOMERS

The experience of some Black Sea countries shows that it is possible to find a substantial number of potential customers in each country. Operational oceanography can provide immediate benefits in the Black Sea area in such activities as: port operations; ship routing; tourism; fisheries; coastal protection; offshore oil and gas; climate prediction; public health; pollution management; aquaculture.

Potential areas of application of the Black Sea GOOS data and products are presented in the Black Sea GOOS Report No. 1.

3.6 THE BENEFIT TO THE BLACK SEA COUNTRIES

To assess the economic and social benefits from operational oceanography, Black Sea GOOS activities will be designed to foster operational oceanography in the Black Sea basin, to collaborate with, and maximize the benefits from, EuroGOOS and MedGOOS, and to promote the integration of these activities into the framework of GOOS.

Black Sea GOOS aims to promote studies and evaluation of the economic and social benefits produced by operational oceanography. Black Sea GOOS is a joint effort of all bordering countries, which will set the basis for the monitoring, modelling and forecasting. The collaboration of the other Black Sea countries will have an impact on marine-related industries and services, such as coastal recreation, transportation and fisheries. Among the riparian countries, Bulgaria, Romania, Ukraine and Georgia can have access to the world's oceans only through the Black Sea. Thus the Black Sea is one of the important socio-economic links for these countries. Black Sea GOOS will play an important role in the sustainable use of this sea and improve the quality of its environment. Russia has a coast on several seas, but the Black Sea is the only sea that is warm enough to allow recreational activities. Improving the water quality of Black Sea through Black Sea GOOS will increase the quality of life in this country. Turkey has a coast on the Mediterranean Sea, the Aegean Sea, the Sea of Marmara and the Black Sea, but over 80% of the fish catch of Turkey is from the Black Sea. Typically, the marine industries and services contribute between 3% and 5% of GNP for a developing coastal state (EuroGOOS, 1996). Black Sea GOOS can add significantly to the efficiency, safety and productivity of these activities. Additional benefits arise from the use of marine forecasts and data to improve and extend seasonal and inter-annual forecasts of weather and climate over the adjacent landmasses. Accurate estimates of the GNPs of most of the Black Sea coastal states are not available simply because, for some, they have not been estimated at all. As a result, a cost–benefit analysis involving all the six Black Sea states is improbable at the outset. For Turkey alone, the contribution of the Black Sea is estimated to be 0.6–1.0 billion USD. If the benefits gained by a predictive system are taken to be 0.1% of this amount, it would imply benefits of 0.6–1.0 million USD. This can be extrapolated to the other Black Sea countries, yielding 2–3 billion USD for the region.

3.7 THE RISK OF NO ACTION

Failure to exploit the previous investment and failure to invest further by developing awareness in the marine services of the Black Sea countries will lead to less efficient maritime industries, increased losses from poor environmental management and marine pollution, increased public health risk, and penetration of Black Sea markets by European organizations offering services in the Black Sea area. In such a case, the Black Sea institutions and companies for oceanographic services would fail to gain their share of a global market measured in billions of dollars. Inadequate marine environmental prediction systems will result in lack of investment in projects which appear environmentally sensitive, but which could be acceptable and beneficial if exploited intelligently.

3.8 RESOURCES

In the Black Sea countries there are already different facilities, which may form a basis for the development of operational oceanography. These include the national hydrometeorological services with their operational coastal observations, marine forecasting services, infrastructure and data management, as well as the experience of many oceanographic institutions in marine scientific experiments, numerical modelling, remote sensing, etc. A substantial number of institutions in the Black Sea countries participate in various joint projects supported by international agencies such as WMO, IOC, NATO–ESAD, GEF, EU etc.

Most of the Black Sea countries have economies in a state of transition, so there are enormous difficulties for funding to upgrade the existing technologies that eventually serve the development of operational oceanography. In such a situation the integration of existing projects supporting the development of operational oceanography in Europe, as well as the creation of new acceptable Black Sea GOOS projects with external finance, is vital.

Operational oceanography provides an opportunity for investment and development, which promises to produce a significant economic return to the Black Sea countries and to provide extensive benefits in management of the environment, protection of public health and safety, and assistance in the prediction of climatic change.

3.9 EXISTING OBSERVATION AND MONITORING SYSTEMS ARE THE BASIS OF BLACK SEA GOOS

Black Sea GOOS will build on existing observation and monitoring systems and will develop mainly through commitments from the participating agencies. Presently, most of the components of an operational system are available within national or international programmes. The main tasks for Black Sea GOOS will be to co-ordinate activities, develop coupling and interfaces, operational and technically compatible routines, to optimise the scientific design of the sampling system in terms of observing strategy and quality control, to improve components and harmonize products based on *user* requirements and economic assessments. These are complex technical matters requiring the application of new technology and science.

To meet user requirements, both geographical coverage of the products and regular products on different levels of data aggregation are lacking. Today most oceanographic products are produced in a classical academic way, which means that they are seldom very user-friendly or available when needed.

The aim of Black Sea GOOS is to capture and process information about the sea and convert it into products required by a wide range of end users. In some Black Sea countries this activity is already being carried out by the national meteorological services that provide a wide range of marine meteorological and oceanographic information to support shipping, fisheries, coastal-zone management, tourism and recreation, thus improving the safety of life at sea.

The primary task is to integrate the existing systems into an entity able to meet the users' demands for a high-quality operational oceanographic service and to minimize the production costs. Black Sea GOOS will be implemented through two modules:

- ***Marine Service Module (MSM)***
- ***Regional Management and Analysis Module (RMAM)***

The first module is concerned with the development of products and services, and the second module meets the scientific and technical requirements of a definable subset of users.

These modules are based on optimal utilization of the existing facilities and improvement in the observations and modelling. This includes:

- Co-ordination of existing observation facilities supplemented by identification and establishment of required additional observation facilities;
- Establishment of an efficient system for the free exchange of data amongst the participating institutions, including agreements on formats and data quality;
- Improvement of forecasting capabilities by the development of an operational mesoscale analysis system and coupling of atmosphere and ocean circulation models;
- Establishment of an information system disseminating products to the user community efficiently.

Figure 6 shows the aforementioned structure.

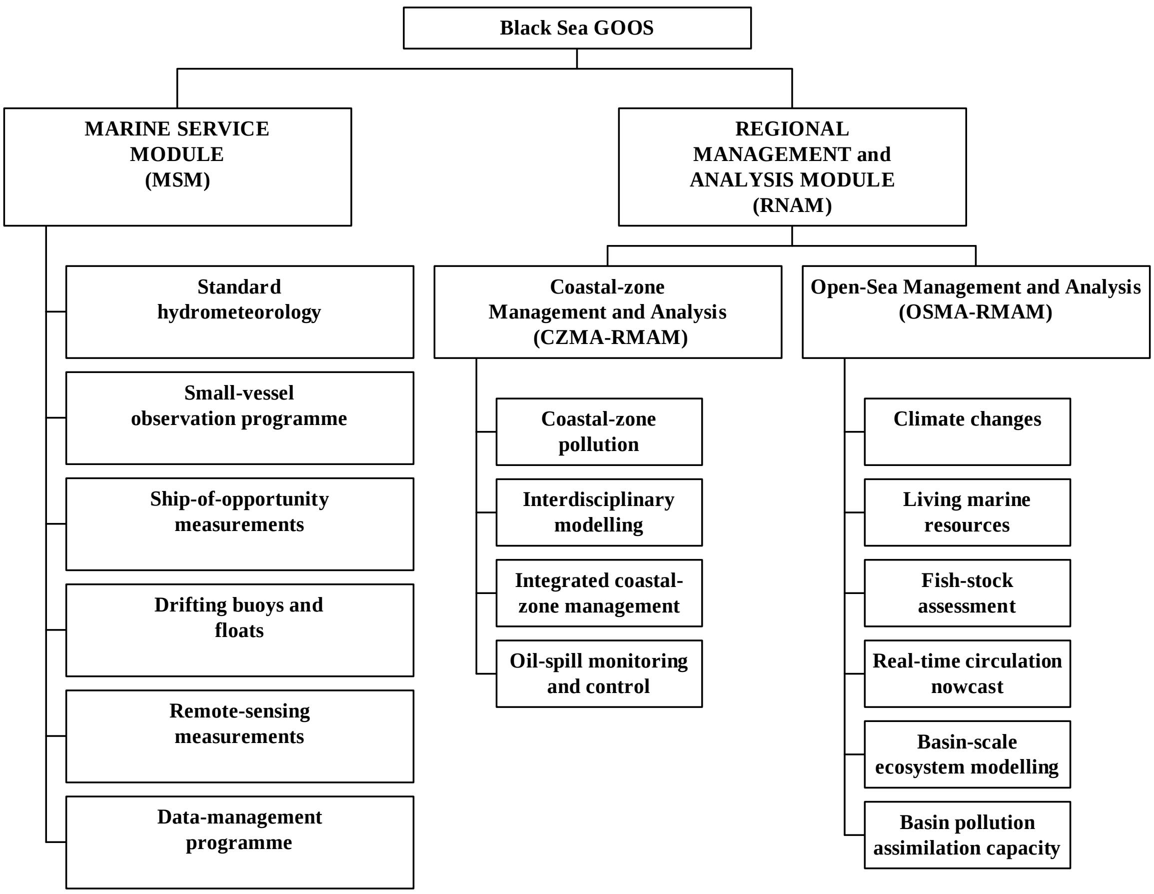

Figure 6. *Structural diagram of the Black Sea GOOS*

4. MARINE SERVICE MODULE (MSM)

The MSM will be guided by the basic principles, which means the observing system will produce data products that address a broad spectrum of user needs:

- Observations will be designed to address specific problems that occur in the basin and affect human activities at various levels;
- The users of the data and data products will interact with technical experts and scientists in designing, operating and improving the system in response to the evolving needs of user groups.

The development of MSM involves a cost-effective use of existing data, expertise and infrastructure; i.e. the entire process from measurements to products will be made as cost-effective as possible:

- MSM will incorporate, enhance and supplement existing programmes as appropriate; it will develop a comprehensive observing system through shared use of infrastructure from measurement systems and platforms to communication networks, data-management systems, assimilation techniques and modelling;
- Measurements will be routine (uninterrupted flow of data of known quality) and data will be assimilated, analysed and transformed into products efficiently;
- Products will be designed to ensure social and economic benefits that will largely compensate the operational costs of the observation system.

Process-oriented scientific research that leads to new knowledge, improved technology, and more powerful models is of critical importance to the development of MSM:

- MSM will enable a constructive and timely synergy between process-oriented research and the generation of information and products in response to user needs;
- The observing system must be integrated and sustained; the successful achievement of the goals of MSM requires that it capture a wide spectrum of environmental responses (the temporal and spatial dimensions of variability) to external forcing;
- Observations will be sustained to capture events and long-term trends (i.e. to document high- and low-frequency variability), enhance scientific analysis and support model predictions;
- The observing system will comprise a range of actions from synoptic measurements of physical, biological and chemical properties on various relevant time- and space-scales to data management (multiple data types from disparate sources) and analyses that meet the needs of end-users;
- MSM will be designed and implemented in collaboration with EuroGOOS.

The following types of measurements are within the scope of MSM:

- Standard hydrometeorological parameters;
- Monthly measurements from small vessels along selected transects from the coastal zone to the continental shelf and slope;
- Measurements along selected sections, using self-contained, auto-logging instrumentation packages on ships of opportunity (e.g. merchant vessels and ferries);

- Automatic measurements by drifters and ARGO type floats;
- Satellite observations.

4.1 STANDARD HYDROMETEOROLOGICAL OBSERVATIONS AND SERVICES

Wind, temperature, humidity, cloud cover, precipitation and evaporation are among the measurements routinely made at the Black Sea coastal meteorological stations. A tide-gauge network around the Black Sea is essential to calibrate the satellite altimeter data. All these data should be made available to Black Sea GOOS on a real- or near-real-time basis.

National meteorological/hydrometeorological services of the coastal countries maintain 46 coastal marine meteorological stations (Bulgaria – 6, Georgia – 8, Ukraine – 16, Romania – 4, Russian Federation – 5, Turkey – 7. For example, the main Ukrainian components of the national marine observation network are shown in Fig. 7). In accordance with the WMO Technical Regulations the following are measured: air and sea temperature; direction and speed of wind; height, period and direction of waves; atmospheric pressure; solar radiation; visibility; precipitation; three-hour humidity. A limited number of stations observe sea level, some chemical parameters, air pollution, etc. Some coastal marine meteorological stations have more than 50-year-long records of observations of certain parameters/elements. At all the stations observations are made manually.

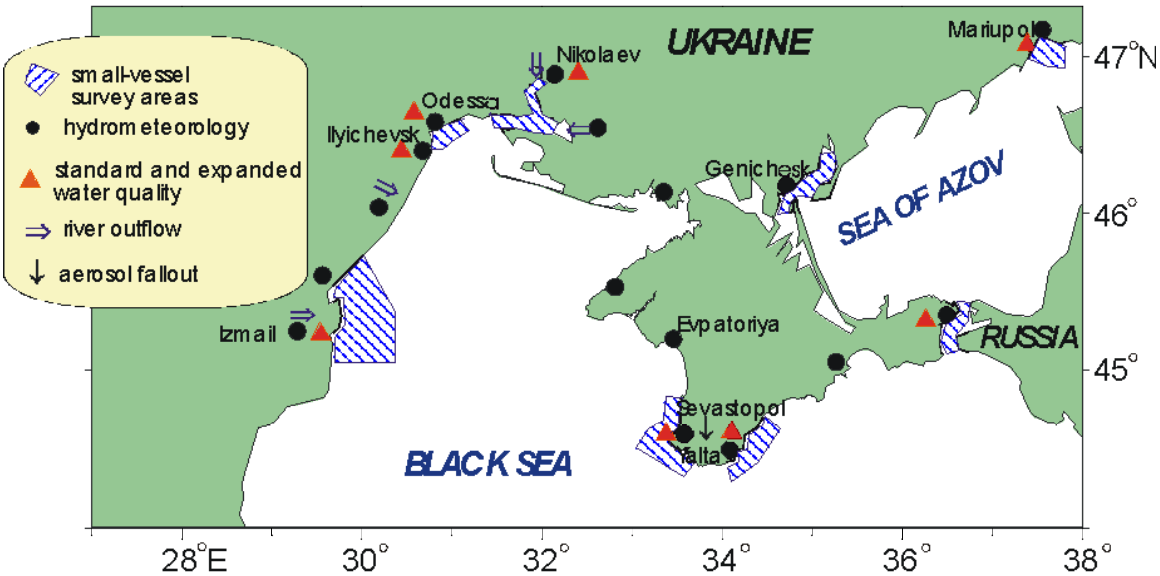

Figure 7. *Marine-observation network (main components) of the Ukrainian Hydrometeorological Service*

In addition, there are three automatic stations in Varna (Bulgaria), Constantsa and Gloria (Romania) with a limited number of sensors.

Coastal stations report their observations so that messages with coded data are collected at national meteorological centres as a rule not later than 20 minutes after the time of observation.

Marine operational forecasting systems for the Black Sea have been developed in several of the riparian countries. They typically comprise:

- A limited-area atmospheric model for the Black Sea region;
- A wave model, taking the wind input from the atmospheric model;
- Visualization system for weather and wave parameters;
- Verification procedures.

Rapid advances are being made in the atmospheric modelling. The operational models cover the Black Sea region with a horizontal resolution of about 10 km; they use sophisticated physics to describe the atmospheric and surface-soil physical processes. Two national meteorological services (Bulgaria and Romania) are using the ALADIN limited-area model coupled with the French global model ARPEGE.

The operational marine hydrometeorological services of Ukraine, Turkey, Russia and Georgia have other supporting components. A short description is presented in Annex I.

4.2 SMALL-VESSEL OBSERVATION PROGRAMME

This programme involves continuous measurements, as shown in Table 1, along selected transects (~100 km long, 6–8 oceanographic stations per transect) across the shelf, from the coast to the interior basin, carried out roughly every two weeks. The narrowness and steepness of most of the Black Sea continental shelf will impose efficient and nested monitoring observations with limited-area coverage. The measurements are carried out bi-weekly within a day or so across the coastal and shelf areas, and at continental margins. A number of small research vessels will collect data along a transect within pilot areas around the basin and off their own ports (to minimize costs of ship time). The programme will also take advantage of the fact that major marine institutes of the Black Sea own small research vessels designed for coastal and shelf studies. The programme is expected to provide time-series data to be assimilated into the nested coupled biological and hydrodynamic models. Such a programme is affordable only with small vessels, in terms of cost, practicability and vessel availability for the participating institutions. (See the proposed network in Figure 8) This programme is expected to provide unique time-series data annually for the entire basin, which is crucial to assessing the variation in the environmental parameters monitored and investigated.

At present, all of the major Black Sea marine institutes possess Sea Bird Electronics CTD probes with sampler rosettes. These are equipped with fluorometers, transmissometers, a beam-attenuation-coefficient sensor, a pH sensor, and standard biological sampling equipment. A good number of research vessels are capable of operating in the Black Sea. Sediment traps may also be deployed at several critical locations, as needed to obtain data on the particle flux from the surface layer downwards.

Table 1. *Parameters to be measured by the small-vessel programme*

Meteorological variables:	Barometric pressure, wind speed and direction, air–sea heat fluxes, freshwater flux (evaporation–precipitation), cloudiness, air temperature, and surface spectral radiation
Physical variables:	Temperature, salinity, current, light transmission, and photosynthetically active radiation at the corresponding depth and its attenuation
General variables:	SST, pH, BOD1, BODS, particulate and dissolved TOC, alkalinity, H_2S, and redox potential (eH)
Nutrients:	Orthophosphate, total phosphorus, ammonium, nitrate, nitrite, total nitrogen and silicate
Metals:	Cadmium, mercury and lead
Biological:	Chlorophyll-*a*, phytoplankton and zooplankton abundances, primary production, bacterial biomass, fluorescence
Other substances:	Persistent organic pollutants, plastics and litter, oil slicks, and petroleum hydrocarbons, contaminant level in biota

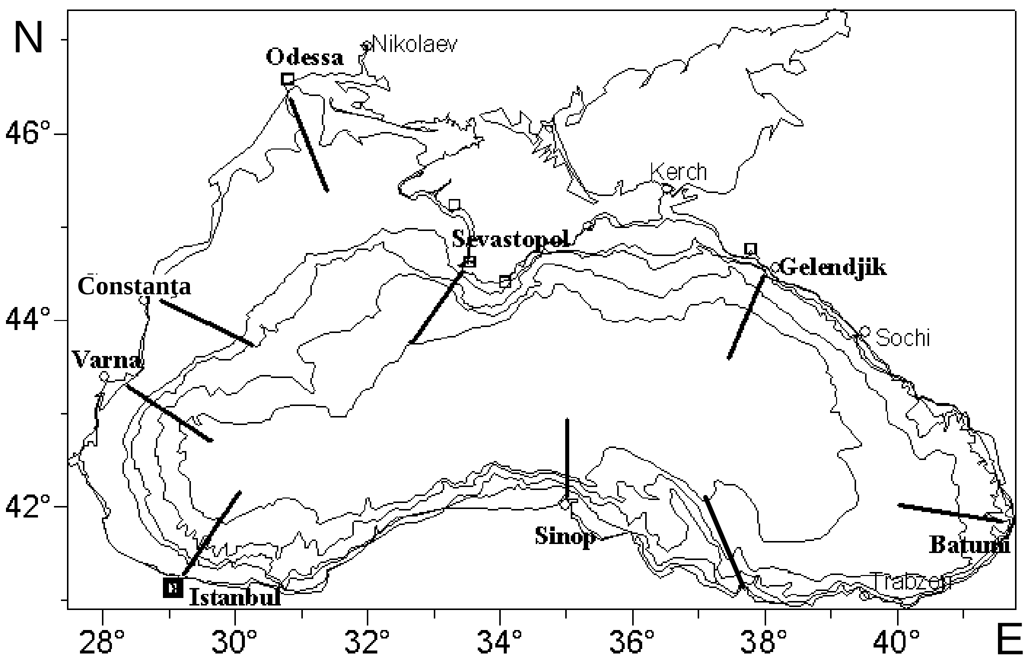

Figure 8. *Location of transects for the Small-vessel Observation Programme in the Black Sea*

4.3 SHIP-OF-OPPORTUNITY MEASUREMENTS

These data constitute the most important element of MSM's measurement system. Regularly scheduled launchings of XBTs/XCTDs, together with various discrete and continuous sampling/measurement, complement efforts to monitor the large-scale physical and biogeochemical structure of the Black Sea. Platforms used may include merchant, fishing, military or small oceanographic vessels. It is envisaged that the ship-of-opportunity measuring system for BS–GOOS, if properly organized, will suffice for the continuous monitoring of atmospheric forcing (curl of the wind stress, heat flux), intensity of the general circulation and sub-basin-scale features, optical parameters, nutrient concentrations and primary production levels at the sea surface.

Specifically, ship-of-opportunity observations will include:

- Regular meteorological observations by autonomous logging meteorological stations;
- Observations of upper-layer water-column stratification by XBT or XCTD launches;
- Continuous measurements of sea-surface temperature, conductivity and bio-optical variables with a standard CTD probe by continuous pumping of water through a reservoir with a volume of approximately 0.5 m^3;
- Observations of currents, sea-surface temperature and atmospheric pressure by means of drifting buoys launched from ships of opportunity;
- Observations of currents, sea-surface temperature and atmospheric pressure, and temperature profiles of the upper 200 m (thermocline topography) by diving drifters also launched from ships of opportunity;
- Discrete sampling for the onboard measurement of concentrations of various biogeochemical variables, using an express-analyser technique, or concentrations of pollutants;
- Discrete biological sampling (for phyto and zooplankton abundance) at the sea surface;
- Continuous plankton-recorder observations;
- Ferry boxes.

Man's activities have greatly increased the input of chemicals which act as nutrients for plankton growth in the sea. To study the effects of these nutrients on plankton blooms in the Black Sea, autonomous remote-observing systems should be created, to provide essential data on algal-bloom dynamics relative to the physical and chemical conditions in the water. A key aspect of these systems is the use of sensor packages installed on ferries (so-called ferry boxes). This measuring equipment provides reliable data with minimal human intervention.

Possible measurements would be chlorophyll–fluorescence, turbidity, salinity, temperature, ship's position and time, at a rate of 1 Hz, which gives a spatial resolution of about 7 m when the ferry is at full speed. From these data, maps can be drawn detailing the size of plankton blooms and when and where they occur.

Ferries run regular and consistent routes, providing the systematic data required for detecting changes in the oceans and for running models. The concept of using ferry boxes is an initiative of EuroGOOS. Globally, such measurements will play a vital role in determining the pace and consequences of environmental change.

Figure 9 depicts the common ship routes in the Black Sea; for each route, the number indicates the fewest ships regularly operating on that route. The crews of these ships are generally well acquainted with oceanographic fieldwork. These ships operate on a regular weekly basis from Odessa, Evpatoria, Sevastopol, Yalta and Novorossiisk. At speeds of 9 to 11 knots, it takes 20 to 35 hours from the western ports and about 45 hours from Novorossiisk to reach Istanbul. This means that every 3 to 4 days each ship crosses the circulation features of the basin. It is logical to recruit one ship of opportunity each from Odessa, Evpatoria, Sevastopol, Yalta and Novorossiisk. The ship-of-opportunity measurement system, when properly organized, may thus provide an excellent opportunity to monitor the basin, sub-basin and mesoscale features of the system. The measurements will be selected from the list in Table 1, depending on the capabilities and opportunities, and may vary from vessel to vessel.

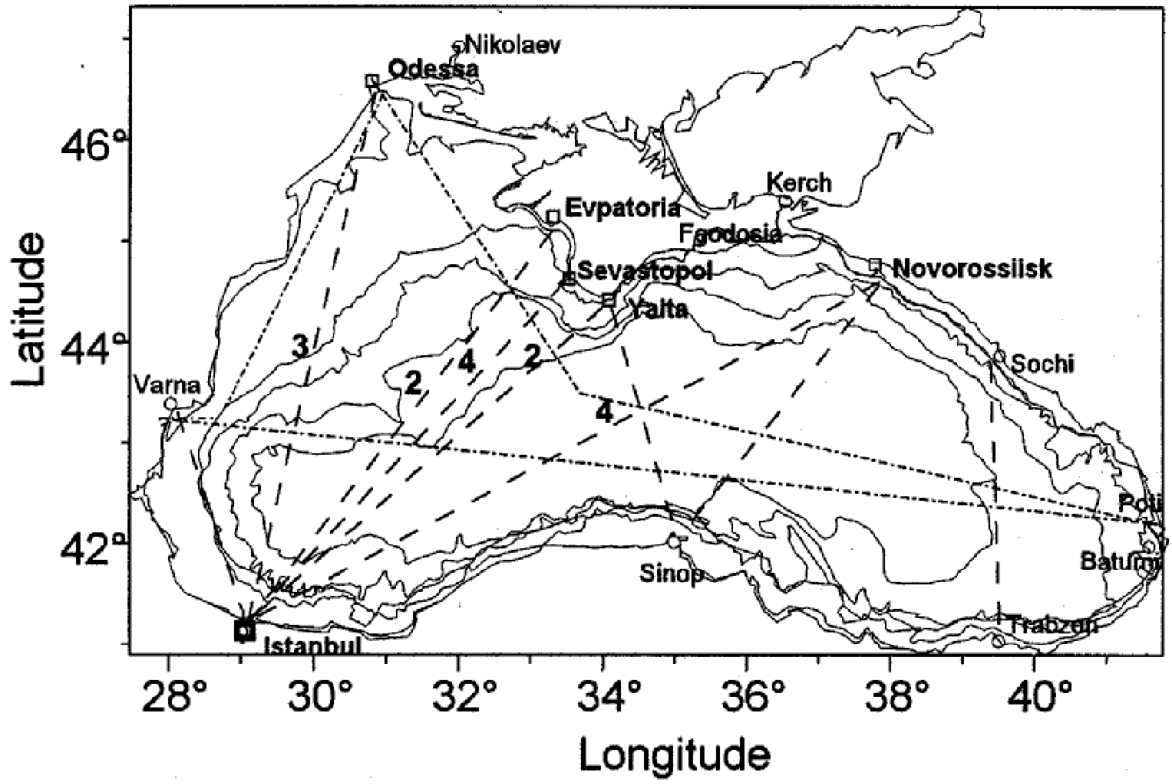

Figure 9. *Common ship routes in the Black Sea*

4.4 DRIFTING BUOYS AND FLOATS

Drifter data facilitate better understanding of the dynamics of the Rim Current and the associated mesoscale circulation (Fig. 10). Drifters may be deployed either at fixed-depth or fixed-density levels. The use of drifters and drogues for biological studies is relatively recent. Drifting buoys carrying a spectro-radiometer, a fluorometer, a beam transmissometer, an acoustic Doppler current profiler, thermistors and conductivity sensors are available and are used successfully in various observational programmes. The drifting buoys may even carry an automated water sampler from which water is collected at 6-hour intervals for plankton and nutrient analysis. Another type of drifter, the ALACE float, is able to operate both vertically and horizontally in the water column, providing a three-dimensional picture. The main advantage of drifters over other platforms is that they provide a relatively inexpensive means of obtaining broad geographical *in situ* sampling.

The temperature measurements from surface drifters may be used to calibrate satellite SST data, particularly when and where shipboard observations are sparse or non-existent. When they are equipped with thermistor chains measuring water temperature down to about 300 m or programmed to undulate, they will also provide a cost-effective way of complementing hydrographic sections carried out by research vessels or by ship-of-opportunity XBTs.

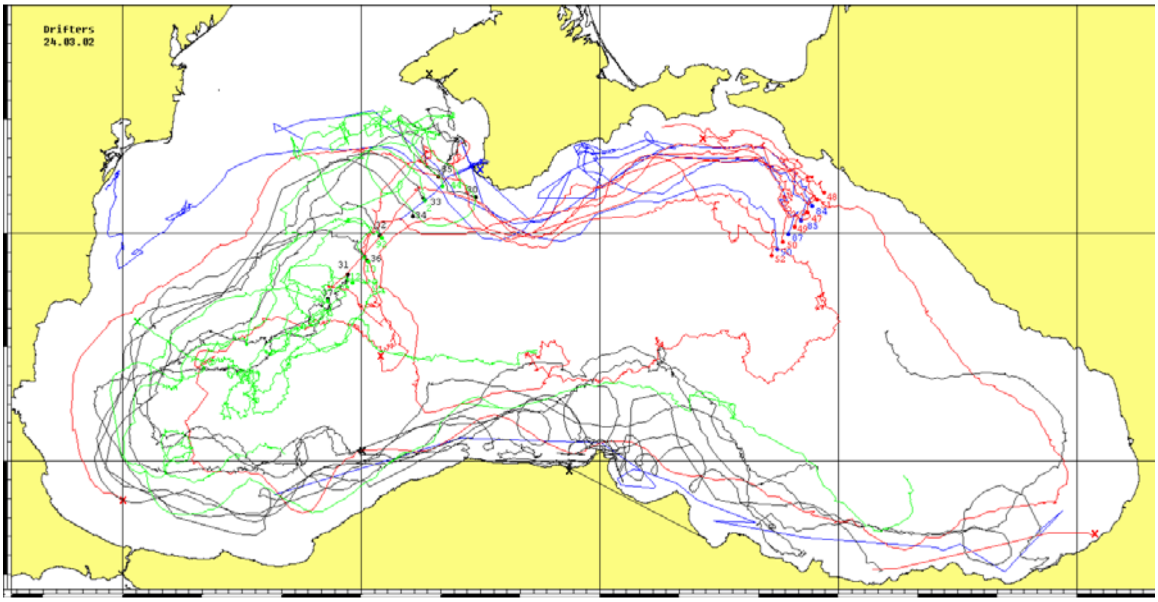

Figure 10. *Trajectories of 35 drifters from 22 October to 23 March 2002*

Another advantage of the drifters is that they can be deployed from research vessels as well as from ships of opportunity, thereby allowing a flexible network of observations.

4.5 REMOTE-SENSING MEASUREMENTS

In situ measurements of oceanographic properties using moorings, drifters and sampling on station by research vessels and ships of opportunity are complemented by satellite remote-sensing data, which provide quasi-synoptic, basin- and sub-basin-scale knowledge of biological production and plant biomass (via SeaWiFS), sea-surface temperature (via advanced very high resolution radiometer, AVHRR) and sea-surface height (via Topex–Poseidon and ERS2 altimeter measurements). The latter two techniques help determine the large-scale and mesoscale near-surface currents which are important for the advection of living and non-living constituents and the identification of shelf-sea fronts, banks and ridges, shelf edges and upwelling zones, where zooplankton and fish populations are known to accumulate for feeding, spawning, and early-life development. LANDSAT images are also useful for identifying pollution sources and tracking land-use changes.

Additionally, the NSCAT scatterometer provides data on the wind speed to within 2 m/s and on wind direction to within 20 degrees, with 50-km spatial resolution and 2-day sampling interval. These data have been available since late 1996.

The remote sensing and observations must be considered together. They can constitute a virtually complete set of sampling strategies covering the full spectrum of time- and space-scales. The remote-sensing technology gives quasi-synoptic snapshots of a large area with fine spatial resolution, which is practically impossible using drifters and other *in situ* techniques. On the other hand, conventional oceanographic measurements provide high-resolution data on the water column and include a wide range of measurements of biological, biochemical and physical properties, which cannot be obtained by remote-sensing methods. The synergy between *in situ* and remote-sensing measurements is therefore vital.

4.6 DATA-MANAGEMENT PROGRAMME

Efficiency in the data flow is essential for an operational forecasting system. The relevant data sets, which are planned to be assimilated into the operational prediction systems, must be received, assembled, quality-controlled, processed and transmitted in near-real time. The data sets and derived products must then be disseminated to the user community and be archived. The database for Black Sea GOOS must include not only the standard oceanographic and marine environmental data, but also the meteorological time-series and the remotely sensed observations, such as the SeaWiFS, AVHRR and Topex/Poseidon. Some modelling results for selected comparisons and later studies should also be included in the data base.

The Black Sea Data and Information Management System (BS–DIMS) will be based on contributions by marine and meteorological organizations, institutes and data centres in the Black Sea Region. Various international as well as national and regional Black Sea programmes under development have different data- and information-management strategies encompassing physical, chemical, biological and hydrometeorological observation. Initial implementation of Black Sea data and information management will be accomplished in an interactive fashion by linking the existing data banks.

The diversity of the existing systems and the lack of specific details on the future requirements prohibit implementation in the near future of a centralized data-management system with strict control of formats, quality-control procedures, accuracy and precision standards, and data-product “certification”. Thus the BS–DIMS is designed to develop guidelines on data-management practices for the programmes contributing to the Black Sea GOOS.

There are two other important items that must be included in the design of the BS–DIMS. There is a need to connect the programmes and the participating data and science centres under a unified and centralized “information services system’’. This contributes information about the programmes and observations and shows how to access the data. The second item is the requirement for carefully designed and automated self-controlled data and information flow. Thus the working of the system can be monitored periodically, and problems located.

There are four general classes of users of the Black Sea GOOS data and information:

- Operational users;
- Authorities and managers of large-scale projects;
- Tourist industry;
- Scientists, engineers and economists doing special research, strategic-design and other studies to advance the application of the Black Sea GOOS data and information.

The operational users analyse the data that have been collected and then produce a prediction of weather, sea state or the sea level, so as to anticipate a severe storm, to implement a regulation, such as the closure of a fishery for a specific health danger.

The authorities or managers of large-scale projects need timely oceanographic information, which includes regular statistics and climatic trends.

Scientists, engineers and social scientists require accurate, long-term data sets for: research on physical, biological and chemical oceanographic processes; model development and testing; design criteria for ships, structures and marine facilities; and studies of the effect of climate change on economies and populations, etc. For these types of users, accuracy and completeness of the data sets are more important than availability of the data in real or near-real time.

The BS–DIMS requires a series of intersecting end-to-end procedures that must:

- Ingest various versions of *in situ* and satellite data and metadata;
- Apply the appropriate level of quality control based on the delivery time for each data set or product;
- Provide for the efficient archival for updating of data as information becomes available;
- Provide for the archival of the best available final copy of the data, metadata and products for future users, with updates of the archives if re-analyses are done or better copies of the data and information become available;
- Provide feedback on data problems to data-acquisition groups, on the usefulness of the data and products to users and to the developers of the systems, and on the timeliness and completeness of the data flows to data collectors and managers of the data flows.

Most of the systems in operation today have been targeted for one class of users; for example, the weather services or physical oceanographic researchers. The products have generally been left to these users. The Black Sea GOOS needs a different paradigm: the service chain.

The service chain embodies the idea of a distributed system that takes data, performs quality control, analyses the data if necessary, delivers product to a broad community at various times after collection, and archives the data for continuing service to the research and engineering community.

Electronic networks will play an increasing role in the development of BS–DIMS. Therefore existing communication capabilities must be improved significantly in the initial stages of Black Sea GOOS. The availability of faster Internet connections in the region is crucially important for the successful implementation of the Black Sea GOOS.

The oceanographic institutions participating in the Black Sea GOOS programme have long-standing experience of data-handling procedures. The software and hardware capabilities, however, need to be updated to handle large volumes of data flow from satellite-tracked observation systems and for archiving. The software also needs to be extended to provide the means for joint processing and analysis of a variety of data. A specific database policy must be developed and approved by all the participants.

A critically important topic is relevant metadata collection. Metadata are crucial if data are to be interpreted properly and readily used across disciplines. All possible effort must be made to provide, at least, concise metadata with all historical data sets. Recent data must be supplied with full metadata in all cases. Metadata have to be in a form that can be used efficiently by all data analysts.

Data quality has a fundamental importance for the Black Sea GOOS. Attention must be paid to data-quality control and the arrangement of data sets with pertinent and internationally accepted quality flags throughout the data flow. The proper protocols for data collection and treatment should be defined (especially for biogeochemical data). Accepted international standards should be used wherever possible for media, formats, processing and transmission of data sets.

Quality time-series and climatic data sets must be created in the Black Sea GOOS. Special software should be designed to provide user-friendly access to this type of data.

The entire BS–DIMS data sets, operational and historical, will be collected and managed. Most data systems implemented in BS–DIMS will have operational data flows. The management of model data will be one of the fundamental elements of BS–DIMS, because all the aspects of climate and global change of the Black Sea state will come through models that assimilate data and produce fields interpolated in space and time, in either now-cast or predictive modes.

4.7 STRATEGIC PLAN OF THE MARINE SERVICE MODULE DEVELOPMENT IN 2002–2006

4.7.1 *General Terms*

The near-future mission in MSM is to identify the addresses and personal contacts for at least 50 potential customers and user agencies for operational oceanographic information and forecasts in each country in the Black Sea region. The identification of customers and their requirements for operational information and data products is definitely possible but not easy. There are different classes of users for each level of data processing, starting with raw observational data, and working through stages of data-quality control, assembly, gridding, assimilation, modelling and high-level product generation. Each industrial, commercial or governmental sector also requires different parameters and variables to be processed in different combinations, for predicting different impacts.

4.7.2 *Short-Term Objectives for 2003–2005*

A successful operational marine service is not possible without appropriate infrastructure for the Black Sea GOOS. This infrastructure includes all kinds of required regular observations, information technology for telecommunications and data management; as well as the technologies for data processing and creation of real products and their distribution to the end-users.

A working group on operational marine services, comprising scientists, technical experts and end-users needs to be established to identify the needs for marine data and forecasts.

The proposed working group on operational marine services should undertake certain key activities:

- Investigate what improvement in the operational observing network could be achieved in the near future, particularly covering:
  - Regular observations (e.g. sea temperature, salinity and atmospheric factors) along several routes in open sea (on ferryboats),
  - Marine observations at coastal marine observing stations,
  - Observations by regular time-series stations,
  - Small-vessel observations in the coastal zone,
  - Satellite remote-sensing data (SST and surface currents);
- Take all necessary actions for the creation of the most appropriate operational models for the forecasting of weather, waves, warnings, sea ice, temperature, salinity, sea level, oil drift, etc;
- Co-operate and co-ordinate its activities with those of other teams on up-to-date forecasting and prediction models for the sea–atmosphere circulation and ecological models;
- Prepare and organize technical demonstrations for end-users in every country;
- Promote close co-operation with EuroGOOS;
- Investigate the possibilities for external investment in the creation of the Black Sea GOOS infrastructure, collaborating with the programmes developed by EU, IOC, WMO, GEF, NATO–ESAD, etc.

A task team should be created and charged with the implementation of a pilot study of the operational oceanographic information system for the Black Sea region providing:

- Real-time telecommunications between operational observing stations and processing centres and agencies;
- Access for the most important end-users to up-to-date operational oceanographic services.

4.7.3 *Medium-Term Objectives for 2005–2007*

To achieve the medium-term objective the working group on operational marine services should undertake the following activities:

- Create the infrastructure for the Black Sea GOOS including the most appropriate forecasting and prediction models, as well as data management using up-to-date distribution technology;
- Develop a routine system of customer identification;
- Develop a regular schedule of dialogues with users groups should be developed;
- The full establishment of the operational oceanographic information system (Intranet) for the Black Sea region providing:
  - real-time telecommunications between operational observing stations and processing centres and agencies,
  - access of the most important end-users to up-to-date operational oceanographic services,
  - broaden the customer base by strengthening links to climate variability forecasting,
  - continuing technical demonstrations for end-users in every country,

– as for the short-term objectives, promotion of investment and external funding through collaborative projects with the relevant international organizations and agencies.

5. REGIONAL MANAGEMENT AND ANALYSIS MODULE (RMAM)

Data and information management and the transformation of data into useful products comprise an essential element of the RMAM of the Black Sea GOOS. RMAM data products, such as forecasts and now-casts of sea and marine-ecosystem states, are logically produced on all scales, typically involving large sea areas.

Regional analysis centres (RACs), which would serve to compile data and information on appropriate scales, and to generate appropriate forecasts and other data products, should be the fundamental unit on which RMAM of the Black Sea GOOS is developed. The regional marine science organizations can host RACs that exist as regional observing programmes.

The implementation of the RMAM of the Black Sea GOOS will be facilitated by the establishment of two panels:

- ***Coastal-Zone Management and Analysis (CZMA–RMAM)***
- ***Open-Sea Management and Analysis (OSMA–RMAM)***

These panels are necessarily inter-related and intersecting, and they will share observations, data networks and facilities, as needed, within one integrated system.

An improved understanding of the coastal and open sea can lead to mitigation or prevention of severe problems due to eutrophication or overexploitation of resources. This understanding probably depends ultimately on relatively few fundamental scientific principles that govern how the coastal and open sea work, and how they interact with processes inshore and farther offshore.

5.1 COASTAL-ZONE MANAGEMENT AND ANALYSIS (CZMA–RMAM)

Societal interest in coastal waters has always been high, but increasing human migration to coastal communities raises complex public-policy issues ever more frequently. Long-term continuing concerns, such as efficient and sustainable utilization of natural resources and preservation of environmental quality, are augmented by local problems that range from local fish kills to medical waste discharged on beaches.

The coastal zone is a unique environment in that it is the only place on Earth where terrestrial, marine, atmospheric and human inputs of energy and matter all converge. It also supports the greatest concentration of living resources and people on 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 to receive, process and dilute the effluents of human society will increase. Therefore, it should come as no surprise that coastal ecosystems are experiencing unprecedented changes, from habitat loss, oxygen depletion, harmful algal blooms, fish kills, and declining fish stocks to beach closures, coastal erosion and flooding. The resulting conflicts between commerce, recreation, development, utilization 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 detect and predict the changes that are occurring in coastal ecosystems.

CZMA–RMAM is designed specifically for the coastal zone, with the continental shelf break being taken as the seaward boundary. Accomplishment of the tasks requires a coherent programme with observational, monitoring and modelling components. Four independent subprogrammes complement each other: (1) Pollution monitoring; (2) Interdisciplinary modelling; (3) Coastal-zone management; and (4) Oil-spill monitoring and control. Each subprogramme is described briefly below.

5.1.1 Coastal-Zone Pollution

Pollution can induce changes in the biogeochemical structure and ecosystem characteristics of the Black Sea. Therefore an estimation of its extent is needed for the sustainable development of coastal and marine resources. This requires:

- Assessment of the state of the Black Sea and its resources;
- Identification of existing environmental problems;
- Documentation of natural and man-made changes in the ecosystem;
- Support for research by making available scientifically valid data;
- Provision of data to environmental managers to help them: ensure the maintenance of the biodiversity and integrity of marine communities; minimize the loss of species; limit human influences on living marine resources; protect critical habitats; and safeguard human health.

CZMA–RMAM focuses on biogeochemical–ecological measurements for understanding the present status of and future trends in:

- Ecosystem processes (productivity, nutrient fluxes, plankton biomass and species composition);
- Biodiversity, habitat loss and degradation;
- Changes in community structure;
- Industrial organic compounds and trace-metal concentrations.

The collective sampling and observational systems needed to accomplish the goals of CZMA–RMAM will require information on many interdisciplinary variables monitored on a broad range of time- and space-scales. All the riparian countries of the Black Sea should design the ultimate sampling system to be as cost-effective and affordable as possible. The sampling plan will include a comprehensive set of measurements that support environmental-management issues, including sustainable use of Black Sea resources. Sampling strategies must include time-series to provide continuity of data for adequate characterization of inter-annual variability and long-term trends, seasonal cycles and variability, sub-mesoscale and mesoscale eddies, jets, fronts (days to months), high-frequency cycles and phenomena (e.g. surface, internal and inertial waves, and tides). A hierarchy of sampling systems will provide a continuum of information on space-scales from a few kilometres up to 200 km, and time-scales from a day up to a few months.

Sampling and monitoring of "hot spots" (typically located near riverine inputs, harbours and marinas, industrial sewage outfalls, fish farms and other aquaculture facilities) in coastal and nearshore water on the basin periphery should occur as frequently as possible, preferably once a week, which is within the scope of the CZMA–RMAM. The major hot-spot locations are shown in Figure 8; the exit of the Bosporus to the Black Sea is considered an important one. Farther offshore, in the open sea, sampling and monitoring may be performed at monthly or seasonal intervals.

The monitoring of contaminants that can threaten public health through direct human contact or seafood consumption is important for managing the coastal ecosystem. Toxins that occur naturally in marine organisms and in alien pathogens that enter the marine environment through sewage and industrial discharge may be hazardous. Monitoring these toxins, however, will not be considered by CZMA–RMAM.

The proposed list of measurements and the sampling strategy may be revised, based on logistical considerations and the available information. Some of the CZMA–RMAM sampling and measurements should be co-ordinated with other relevant national and international programmes.

5.1.2 Interdisciplinary Modelling

The western Black Sea shelf is a region of active biogeochemical interactions between the land and the deep, interior basin. It provides a pathway for receiving, transferring and transporting large amounts of terrigenous, natural and man-mobilized materials from the land to the interior of the basin. The flux of this terrestrial material and its spatial and temporal variation and its ultimate fate need to be understood quantitatively. CZMA–RMAM proposes a set of numerical-modelling studies to support the monitoring programme, to evaluate and to understand the coastal-zone problems, and more specifically to:

- Assess and quantify the important processes controlling seasonal to inter-annual fluxes of carbon and nutrients between the atmosphere and the continental shelf;
- Determine the capacity of this coastal system to transform and store particulate and dissolved matter;
- Quantify the effects of changes in external forcing conditions on the structure and functioning of coastal ecosystems.

CZMA–RMAM involves three different modelling approaches using budget, process and system models. The starting point is to construct **budget models** to estimate the fluxes of water, nutrients and other materials in the western Black Sea shelf region over annual and multi-annual time-scales. Budget models include all major sources and sinks, both external and internal, as well as the predominant processes of internal transformation of the environmental components in question, and usually require a substantial amount of quantitative data. Comparing fluxes through the system that differ in certain environmental parameters, these models can make tentative predictions of the consequences of environmental change. For more elaborate predictions, budget models will be essential to the identification of key processes and to the production of dynamic simulation models based on coupled-process models.

Process models identify specific physical, chemical and biological processes important in the coastal zone and how they are influenced by major environmental forces (e.g. wind, temperature, light). They are generally constructed on the basis of process studies carried out in the field or laboratory. In most cases, they are developed in isolation from the total system with a limited number of variables and parameters and with the use of a specific empirical data set gathered at a specific location. Individual process models constitute important building blocks of more sophisticated system models.

System models, commonly built using process models, attempt to describe the behaviour of the whole ecosystem of the region and embrace its physical and biogeochemical aspects. They integrate information on what are considered to be the most important variables and processes for the entire ecosystem, and focus on describing the interaction among state variables. System models have well defined spatial boundaries and temporal scales, and their behaviour depends upon the scales selected. They can be either descriptive (e.g. flow or network analysis) or dynamic (e.g. simulation models).

Today's most advanced system models describe coastal circulation. The few major physical forces in play are relatively well understood. Three-dimensional circulation models with high spatial resolution have been developed for a large number of estuaries, bays and continental-shelf regions. These models provide an essential foundation for developing models of sediment transport, water quality and ecosystems. The Black Sea scientific community is particularly advanced in circulation-modelling studies, and several models with different levels of complexity are readily available for the western Black Sea shelf zone.

The most complicated and least reliable group of system models is the **ecosystem models.** They cover physical, chemical and biological processes, variables, and parameters, many of which are poorly understood. Developing them also requires a substantial investment of resources. Recent modelling efforts (Oguz *et al*., 2000b, 2001a, 2001b), particularly applied to the central Black Sea's conditions, are well suited for this type of study and will be adopted for the western Black Sea shelf waters to study and clarify the present state of the secondary and higher trophic-level community structure, the impacts of ecological perturbations due to the introduction of exotic species, as well as the impact of seasonal and inter-annual variability on the water-column biogeochemistry. A conceptual model of the coastal ecosystem is illustrated in Figure 11.

System models may also predict the system's response to both natural variability and human activity (e.g. changing sea level, increased temperature, reduced freshwater runoff, and increased nutrient input) and to understand how environmental variables influence critical biogeochemical processes. This approach is particularly useful for extrapolating the present state of the ecosystem to the future and predicting the system's functioning under new conditions. The predictive capability of ecosystem-simulation models can be used as a management tool for investigating alternative management plans and response scenarios to climatic and man-made environmental changes.

Although ecosystem-simulation models are usually limited by lack of theoretical and experimental knowledge of the performance of all components of the ecosystem, when applied correctly, they can provide useful insight into the system's internal processes. The description of these processes can help predict system behaviour with changes in the control functions, such as are envisaged with environmental change. We can avoid some of the theoretical and experimental limits of these models by conducting parallel studies on process models and more systematic measurements.

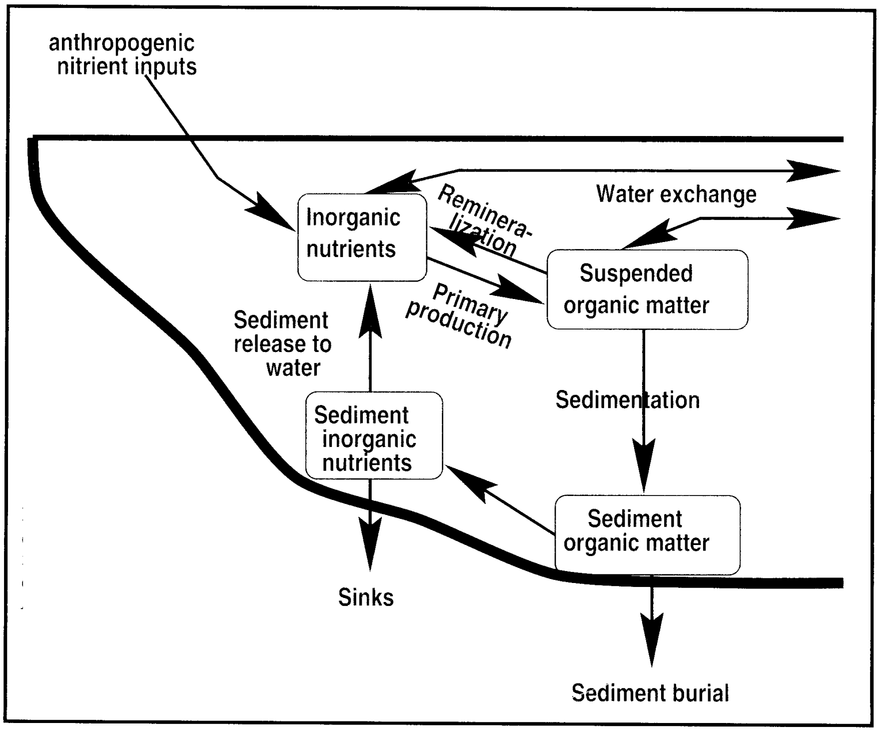

Figure 11. *The food-web model applied to the coastal zone of the Black Sea*

5.1.3 Integrated Coastal-Zone Management

The rapid coastal growth, the depletion and destruction of resources and the strategic importance of coastal-zone environments require the Black Sea's coastal nations to develop and implement coastal-zone management programmes that allow continued use of the resources for economic development. **Integrated coastal-zone management,** in this context, is a dynamic process that develops a co-ordinated strategy and implements it to achieve the allocation of environmental, socio-cultural and institutional resources for the conservation, rehabilitation and sustainable multiple use of the coastal zone. It should be conducted so as to meet the needs of present and future generations and to preserve essential ecological processes and biological, landscape and cultural diversity.

Establishing a system of coastal-zone management necessitates institutional and legislative tools to ensure participation of the relevant parties and the co-ordination of aims, policies and actions from the regional and decision-making viewpoints. In 1990, the Coastal-Zone Management Subgroup of the International Panel on Climate Change recommended, "by the year 2000, coastal nations should implement comprehensive coastal-zone management plans." The United Nations Conference on Environment and Development (UNCED), through its Agenda 21, also encouraged coastal nations to use the full panoply of tools to deal with all the problems of the coastal zone, including the impact of global climate change. Impact assessment, systematic observations, information-management systems and the preparation of profiles will require the information derived from coastal oceanography; likewise, the coastal oceanography community may need to look at some new priorities proposed by Agenda 21.

CZMA–RMAM's coastal-zone management subprogramme complements the pollution and coastal-zone monitoring and modelling programmes, and forms the socio-economic dimension of CZMA–RMAM. Its primary objective is to prepare plans to:

- Help managers with the sustainable development of coastal zones and the maintenance of their diversity;
- Develop programmes for protecting, preserving and restoring natural resources;
- Help reduce or prevent pollution of coastal areas so as to protect human health and the natural integrity of the coastal resources;
- Support a viable economy and an adequate infrastructure in the coast zone that does not compromise the natural integrity of the coastal resources;
- Promote awareness and understanding of coastal issues and a sense of stewardship of the coastal zone;
- Promote an interdisciplinary, integrated view of the environmental consequences of activities and projects and evaluate those consequences in accordance with adopted policies. (To this end, this subprogramme ultimately seeks to improve the state of the coastal environment).

To achieve these objectives, CZMA–RMAM's coastal-zone management sub-programme will:

- Prepare detailed and appropriate baseline information about the physical environment, coastal processes, ecosystems and cultural features;
- Develop environmental-accounting methods that reflect changes in value resulting from the uses of the coastal zone (pollutant discharge, erosion and loss of habitat);
- Prepare coastal profiles that identify critical areas, including eroded zones, physical processes, development patterns and user conflicts;
- Use environmental impact assessments, systematic observations and follow-up of major projects, including the systematic incorporation of results into decision-making;
- Develop contingency plans for man-made and natural disasters (oil spills and sea-level rise);
- Conduct periodic assessments of the impacts of external factors and phenomena, so as to ensure that the integrated coastal-zone management objectives are being met;
- Ensure that information for management purposes receives priority support, in view of the intensity and magnitude of the changes occurring in the coastal zone and other marine areas;
- Establish multi-institutional, co-operative work to develop systematic observation, research and information-management systems.

5.1.4 Oil-Spill Monitoring and Control

In 1995 alone, almost 1,500 large tankers passed through the Bosporus travelling to and from the Black Sea ports. Traffic has increased further since the shipping began from the Caspian oil fields. The risks of transporting oil, together with the poor state of the Black Sea countries' preparedness to cope with catastrophic accidents, is a major environmental concern, demanding further scientific studies. These countries generally have inadequate contingency plans, equipment and trained staff to deal with such accidents. CZMA–RMAM therefore intends to work further on establishing a regional oil-spill-response mechanism and a well-designed regional oil-spill-contingency plan. These studies naturally complement the measures taken by governments in keeping with the commitments to enforce the MARPOL regulations by 2002. The oil-spill monitoring and control programme covers issues such as pollution-damage assessment, contingency planning, operational response and co-ordination, modelling and prediction, dispersion, recovery procedures, bioremediation and political and socio-economic consequences.

Many different kinds of contingency plan exist for dealing with oil spills. Some are designed to deal with an oil spill that might occur at a very specific place, such as an oil-storage facility or a port. Others are designed to deal with spills that might occur anywhere within a large geographic region; these spills can be addressed most effectively on a regional basis and constitute a main concern of the CZMA–RMAM programme.

Developing contingency plans within CZMA–RMAM involves establishing the following (Thompson 1999):

- A communication system to support a regional oil-spill response system;
- A central repository for information on the laws and regulations of all Black Sea countries;
- Training on oil-spill response, including conduct of computer-simulated spill scenarios that help prepare personnel for a wide variety of situations to ensure that they can respond quickly and effectively;
- A data base of information on commercial technologies;
- Plans to train personnel to make reasonable, well informed choices about methods of containing and removing a spill when it occurs;
- Implementation of oil and chemical spill fates-and-effects modelling for risk assessment, contingency planning, cost-benefit analysis and natural-resource damage assessment.

CZMA–RMAM is an excellent forum for developing such regional-scale plans in the area and for creating and sustaining a well trained, well organized, technologically up-to-date oil-spill-response system.

5.2 OPEN-SEA MANAGEMENT AND ANALYSIS (OSMA–RMAM)

The goals of this sub-module are:

- To monitor, describe and understand the physical processes that determine the Black Sea circulation and the climate change in the region;
- To provide the observations needed for the prediction of climate variability and climate change;
- To develop a system to monitor marine ecosystems and the biological, chemical and physical parameters controlling their variability; the plans for the Black Sea should include specifications and a framework for an adequate package of observations and research to understand and forecast major change and variability over time-scales of seasons to decades;

- To provide information on the nature and extent of adverse effects, including increased risks to human health, marine resources, natural change and ocean health; the Black Sea data collection, biomonitoring and assessment of biological effects should be carried out using commonly agreed methods and standards, emphasizing development of a set of reliable, relatively easily applied biological-distress indicators by which to determine the health of the environment.

OSMA–RMAM is designed specifically for the open sea. Accomplishing the tasks requires a coherent programme with observational, monitoring and modelling components. Six independent sub-programmes complement each other: (1) Climate change (Section 5.2.1); (2) Living marine resources (Section 5.2.2); (3) Fish-stock assessment (Section 5.2.3)**;** (4) Real-time circulation now-cast (Section 5.2.4)**;** (5) Basin-scale ecosystem modelling (Section 5.2.5); and (6) Basin pollution assimilation capacity (Section 5.2.6). Each sub-programme is described briefly below.

5.2.1 Climate Change

Climate change comprises the long-term (on the decadal time-scale) changes in the coupled ocean–atmosphere system parameters due to natural and human causes. The best-known example of climate change is the global warming.

Recent studies have shown that climate change (global warming) will lead to a sea-level rise of several millimetres per year as well as a rise in the frequency and intensity of storms. The combined effect of these two effects could have serious consequences (such as severe coastal flooding and shoreline erosion).

In general, climate change is expected to lead to:

- Higher temperatures;
- Melting of glaciers and land ice;
- Thermal expansion of ocean water;
- Sea-level rise;
- Changes in the intensity, frequency and direction of storms;
- Changes in rainfall and evaporation;
- Sea-temperature rise and changed currents (which may affect the fishing areas);
- Changes in coastal and open-sea ecosystems, for the foregoing reasons.

The probable effects of climate change listed above are of great importance for many human activities and need to be constantly observed and predicted.

Two main topics can be allocated to this module of OSMA–RMAM GOOS:

Analysis of long-term changes based on the coastal station network data (time-series of air and water temperatures, winds, precipitation, cloudiness, sea level, water salinity and dissolved oxygen; in addition, for delta and estuarine stations, riverine discharge). Such analysis will facilitate:

- The monitoring of the Black Sea and its water- and salt-budget changes;
- The identification of significant trends in the marine-system parameters;

- The establishment of possible regional correlations between long-term external and local natural and socio-economic processes, as the basis for an ICZM strategy;
- Determination of the open-sea areas having enough historical data to support regular oceanographic observations; combination of such "*in situ* test regions" and modern satellite data (on sea-surface temperature and sea level) will allow new ways of observing some important open-sea manifestations of climate change.

The estimation of trends in the hydrometeorological and ecological parameters of the basin is a very important task of the BS–GOOS, since it is necessary to the monitoring of long-term changes in the Black Sea ecosystem. The need to predict probable changes in the Black Sea ecosystem is related to the need for the maintenance of the Black Sea basin.

Major attention is now being given to the development of methods of ecological monitoring with the application of space remote-sensing systems. Modern satellite equipment provides information on the sea level, geostrophic currents, the near-surface wind field, waves, sea-surface temperature and biological parameters of sea water, such as chlorophyll content.

To understand the present state and future trends, it is necessary to make anomaly maps of air temperature, wind velocity, coastal sea-level, physical, optical and biological variables, and atmospheric pollutants; and later on to map the physical and biochemical fields of the sea, with the assimilation of remote-sensing data and historic hydrographic data into models.

The information obtained from these various analyses and estimations just mentioned will allow the pinpointing of trends in climatic change; for different parameters and an assessment of the associated risks. The results of analysis should be presented in a form comprehensible for decision-makers.

5.2.2 Living Marine Resources

The sustainability of the oceans' living marine resources (LMR) is threatened by many factors: overfishing, habitat disturbance and loss, pollution and climate change; all combine to reduce the health of the world's oceans. Vital to addressing these issues is better information on the state of the world's LMRs, and the factors driving change.

Goal and Objectives

The goal of the LMR monitoring programme is **to provide operationally useful information on changes in the state of living marine resources and ecosystems.**

The objectives are: to obtain relevant oceanographic and climatic data, and biological, fisheries and other information on the marine ecosystems; to compile and analyse these data; to describe the varying state of the ecosystems; and to predict future states, including those of exploited species, on useful time-scales. A consequence of these efforts should be the identification and development of more powerful and cost-effective means for monitoring marine ecosystems required to meet the OSMA–RAM goal.

In achieving this goal, the LMR monitoring programme should attempt to provide information that:

- Describes changes in ecosystems over time, including fluctuations in abundance and spatial distribution of species;
- Helps to interpret the observed changes in relation to such factors as natural environmental variability, man-induced climate change (including increased ultraviolet radiation), mass mortality/diseases, and fishing;
- Contributes to the forecasting of future states of marine ecosystems.

Modelling

A key link between the observing programme and useful predictions of system dynamics is process studies and modelling. Programmes will provide critical information on physical–chemical–biological processes, develop advanced observing technology, and identify crucial variables and locations for long-term series analyses of climate variability and marine ecosystem response. In turn, LMR will provide time-series data for research programmes.

Requirements

The first steps towards implementation of an LMR monitoring programme must be the integration of existing observing systems into a more consistent, ecosystem-based approach utilizing the regional design principles, and a significant increase in capacity. Ongoing observing programmes, which could be such as those identified as LMR components of the Black Sea GOOS Initial Observing System, exist, since the rudimentary monitoring capacities exist. The challenge now is to identify existing programmes and deficiencies and to find resources to develop the programme on a basin scale.

National and international agencies that have ultimate responsibility for the implementation of LMR have to:

- Adopt a broad, ecosystem-based approach to living marine resource assessment and monitoring. LMR recognizes that the Black Sea ecosystem is unique and that observing systems must be tailored to specific local conditions and requirements;
- Establish regional analysis centres (RACs) for each major ecosystem. RACs will manage, analyse and synthesize ecosystem data from monitoring and assessment programmes, and produces the specific products for end-users. Capacity-building will be facilitated as scientists from riparian countries at different stages of development work together to make observations and interpret them in ways consumers will find useful;
- Utilize existing and developing observing technologies for cost-effective, synoptic sampling, e.g., remote sensing (ocean colour, wind fields, sea-surface height, temperature and salinity), instrumented continuous plankton recorders and optical plankton recorders;
- Strengthen links with national and international research and observing programmes that could contribute to LMR, most notably GLOBEC and Census of Marine Life.

Moreover, the functioning of marine ecosystems is affected by circulation and blending in the physical environment, so the LMR monitoring system must also include the important physical variables. However, monitoring of such variables is well advanced, so the LMR design plan will assume its existence but will not provide for it in detail. The goal of LMR Black Sea GOOS is to provide operationally useful information on changes in marine ecosystems and their living marine resources. The principal users of the output of an LMR monitoring system will be those concerned with sustainable harvest and management of the living marine resources. Therefore, the LMR Black Sea GOOS programme must also focus on commercial fisheries. Also, national policies and international conventions on biodiversity and ecosystem protection require consideration. This consideration has changed, and will further change, the nature of fishery management. Thus the LMR observation programme must go beyond the monitoring of a few target species to allow assessments of the state of living marine resources in a broad ecosystem context.

Regional Observing System

Recognizing the increasing homogeneity of marine ecosystems as one moves from the coast to the open sea, the open-sea measurements should be minimal. A common observation scheme is likely to be applicable as the first step.

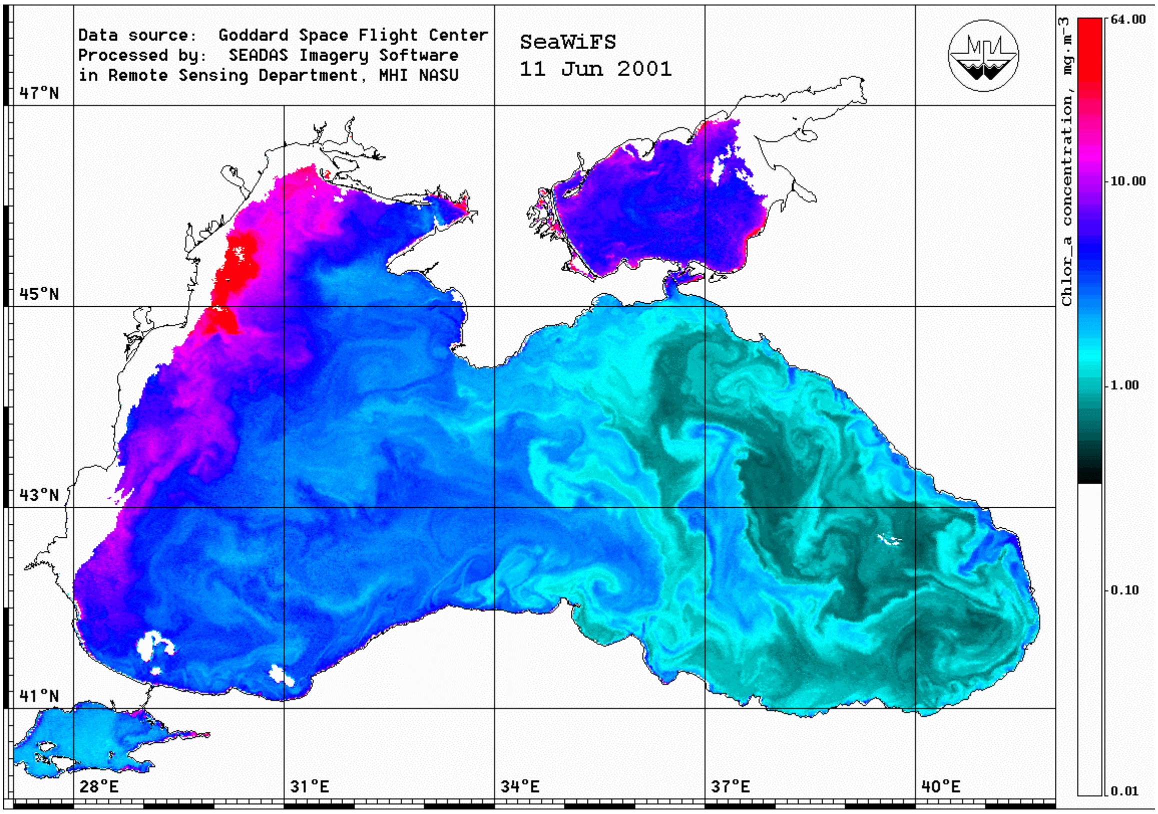

Figure 12. *Example of chlorophyll-*a *distribution derived from SeaWiFS data for 11 June 2001*

Sea-colour remote sensing will be an essential component of the observations, since basin-scale contrasts in the bioproductivity are well presented on visible-band imagery

Observations from ships should be another major component complementing remote-sensing data. Use of the fishing industry statistics is necessary to ensure the linkage between the low and high levels of the trophic chain.

Changes in marine ecosystems are forced externally by the variable physical environment and by human activities. Fishing has important effects, but other activities, such as oil, gas and mineral production, pollution from coastal sources, and tourism are of increasing importance. Interactions within ecosystems also cause changes in individual components, for example through predator–prey interactions. If useful products are to be made available, such as now-casts or forecasts of the distribution and abundance of a desired component or of changes in ecosystem states, all of the necessary parameters, or at least proxies for them, must be monitored. In addition, these parameters must be incorporated into appropriate ecosystem models to produce the desired products.

The design of specific observing plans must be customized later by experts and scientists.

The outline for an OSMA–RMAM LMR regional observing system should include the following elements:

- **Objectives**: To provide operationally useful information on the state of living marine resources and their ecosystems. Such information should include changes in physical conditions and ecosystem components required for now-casting and eventual forecasting of the ecosystem and of its living resources. Specifically, each observation system must consider local objectives, e.g., support of management, support of fishing and other operations, support of scientific activities, protection of the environment.
- **Users**: Those who require knowledge of ecosystem changes for research purposes and for management of human activities affecting ecosystems and their components, especially those concerned with the harvest of fish and shellfish and the sustainability of that harvest.
- **Characteristics**: Practicable, cost-effective plans within the capabilities of those concerned with living marine resources in the region. Minimal initial monitoring plans should use existing observational programmes and methods to the greatest extent possible.
- **System analysis of key ecosystem processes and features**: Description of the physical features, predominant biological processes and observed variability in physical and biological characteristics on interannual and interdecadal time-scales.
- **Monitoring requirements**: Identification of ecosystem components and conditions that should be monitored for LMR purposes, together with priorities for components to be observed and desired sampling frequencies appropriate for the region. This should include a consideration of available and potential measurement tools and opportunities.
- **Products**: Description of how the required monitoring information will be used to develop products for the identified users, and what those products will be. This should include identification of appropriate diagnostic, simulation and data-assimilation models.

5.2.3 Fish-Stock Assessment

As stated in previous sections, the Black Sea fisheries have been seriously damaged as a result of eutrophication, overfishing and the introduction of alien species, such as *Mnemiopsis*. As a complicated and socio-economically important problem, fishery management cannot be improved solely by administrative actions (e.g. regulating the fishing industries). It also demands parallel research effort on the broader ecological needs for restoring the fish stocks.

Because of its origin, climate and, to a great extent, productivity, the Black Sea hosts large quantities of migratory pelagic species, the most important of which is the anchovy *(Engraulis encrasicholus).* Now the backbone of the Black Sea fishery, especially after the sharp decline in the large pelagic fishes, such as bonito *(Sarda sarda)* and bluefish *(Pomatomus saltatrix),* anchovy spend the winter in the Sea's warmest parts, off the Anatolian, Crimean, and Caucasian coasts. In the spring, they migrate north to feed and spawn and then return to the wintering places in the autumn. The anchovy and all the other commercially exploited fishes in the Black Sea are also transboundary migratory species that cross the coastal waters of all six riparian countries. This feature makes fishery management even more difficult: each Black Sea country wants to take the highest share of the stock while the fishes pass through their territorial waters. Attempts to manage the stocks internationally have failed, simply because no realistic data on the size of the stocks were available. For mostly political reasons, fishery scientists in the Black Sea countries co-operated rather poorly and were unwilling to exchange data with each other. While there were several individual endeavours to assess the Black Sea pelagic fish stocks, all came to a similar conclusion: unless all Black Sea countries participate in a concerted stock-assessment survey, results would never be realistic.

Furthermore, there is a heavy pressure on the pelagic fish stocks today. Within the last 20 years the Black Sea fishing fleet has expanded so much that its catch capacity is far beyond the stocks' renewal capacity and is depleting the fish stocks. The growth of the fishery sector has increased the number of people dependent on fisheries, which now support some 2 million fishermen, fish-processing factory workers and their dependants. The overfishing problem, therefore, has a socio-economic dimension. To prevent overfishing and maintain the sustainability of this shared resource, co-operation among all six Black Sea countries is indispensable. A well co-ordinated fishery survey of pelagic species, assessment of the stock size, population dynamics, migration routes of the commercial species and trophic relationships among species is necessary to design a sound fishery-management strategy.

Another threat to the profitability of the fish stocks is eutrophication. The most striking evidence of the impact of eutrophication on the fishes is the shift in their spawning grounds. In contrast to the past, in the early 1990s a higher concentration of eggs was found in the southern and particularly the south-eastern Black Sea than in the north-western region, which is known as the main spawning ground of the migratory species, especially anchovy. This is probably a sign of environmental deterioration driven by eutrophication on the north-western shelf. Another concern with respect to fish spawning is the possible predation by the ctenophore, *Mnemiopsis.* Both issues require co-operation among the Black Sea scientists on a synchronous, basin-wide ichthyoplankton survey, addressing: determination of the major spawning grounds of the commercial species, and the threats to egg production.

The declining demersal fishery is a clear consequence of the degrading ecosystem, which is in turn intimately related to land-based human activities. The light-penetration depth, the photosynthetic benthic-algae meadows, and the availability of oxygen to the demersal fishes have all diminished. Consequently, the demersal fish stocks, which are highly commercial and have been heavily exploited for decades, are now almost extinct. Although these stocks undergo no long-distance transboundary migrations, they are also of ecological and socio-economic importance for the Black Sea. CZMA–RMAM, therefore, intends to conduct research on the following:

- **Regionally co-ordinated fishery surveys** to monitor the population sizes of the shared pelagic stocks, conducted seasonally, by acoustical estimation of the stocks, determination of the anchovy spawning grounds, and assessment of the size of the spawning parent stocks;
- **The study of the population dynamics of the stocks** to investigate the factors affecting population size: mortality due to fisheries, predation and other natural causes; growth rate of the species; and recruitment. To design a sound management programme, the diet composition, trophodynamic parameters (ingestion, assimilation, and egestion ratios) and production, as well as the biomass ratios of the major species should also be studied;
- **Compiling all available data from all coun**tries to construct a model to determine interspecies relations among various fish species and fisheries. The model should be designed as a tool that not only gives an insight into the functioning of the ecosystem but also verifies the integrity of the results.

5.2.4 Real-Time Circulation Now-cast

Observing and modelling dynamics and ecosystems are complementary activities that will require strong interactions among instrument developers, observers, modellers, assimilators and users, if OSMA–RMAM Black Sea GOOS is to realize its full potential. Effective operational models depend on a steady flow of data that are both quality-controlled and quality-assured, where quality control means ensuring that data meet certain standards and quality assurance means the documentation of the quality control. The main point is that operational modes are critically dependent on routine access to reliable observations in a timely fashion.

The Ongoing Development and Coupling of Numerical Models

Numerical modelling of the coastal ocean has matured so that there is now a number of operational systems that provide required products to a large range of users. Most operational models currently in use forecast physical-state variables such as sea-surface and wave heights. A numerical eddy-resolving model with assimilation of altimetric data operates at present in the Black Sea. An example of the dynamical sea level, which is the stream function of the surface geostrophic currents, a hindcast for 24 June 1993 is presented in Figure 13.

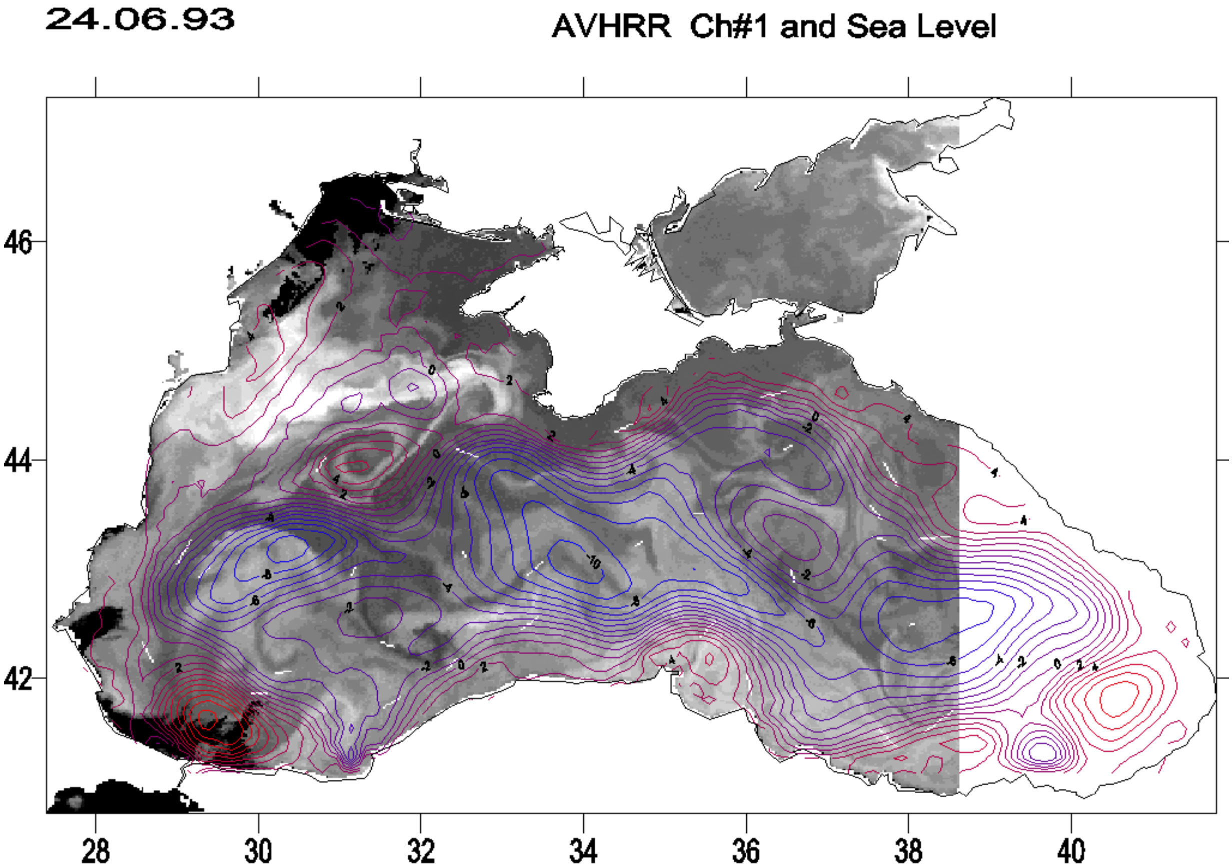

Figure 13. *Isolines of the sea level are overlaid on the AVHRR image to show how surface currents induce heterogeneities in the particulate-matter distribution in the upper sea layer.*

An example of mesoscale sea-surface currents after altimetric data assimilation is given in Figure 14**.** The set of marginal anticyclones is clearly delineated.

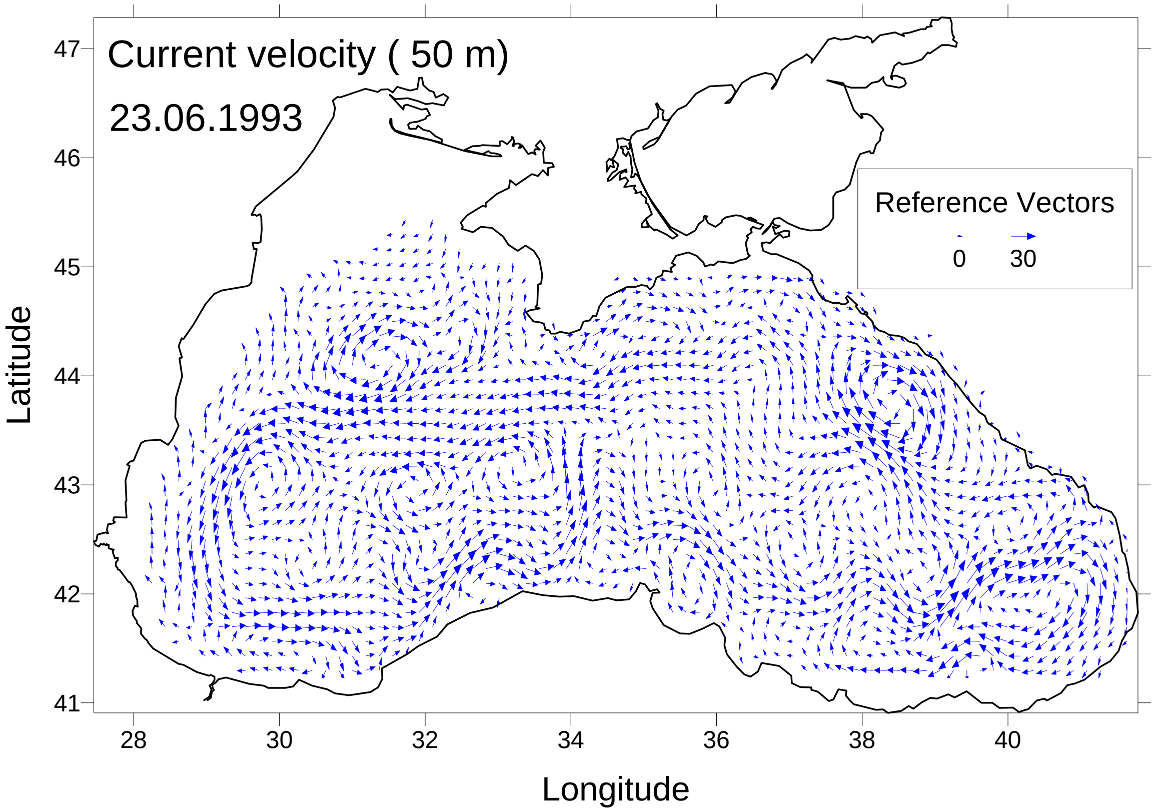

Figure 14. *Sea-surface currents after assimilation of altimetric data.*

However, rapid advances are being made in modelling chemical and biological variables. It is important to emphasize that much work remains to be done to improve these models, particularly in the parameterisation of processes for coupled physical–biological and physical–atmospheric models. In this regard, the development of robust models that can be applied to many ecosystems in different locations (global models for local ecosystems) will be facilitated by implementing mechanisms that enable modelling groups to compare the abilities of different models, to share results and code, and to exchange personnel. This will be a particularly important component of capacity-building in those countries that have yet to develop the required expertise.

Two approaches are commonly used in coastal-zone modelling to increase resolution in areas of greatest interest: finite-element modelling and nesting of finite-difference models. A number of issues must be faced when using either approach; e.g. computational efficiency of finite-element models and two-way interaction with nested, finite-difference models. It is to be expected that these issues will become increasingly important as more comprehensive models of interactive physical–chemical–biological processes are developed. On the positive side, the ability to increase resolution in areas of special interest will eventually blur the distinction between “coastal” and “deep-ocean” modelling. This will accelerate the integration of the deep-ocean and coastal components of the observing system.

The advantage of modularity when coupling models of various types has long been recognized by the atmospheric community (e.g. for linked atmosphere–wave–ice–ocean modelling). Considerable effort has been spent in the development of “couplers” that allow models to communicate with each other at different times (asynchronously). It is to be expected that modularity will also be an important feature of comprehensive coastal models that realistically simulate interactions among physical and ecological systems and among terrestrial and marine systems (e.g. linking drainage-basin hydrology and nutrient transport to changes in the water quality of receiving waters; linking storm-surge forecasts to land cover in the coastal zone that modulates the extent of flooding). Couplers will allow various models to be added and removed from the system in order to assess their effectiveness and allow the observing system to improve in an orderly way. Expertise in the development and use of couplers should be made broadly available to accelerate the development of coupled coastal models.

The Importance of Data Assimilation

Most operational coastal-zone models require some form of data assimilation to ensure they do not drift too far from reality. The assimilation techniques presently being used range from simple data insertion and “nudging” based on multivariate statistical interpolation to more sophisticated techniques, such as the “a joint method” and “Ensemble Kalman filtering” (see Walstad and McGillicuddy, 2000). Data assimilation is still a relatively new activity for oceanographers and a number of important problems remain to be solved. These include the following:

- The more sophisticated assimilation schemes require the typical magnitude and time- and space-scales of the observation and the model errors to be specified. This is extremely difficult to do for complex, non-linear models;
- There is much to be gained by taking into account the time-history of oceanographic observations (e.g. sequences of satellite images) when assimilating data into ocean models. This approach is, however, computationally expensive and oceanographers are concentrating on developing practical schemes in which the accuracy of the model may be sacrificed for a much-needed increase in computational efficiency;
- The provision of reliable statistics on errors for estimated fields is difficult for highly non-linear models. One solution is to use an ensemble of forecasts to determine the sensitivity of estimated quantities to initial conditions, boundary forcing or internal model dynamics. However, this approach is computationally intensive;
- Multiple data sets must be simultaneously assimilated into models with due consideration of their respective error structures and the multivariate aspects of assimilation. The development of multivariate assimilation tools is progressing rapidly for the open ocean where the number of variables is small. However, this will be especially challenging for coastal models for which data from in situ and remote sensing must be integrated;
- Data assimilation techniques are not yet used to help nest a hierarchy of models of different resolution. Although it has been shown that accounting for coarse model errors eliminates spurious numerical adjustments when higher-resolution coastal models are used, such errors are rarely taken into account. More work is needed.

In addition to these challenges, assimilation requires knowledge of coastal-ocean processes, statistics and numerical modelling. At the present time there is a shortage of well trained personnel in most parts of the world. This is a serious impediment to the development of operational coastal oceanography, particularly for those indicators that require models of ecosystem processes.

5.2.5 Basin-Scale Ecosystem Modelling

Since sea forecasts are an essential tool for optimum utilization and management of resources, the activities in this sub-module must be supported by parallel ongoing process-oriented modelling to understand the effects of physical and biogeochemical processes on the functioning of the Black Sea ecosystem and their internal feedback. Knowledge gained by the process-modelling studies ultimately helps to upgrade the operational forecasting capabilities of the system.

The major process studies considered within the biogeochemical modelling component of the system comprise:

- Incorporation of different groups of gelatinous carnivores (such as *Aurelia aurita*, *Pleurobrachia*, *Mnemiopsis leidyi*) and benthos into the existing models and thus exploration of the recent ecosystem changes as a result of the simultaneous explosion of their biomasses during the last two decades;
- Construction of population-dynamics models for particular zooplankton species (e.g. *Mnemiopsis leidyi*) to study the roles of successive stages of their life cycles on the ecosystem;
- Modelling redox processes across the oxic/anoxic interface governed by nitrogen, sulphur, iron and manganese cycling;
- Extension of the existing coupled physical–biochemical model to the shelf ecosystem using different limiting nutrients and pelagic–benthic interactions;
- Studying the role of meteorological factors in determining the intensity and year-to-year shifts in the phytoplankton spring bloom between mid-winter and early spring;
- Studies of the translocation and changes in the spawing/overwintering characteristics of fish-egg and larvae stocks and their correlation with primary production, on the regional as well as the basin scale;
- Coupling the lower and higher trophic levels of the ecosystem.

Development of Numerical Models for the Prediction of Ecological Processes

Numerical models of ecosystem dynamics have been developed and calibrated for several coastal ecosystems around the world (see Cerco and Cole, 1993; Franks, 1997; Robinson, 1999; Kudela and Chavez, 2000). They typically contain explicit representations of trophic interactions between nutrients, primary producers, bacteria and zooplankton.

They can consider both benthic and pelagic subsystems and their interactions (e.g. Cerco and Cole, 1993). Most ecosystem models have been used in a hindcast mode to predict the response of phytoplankton and other components of marine ecosystems (e.g. HABs, zooplankton, benthic macrophytes, dissolved oxygen) to variations in nutrient inputs, PAR and mixed-layer dynamics. Experience is limited in assimilation of satellite colour data and in initialization with measured nutrients and phytoplankton biomass concentrations (e.g. Robinson, 1999). Wider experience has been gained in the calibration of parameters of ecological processes using simple biochemical models and joint techniques. Such models should be interfaced with near-real-time data-acquisition systems, as discussed in the observing subsystem section of this Black Sea GOOS Plan, and experimental forecasting should be initiated. Some relevant experience already exists for one-dimensional physical models (models with the time and vertical space dimensions only) interfaced with operational atmospheric analyses to compute fluxes at the air–sea interface.

5.2.6 Basin Pollution-Assimilation Capacity

Hydrocarbon Pollution

One of the basic problems of modern applied oceanography is to forecast consequences of oil contamination of the marine environment due either to a spill during of its transportation and military conflicts or the systematic inflow with river discharges and waste waters. The problem is especially acute in semi-enclosed seas. Their rather small size and the increasing human pressure in the riparian states can lead to catastrophic consequences for the marine ecosystem. The planned intensification of oil transportation in the Black Sea or, for example, oil pollution near the southern coast of Crimea in 2000 can easily cause an ecological catastrophe in the basin.

Tasks include:

- Collection of existing data on the distribution of oil;
- Summarizing and verifying these data;
- Developing parameterisation of the main biogeochemical processes governing the distribution and assimilation of oil in the marine environment, both in the oxic and the anoxic layers of the Black Sea;
- Running numerical simulations on the most typical oil loads transported in the Black Sea to predict the assimilation capacity and the consequences of oil spills and systematic oil contamination.

The consequences of technological accidents in the Black Sea coastal industry will be evaluated by numerical simulation. Pollutant transport, as well as the areas of its maximum concentration and probable scenarios of its further evolution, will be considered. Analogous simulations will be carried out for accidents with oil pipelines, oil carriers, etc. resulting in ejection of oil and oil products into the sea.

The pollution-tracking technology will be realized in the form of a software package for hind-casting and now-casting of three-dimensional current velocity, temperature, salinity, pressure and pollution fields. Its use makes it possible to work out objective recommendations and to plan nature-protecting measures for different critical situations in the Black Sea.

Heavy Metals and Radioactivity Pollution

The Black Sea is the world’s largest permanently anoxic basin, with a strong redox gradient across the oxic/anoxic interface which influences the quantities and distribution of the dissolved trace elements. The heavy metals mobilized by human activities make a significant contribution to the deterioration of the aquatic environment.

Compared with the aerobic water, the anaerobic deep water of the Black Sea contains extremely low concentrations of cadmium, nearly the same concentrations of nickel and a much higher concentration of manganese. More specifically, maximum surface concentrations for all metals are observed in the north-western part of the Black Sea and lower ones, in open waters. Great variations in the surface concentrations of manganese, nickel and copper have been detected in the north-western part and around the Crimea, due to the direct contamination from the land via the rivers. For the open sea the predominant role is played by atmospheric fallout and the transport of heavy metals from the nearshore zone to the open sea.

Tasks include:

- Monitoring of heavy-metal distribution in the nearshore zone;
- Investigating the behaviour of heavy metals in the river–sea interaction zone;
- Estimating heavy-metal transportation from sea-bed deposits into bottom water.

The Black Sea, which for a long time prior to 26 April 1986 was notable for its much higher concentrations of fission products in its marine environment and biota, compared to the other seas of the Mediterranean, was subjected to significant additional pollution after the Chernobyl nuclear power plant accident. This circumstance demands further research on radionuclide migration in the Black Sea and on the effects of chronic irradiation of biotic components of the Black Sea ecosystems, against a background of different kinds of human impact. On the other hand, the inflow of artificial radionuclides can be very effectively used to create advanced radiotracer techniques in bio-oceanographic investigations of the Black Sea.

Research purposes include:

- Control of radioactive pollution of water, hydrobionts and bottom sediments of the Black Sea;
- Comparative study of biological effects of ionizing radiation and chemical pollution on marine organisms, using cytogenetic methods in the light of the conceptual model at the ecosystem level;
- Investigation of the ecological response of the Black Sea to the radioactivity from the Chernobyl accident;
- Assessment of the Black Sea capacity to accommodate long-lived radionuclides;
- Assessment of the intensity of the mixing of river and marine waters, vertical water exchange and sedimentation rate, using radiotracer technology.

Expected Results

Trends in the concentrations of strontium-90, cesium-137 and transuranic elements (TUE) in water, marine organisms and bottom sediments of the Black Sea will be determined. The combined effects of radioactive and chemical pollution on biota in areas with different levels of human impact will also be determined. The capacity of the Black Sea environmental components to accommodate long-lived radionuclides will be determined as well as the response of the marine ecosystems to the Chernobyl accident. The mixing of the marine and river waters in the estuaries of the Dnieper and Danube Rivers will be assessed, and large-scale vertical water exchange will be determined in the main Black Sea current and in the homogeneous saline layer; the sedimentation rate and the geochronology of bottom sediments will also be assessed on a semi-centennial scale, using strontium-90, cesium-137 and TUEs.

6. TRAINING AND TECHNOLOGY TRANSFER

The full involvement of scientists and users from all the Black Sea coastal nations will be critical to the success of the Black Sea GOOS programme. Many of the oceanographic institutions may, however, require capacity-building in human resources, through education and training, and infrastructure enhancement, through new laboratory equipment and communication facilities.

Short-term training can be conducted through workshops and short courses, and would emphasize the practical aspects of the Black Sea GOOS programme for technicians and research scientists involved in its implementation. The standard monitoring aspects of Black Sea GOOS, in particular, will require a large group of well trained technicians. Long-term training and education may include visiting scientists or fellowship programmes aimed at developing joint-research capabilities. Reciprocal exchanges of senior scientists between organizations are an effective way to transfer knowledge.

To share data between the participating institutions will require improvement in the capabilities of some key laboratories that are involved in monitoring and assessment. In particular, it will be important to introduce computer-based data, modelling and information systems, if these institutions are to utilize the satellite data fully.

The capacity-building programme of the Black Sea GOOS can be implemented in co-ordination with other international programmes, such as the Joint Global Ocean Flux Study (JGOFS), Land–Ocean Interactions in the Coastal Zone (LOICZ) and Global Ocean Ecosystem Dynamics (GLOBEC). Following the UNCED recommendations in Agenda 21, UNDP and UNEP have also instituted training programmes for developing countries that cover coastal and marine ecosystems.

7. RELATIONSHIPS WITH OTHER PROGRAMMES

The Black Sea GOOS anticipates co-ordination of its efforts with national, regional and international programmes and activities.

The Black Sea GOOS programme is closely linked with many Black Sea Environment Programme (BSEP) objectives in sustainable development, living-resource management and pollution control and reduction.

The Black Sea GOOS will establish a strong scientific association with the NATO Science for Peace (SfP) programme, which, with its new science plan, is expected to play a critical role in facilitating research in coastal/shelf seas and the continental margins of the Black Sea.

The Global Sea Level Observing System (GLOSS) is also highly relevant to the Black Sea GOOS, because increasing mean sea level represents a threat to some coastal areas, Poti (Georgia) being an example. Particularly helpful for the Black Sea GOOS is the concept of regional GLOSS projects, which is at present under consideration and development. There should be a link with the currently developed programme MEDGLOSS.

The strategy for the development of the Black Sea Buoy Programme (BSBP), which is a component of the Black Sea GOOS, is based on the Drifting Buoy Co-operation Panel (DBCP) Implementation Strategy. It is planned that BSBP will become a part of the European Group of Ocean Stations (EGOS).

At the international level, Black Sea GOOS will establish links with some existing global marine research programmes. When scaled down from the global to the regional scale, the Black Sea GOOS will address several of the scientific and technological issues being considered by the Joint Global Ocean Flux Study (JGOFS), the Land–Ocean Interactions in the Coastal Zone (LOICZ), the Large Marine Ecosystem (LME), the Global International Water Assessment (GIWA) and the Global Ecosystems Dynamics (GLOBEC) programmes, which are implemented within the framework of the International Geosphere–Biosphere Programme (IGBP). JGOFS is a multidisciplinary biogeochemical effort that focuses on the lower-trophic-level carbon cycling of marine ecosystems in different regions of the global ocean. Its main emphasis is on primary production and the oceanic carbon budget. GLOBEC focuses on the zooplankton dynamics and concentrates on the carbon transfer from the lower to the middle and upper trophic levels, including fish and marine mammals. One of its subprogrammes, the Small Pelagic Fish and Climate Change (SPACC), studies climate-induced changes in the fish production of marine ecosystems. The LOICZ programme addresses the role of external forcing on coastal-zone fluxes, such as sediment and nutrient input, as well as the economic and social impacts of global change on coastal zones. It also strives to make a link between the terrestrial, atmospheric and marine compartments in the coastal zones that are interactive in the process under consideration.

Indeed, the link between Black Sea GOOS and many aspects of JGOFS, GLOBEC and LOICZ are direct. Exceptionally high volumes of nutrient loads and contaminants have resulted in considerable transformation of the lower trophic levels of the Black Sea ecosystem. The most dramatic response has been the drastic changes observed in the intensity and annual structure of the primary production and nutrient cycles. Adverse effects of all these changes are also reflected inevitably on higher trophic levels that are further perturbed by the population explosion of the gelatinous carnivores *Aurelia aurita* and *Mnemiopsis leidyi*. They were responsible for altering the food-web structure as they became the main food competitors, foraging mesozooplankton, fish eggs and larvae. These carnivores have no predators, since they are at a dead-end of the trophic web. The most dramatic ecosystem changes have been observed on the north-western shelf and western coastal regions of the Black Sea, which are heavily influenced by the impact of human activities along the Rivers Danube, Dniepr and Dniestr. All these processes, human influences and resulting ecosystem changes, which have taken place over the last three decades, are closely related to the objectives of the JGOFS, GLOBEC, SPACC and LOICZ.

EuroGOOS and MedGOOS are programmes with which Black Sea GOOS has established close scientific correspondence. These programmes have goals and objectives that in essence are the same as those of Black Sea GOOS. In fact, the implementation programme of Black Sea GOOS is developed along the lines adopted by the EuroGOOS and MedGOOS programmes. Simultaneous implementation of these two programmes in these two adjacent and coupled basins of the world ocean would be rewarding from both the scientific and management points of view.

8. IMPLEMENTATION PLAN

8.1 INTRODUCTION

The establishment of an operational oceanographic system for the Black Sea is a complex and resource-demanding task, requiring additional investment in scientific research and technological development, focusing on the special demands for rapid data delivery, optimal model performance, data exchange, user-friendly product dissemination etc. that are a requirement of an operational service. As outlined in the previous sections, some of the components of an operational system do already exist, but expenditure, effort and time are required to:

- Define an optimal observation network;
- Upgrade some of the existing observation stations from delayed mode to real-time mode;
- Install new sensors and equipment;
- Introduce remotely sensed data into an operational set-up;
- Introduce and automate common standards of data quality control;
- Implement real-time data-transmission links;
- Establish a set-up for data analysis;
- Optimise existing models;
- Implement data assimilation;
- Develop and implement coupling of ocean and atmospheric models;
- Develop and implement ecological models;
- Develop and implement an effective and user-friendly information system.

This is a huge task involving scientific research, technological development, committed international co-operation and strong co-ordination.

8.2 OBSERVATIONS

Ocean-data collection is very resource-demanding, owing to instrumentation costs and, in particular, instrument maintenance (cleaning, calibration etc.). An optimal observation system operated through international co-operation will therefore be the most cost-effective way to make the necessary observations. In the world ocean, not even one observing network is optimally designed. There are, however, urgent needs to build up ocean observation systems optimally both from a scientific and an economic point of view.

Scientifically, an optimal observation system is one that can provide the maximum amount of effective information (defined by the purpose of operational or climate oceanography) with a limited cost. The optimally designed system will ensure that the operational ocean model has the best ocean data for constructing initial fields and optimizing model parameters, which are the most essential factors in improving the current operational marine forecasts for the Black Sea. Economically, an optimal observation system means that the system can provide a reasonable data set for operational and climate oceanography at minimum cost.

Optimal observation system design (OOSD) is very challenging work, not only because it is necessary to develop new scientific methods for it, but also because OOSD has first to be simplified and expressed in terms of some scientific questions relevant to our present and future knowledge, such as system-evaluation theory, system-control theory, information theory and modelling/statistical analysis.

An optimal ocean-observation system design for operational oceanography in the Black Sea will involve the following tasks:

- Development of new methods and indices by which to evaluate the existing observing system;
- Development of new methods for the design of an optimal ocean-observing network for climate study;
- Development of new methods for the design of an optimal ocean-observing network for operational oceanography;
- Demonstration of a practical optimal observing network design for Black Sea operational oceanography.

The Black Sea GOOS members already operate, as part of their national responsibilities, a serious network of observation sites, ranging from delayed-mode and on-line real-time fixed stations to ship-based monitoring programmes to remotely sensed data. The existing data-collection network will form the basis for optimisation of the operational observation network. Additionally, links to ongoing and planned research projects will be established with the purpose of exchanging data and final analytical products.

Another immediate task of the Black Sea GOOS is to validate the existing observation network with respect to:

- Upgrading observations from delayed mode to real-time mode;
- Functionality; i.e. is the present instrumentation up to date and does the data quality meet agreed standards?
- Implementation of new technology (radars, new satellite sensors, ferry-box instrumentation, anti-fouling etc.);
- Implementation of observations of environmental and ecological parameters, such as dissolved oxygen, algae, nutrients etc.

8.3 PILOT PROJECTS

The primary task under the Black Sea GOOS co-operation for the 5-year period 2003–2007 is therefore to start the integration and development of the existing systems into a uniform entity in order to meet the users' demands for a high-quality operational oceanographic service and to minimize the productions costs. The Black Sea GOOS will, in the next 5 years, therefore focus on the implementation of the following projects.

8.3.1 Black Sea Expedition

This will comprise co-ordinated cruises with the Turkish, Ukrainian and US research vessels: R.V. *Bilim*, R.V. *Professor Vodyanitsky* and R.V. *Knorr*.

The objectives are:

- To study the biogeochemical cycling of nitrogen, manganese, iron and sulphur species between the oxic surface water and the sulphide-containing deep water;
- To characterize the biological food web in the Black Sea and to measure rate constants that can be used to constrain food-web models;
- To determine the geochemical fluxes at the margins of the Black Sea.

The measurements envisaged are listed below according to the objectives given above. Some measurements will be made during the cruises and others will be made on samples returned to the respective laboratories.

- In the water column: temperature, salinity, dissolved oxygen, sulphide, elemental sulphur, sulphite, thiosulphate, nutrients (nitrate, nitrite, phosphate, ammonium and silicate), manganese, iron, nitrogen gas, as well as alkalinity and total CO_2; bacterial distribution will also be determined. In the laboratory: $\delta^{15}N$ analyses of nitrogen gas, nitrate, ammonium and particulate organic nitrogen.
- Nutrients, primary productivity, new productivity, chlorophyll, bacterial biomass, bacterial production, mesozooplankton biomass and particulate export flux.
- In addition to the measurements just mentioned: radium isotopes, chlorofluorocarbon (CFC) tracers and methane.

Samples will be collected along transects from a station in the western basin to the Turkish coast during Leg 1 and on the north-western shelf and Ukrainian coast on Leg 2. Both Legs will include transects to and from the Bosporus.

Samples will be collected using rosette-mounted sampling bottles, *in situ* water pumps and box-core sediment samplers.

There will be a hydrographic/nutrient data report available six months after the cruise. The specific scientific work will be presented at a scientific workshop held in Turkey or Ukraine about one year following the cruise. Scientific papers will be prepared for high-standard journals.

All data will be submitted to the US National Oceanographic Data Center and the NATO-sponsored Black Sea Data Management System maintained at MHI in Sevastopol, Ukraine, within two years of the end of the cruise.

A preliminary report will be sent to each coastal state within 30 days of the end of the cruise.

8.3.2 Black Sea Surface Drifting Buoys

The participants in the project are:

- Oceanological Centre of the Ukrainian National Academy of Sciences, Ukraine
- Marine Hydrophysical Institute NASU, Ukraine
- P.P.Shirshov Institute of Oceanology, RAS, Russia
- Institute of Marine Sciences, Middle East Technical University, Turkey
- Department of Oceanography, Naval Postgraduate School, USA
- Naval Oceanographic Office, USA.

The work will be co-ordinated by and carried out under the auspices of the IOC Black Sea Regional Committee and relates to the development of the Black Sea GOOS.

Anticipated Results

It is anticipated that, besides the execution of the specified scientific tasks, the project will provide useful information for other modules of Black Sea GOOS, particularly for (1) the OSMA–RMAM, through the description of physical processes that determine Black Sea circulation and climate change in the region, as well as provision of the observational data needed for the prediction of climate variability and climate change; (2) the CZMA–RMAM, through the description of shelf–deep sea exchanges; (3) the MSM, by providing meteorological data, which could not be acquired otherwise, for the development of a large range of marine meteorological and oceanographic services in support of shipping, fisheries, coastal-zone management, tourism and recreation, and improving the safety of life at sea.

Data from the drifters will be made available on-line free of charge for all the participants in the programme and will be used for better description and understanding of physical processes in the Black Sea and their mesoscale variability. The results of drifter-data analysis will be published in peer-reviewed joint papers.

8.3.3 Profiling Floats

The participants in the project are:

- Oceanological Centre of the Ukrainian National Academy of Sciences, Ukraine
- Marine Hydrophysical Institute NASU, Ukraine
- Institute of Marine Sciences, Middle East Technical University, Turkey
- University of Washington, USA.

The project will complement the other means of direct and remote observation, and provide a continuous and three-dimensional visualization of the sea state. The profiling-float measurements of temperature, salinity, pressure and reference velocity, together with sea-surface height from satellite-altimetry data, constitute a dynamically complete description of the upper ocean. Profiling floats provide the subsurface vertical structure of the temperature, salinity and velocity fields that are needed for successful interpretation of sea-level variability. In turn, the excellent spatial and temporal sampling characteristics of the altimeter allow this description of the physical state of the sea to be extended to short spatial and temporal scales that are beyond the capability of an *in situ* observing system.

Objectives

The primary goal of this project is to provide an enhanced near-real-time capability for measuring temperature and salinity throughout the upper 1500 m of the Black Sea and to contribute to a basin-wide description of the seasonal cycle and interannual variability of the circulation and water-mass characteristics. Such enhancements are urgently needed to sustain improved understanding of the variability of the Black Sea over a range of space- and time-scales and to underpin a range of operational oceanographic applications. More specifically, it is aimed at:

- Producing an updated and more realistic climatology of monthly mean temperature and salinity as a function of depth, with error bars and statistics of variability;
- Producing accurate time-series of heat and freshwater storage and of temperature and salinity structure, and the volume of the Cold Intermediate Water structure;
- Determining the predominant patterns and evolution of interannual variability in temperature and salinity;
- Providing maps of the absolute sea-surface height with an accuracy of 2 cm, by combining profiling-float and altimetric data;
- Obtaining an unprecedented data set for model initialisation and data assimilation, which will enable realistic operational real-time global ocean forecasting for the first time in the Black Sea.

Work Plan

Three profiling floats built by the University of Washington were provided to Turkey/Ukraine. A Turkish team deployed the floats, on 2 September 2002. The first float 587 was deployed on the rim current at 41^{o}50`N 29$^o$50`E 1550m parking depth. The float 631 is at 750m and the float 634 is at 200m parking depths at 42^{o}15`N 30$^o$20`E, which is within the western gyre of Black Sea. All floats provide vertical profiling T–S from 1550m (near bottom) depth. The floats transmit data weekly and spend 7 to 8 hours transmitting on the surface with 1 message per 46 to 54 seconds. The data are recovered from the floats via the *Argos* system. The T–S vertical profiles as pressure versus T–S, together with float trajectories are displayed in near-real time on the web site http://flux.ocean.washington.edu/metu. Automatic PALACE Profile E-mail Distribution Unit transfers data to METU Institute of Marine Sciences (IMS) and Marine Hydrophysical Institute (MHI). Two additional floats are envisaged for 2003. Assuming the average lifetime of a float is four years, about 400 profiles are expected from each float and this comprises a reliable time-series of measurements of the Black Sea. Two more will be deployed in 2003 by IMS METU.

The data acquired by the floats will be complemented by standard *in situ* CTD surveys using R.V. *Bilim*. Two surveys are planned for 2003, 2004 and 2005; their timing will be decided by the allocation of ship time and funding from national sources. The positions and number of transects to be covered during these surveys will depend on the positions of the floats.

8.3.4 Bulgarian Coastal-Area Monitoring

The objectives of the Bulgarian Black Sea monitoring activities are:

- To establish a co-ordinated, integrated, scientifically based system for observation and prediction of the Black Sea variables on a regional and national scale;
- To ensure long-term and regular observations of the physical, chemical and biological parameters and states of the marine environment and biota;
- To provide relevant information to the governmental institutions for making decisions referring to environmental protection and rehabilitation for the sustainable development of the Black Sea.

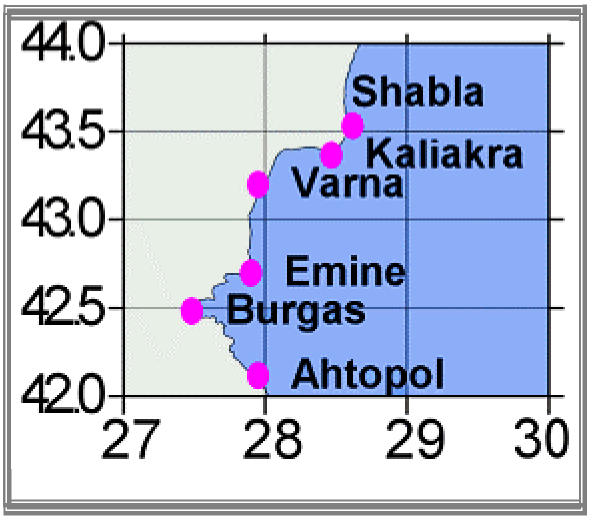

Figure 15. *Bulgarian coastal stations*

The legal basis for the Bulgarian monitoring programmes is agreements and conventions. Users of the monitoring products are ministries, maritime organizations and coastal municipalities, to facilitate their operations, environmental protection, rational use of marine resources, and development of the recreational and socio-economic infrastructure of the Bulgarian Black Sea area.

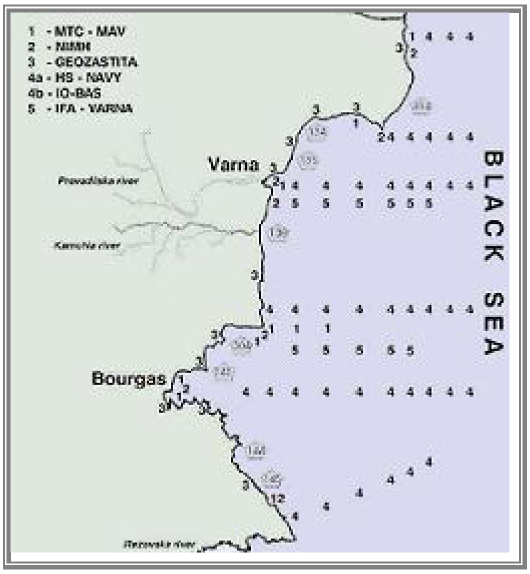

Figure 16. Station network for complex monitoring of the Bulgarian Black Sea coast

The implementation of an integrated system of national monitoring of the Black Sea currently depends on an international assistance programme for the provision of up-to-date equipment and technology (Figs. 15, 16). Some of the co-ordination of the integrated monitoring system have been carried out under the CESUM project (Centre for Sustainable Development and Management of the Black Sea Region), funded by the European Union and hosted by the Institute of Oceanology.

8.3.5 Mapping of Mesoscale Structure of the Black Sea Wind Field

The scatterometer is an effective instrument for monitoring the near-sea-surface wind field. The National Space Programme of the Ukraine envisages using this kind of device for earth observations from the spacecraft Sych-1M. The Sych-1M is scheduled for launching in the year 2004. The spacecraft will be equipped with a radio-physical instrument package containing a side-looking radar and microwave radiometer, a high-resolution visible-band scanner and a microwave/IR/visible-band radiometer.

The side-looking radar has a real swath aperture of 400 km, a resolution of 1.3×2.5 km and operates at the wavelength of 3 cm. The microwave radiometer of the radio-physical package operates at the wavelength of 0.8 cm with a swath width of 550 km and a resolution 25×25 km.

The high-resolution visible-band scanner has three channels: 0.5–0.59 μm, 0.6–0.69 μm and 0.8–0.92 μm. It has a swath width of 48–105 km and a resolution of 24×35 m. The microwave/IR/visible-band radiometer operates at frequencies from 6.9 to 183.31 GHz and wavelengths of 0.37–0.45 μm, 0.45–0.51 μm, 0.58–0.68 μm, 0.68–0.78 μm, 10.4–11.5 μm and 11.5–12.6 μm. The Sych-1M satellite has an improved data-transmission system, which allows reception of a significant proportion of the data through a standard HRPT station.

The scientific programme of experiments with the Sych-1M spacecraft contains the section devoted to the use of the side-looking radar for mapping the Black Sea wind field. The analysis of Sych-1 wind field retrieved from the side-looking radar data and the wind data obtained by the NSCAT and ERS scatterometers has manifested good agreement between the two data sets. Moreover, the relatively high spatial resolution of the side-looking radar allows mapping of the mesoscale structure of the wind field, which is significant for the Black Sea basin.

8.3.6 Operational Mapping of Sea Surface Temperature and Optical Properties of the Black Sea

The operational NOAA satellites, SeaStar and Terra will make regular measurements of the SST and the optical parameters of the Black Sea upper layer. Calculated maps will be made available via Internet in near-real time.

Other projects will be suggested by the Steering Committee. These projects mainly focus on using and optimising the existing facilities for observation and modelling, such as:

- Co-ordination and upgrading of existing observational facilities supplemented by the identification and establishment of additional observation sites;
- Establishment of an efficient system for the free exchange of data amongst the participating institutions, including agreements on formats and data quality;
- Improvements in the forecasting capabilities by optimising and coupling existing atmospheric–ice and ocean models, combined with the development and operation of local and special product models;
- Establishment of an information system that easily distributes the required products to the users.

8.4 DATA EXCHANGE

The Black Sea GOOS is able to take advantage of and build on a number of existing initiatives in data management in the region to provide environmental information to a wide range of users. To meet the requirements of all its users, the Black Sea GOOS will need to:

- Identify and make available all data and products to those organizations adding value;
- Provide international communication networks and efficient standard formats and codes to make best use of them. Such networks and protocols must have sufficient bandwidth to allow straightforward timely interaction with data centres around the Black Sea;
- Implement advanced data-quality control and validation systems; these systems will ensure that the huge volumes of data required and collected are fit for the specific purpose;
- To employ secure archival methods that retain the value of historical data; this requires appropriate collection, maintenance and dissemination of documentation and metadata;
- Establish an integrated international database. For users to locate and recover the information they require, the information should be described in and accessible from advanced data-processing systems. These systems are developed and maintained at the individual institutions and they will be connected and operated in a co-ordinated manner, so that information stored at different sites is as accessible as if it was stored at a single location. These systems will provide a standard set of assessment methods that allow the Black Sea GOOS partners to investigate the availability and retrieval of data and products;
- Establish links to other data and modelling centres for the retrieval of boundary and forcing fields.

The most urgent and vital part of the Black Sea GOOS co-operation is the establishment of an efficient system for the exchange of data between the participating institutions. The data-exchange component faces two problems:

- Clarification of legal aspects of data exchange;
- Establishment of technical solutions.

Black Sea GOOS realizes that the real-time and near-real-time data exchange constitute a relatively new concept for the oceanographic community in the region, as well as in other regions. Therefore an acceptable tool is required for the data exchange. This tool must be developed in such a manner as to encourage the participation of the data producers. However, Black Sea GOOS will, in principle, follow the EuroGOOS data policy.

To address the technical problems of data exchange the Black Sea GOOS will establish a Working Group on Data Exchange. The WG will start the development and implementation of an FTP-box system for interagency exchange of measurement data. The system has been established at a few of the Black Sea GOOS member institutions and tested, with acceptable results.

8.5 DATA-ANALYSIS SYSTEM

Through the EU-funded ARENA project, the Black Sea GOOS is concentrating on the development and implementation of a prototype data-analysis system for the Black Sea, which is focusing on the physical conditions in the Black Sea. This means that it will sequentially demonstrate the temporal evolution of the surface quantities (sea-surface temperature), as well as the 3-D distributions of salinity and temperature. As an environmental indicator, the 3-D distribution of dissolved-oxygen concentration will also be analysed. The prototype will be designed in such a way that more water-quality parameters can be incorporated into the system. It will also be a test case for operational oceanography at the European level.

The demand for environmental information is escalating rapidly, requiring the design and development of increasingly sophisticated and comprehensive monitoring systems. Ocean-data analysis is the diagnosis of the complete and consistent four-dimensional state of the sea from a vast, asynchronous, heterogeneous database. Development of a common Sea Data Analysis System (SDAS) will be one step towards a co-ordinated Black Sea environmental-assessment concept. Moreover, it will be a test case for deregulation of near-real-time data exchange and international co-operation in operational oceanography.

Theoretically, for environmental analysis, two aspects are of primary importance: the physical laws; and the spatial and temporal variance spectra. The physical laws indicate how it might be possible to determine one variable from another, and the knowledge of spectra can be used to determine the acceptable spacing between observations. In practice, we possess restricted knowledge of the physical laws that govern environmental change, and spectra indicate that the sampling should be much denser than we are able to achieve in practice at present.

SDAS will opt for an objective method based on numerical models and data assimilation. Established forecasting models perform well over several months, and sub-grid processes are parameterised. The spatial resolution of the model (hence the analysis) and the relaxation time-scales can be assigned adequately according to the sampling density. For surface quantities, priority will be given to development and putting into operation specific Black Sea blended *in situ* and remote-sensing products.

8.6 MODELLING

Operational oceanographic models are already a part of the operational service at a few institutes around the Black Sea and include models for three-dimensional circulation, wind waves, and dispersion of chemicals.

Coupled dynamic ecosystem models with interdisciplinary data-assimilation schemes will be developed, validated and applied. The models will involve:

- A basin-wide ocean general circulation model (OGCM) for the physical component of the ecosystem, capable of simulating and predicting the three-dimensional structure of the flow field, temperature and salinity distributions and of their temporal evolution, with mesoscale resolution and with particular emphasis on the coastal-shelf areas;

- A biogeochemical model coupled to the physical model for simulating and predicting the seasonal and longer-term variability and spatial distribution of contaminants, nutrients and other living and non-living components of the ecosystem.

A data base management system based on the existing Black Sea database and management system will be developed. This is needed to develop innovative, efficient and practical ways of processing, archiving and disseminating the large volume of data needed by the modellers. A fundamental issue here is the provision of services with fast turnover time without adversely affecting the accuracy of the resulting product, using sophisticated signal-processing algorithms. When complemented with historical data, the existing database and management system will also serve to monitor the environmental trends, which are crucial from the management perspective.

To improve and increase the theoretical, numerical and computer-dependent level of today's operational models, the Black Sea GOOS has identified at least two items on which to concentrate future research and development:

- Two-way coupling of atmospheric and oceanographic models;
- Interface to general local models.

As both atmospheric and oceanographic models are run with increasingly finer resolution, the air–sea interaction becomes more important; to include this more efficiently, the models have to be coupled. This also includes the coupling of wave models with atmospheric models.

As a three-dimensional eddy-resolving model of the Black Sea requires a resolution and computer capacity that cannot be met at all operational institutes, it is an advantage to run a full Black Sea model only at one or two places. However, even with an eddy-resolving Black Sea model, there is still a need for local models resolving archipelagos and other coastal areas with complicated topography. The configuration of the local models may be different from that of the Black Sea model; i.e. for one region a layer model may be more suitable, whereas another region may be best modelled with a vertical sigma co-ordinate. The idea is to provide an operational interface to local models containing open boundary forcing of user-selected parameters and temporal resolution.

9. LITERATURE

This section contains a selection of the literature which has been consulted in preparation of the present plan.

Aubrey, D., S. Moncheva, E. Demirov, V. Diaconu, and A. Dimitrov, 1996: Environmental changes in the western Black Sea related to anthropogenic and natural conditions. *Journal of Marine Systems,* 7, 411-425.

Basturk, O., C. Saydam, I. Salihoglu, L. V. Eremeeva, S. K. Konovalov, A. Stoyanov, A. Dimitrov, A. Cociasu, L. Dorogan, and M. Altabet, 1994: Vertical variations in the principal chemical properties of the Black Sea in the autumn of 1991. *Marine Chemistry,* 45, 149-165.

Basturk, O., S. Tugrul, S. Konovalov, and I. Salihoglu, 1997: Variations in the vertical structure of water chemistry within the three hydrodynamically different regions of the Black Sea. In E. Ozsoy and A. Mikaelyan (Eds.), *Sensitivity to Change: Black Sea, Baltic Sea, and North Sea,* NATO Science Series 2/27 (pp. 183-196). Dordrecht: Kluwer Academic Publishers.

Basturk, O., L.L. Volkov, S. Gokmen, H. Gungor, A. S. Romanov, and E. V. Yakushev, 1998: International expedition on board R.V. *Bilim* in July 1997 in the Black Sea. *Oceanology* (English translation), 38, 429-432.

Belyaev, V. I., E. E. Sovga, and S. P. Lyubartseva, 1997: Modelling the hydrogen sulfide zone of the Black Sea. *Ecological Modelling,* 13, 51-59.

Besiktepe, S. T., U. Unluata, and A. S. Bologa, 1999: Environmental degradation of the Black Sea: challenges and remedies, NATO Science Series 2/56 (393 pp.). Dordrecht: Kluwer Academic Publishers.

Black Sea Environmental Programme, 1993: Saving the Black Sea, (GEE BSEP Newsletter), 28 pp. New York: World Bank.

Black Sea GOOS. Workshop on Operational Marine Services. 1999: Albena, Bulgaria. Black Sea GOOS Rep. No 1. Paris: UNESCO Publications.

Black Sea GOOS: fundamental and applied aspects. 2000: Eds.: Eremeev, V. N., G. K., Korotaev, A. I. Kubryakov, MHI NASU (173 pp.). Sevastopol.

Bologa, A. S., P. T. Frangopol, V. I. Vedernikov, L. V. Stelmakh, O. A. Yunev, A. Yilmaz, and T. Oguz, 1999: Distribution of planktonic primary production in the Black Sea. In S. T. Besiktepe, U. Unluata, and A. S. Bologa (Eds.), *Environmental Degradation of the Black Sea: Challenges and Remedies,* NATO Science Series 2/56 (pp. 131-146). Dordrecht: Kluwer Academic Publishers.

Cerco, C.F. and Cole, T., 1993: Three-dimensional eutrophication model of Chesapeake Bay. *Journal of Environment Engineering*, 119, 1006-1025.

Committee on the Challenges of Modern Society (CCMS), 1997: Black Sea Observation and Forecasting System (BSOFS) Science Plan. NATO CCMS Rep. No. 221. Brussels: NATO.

Committee on the Challenges of Modern Society (CCMS), 2000: Black Sea Integrated Coastal and Shelf Zone Monitoring and Modelling (INCOM) Programme Science Plan. NATO CCMS Rep. No. 248. Brussels: NATO.

Cordoneanu, E. and J.-F. Geleyn, 1998: Application to local circulations above the Carpathian-Black Sea area of a NWP-type meso-scale model. *Beiträge zur Physik der Atmosphäre,* 71, pp. 191-212.

Cociasu, A., V. Diaconu, L. Popa, I. Nae, L. Dorogan, and V. Malciu, 1997: The nutrient stock of the Romanian shelf of the Black Sea during the last three decades. In E. Ozsoy and A. Mikaelyan (Eds.), *Sensitivity to Change: Black Sea, Baltic Sea, and North Sea,* NATO Science Series 2/27 (pp. 49-64). Dordrecht: Kluwer Academic Publishers.

EuroGOOS, 1996: Strategy for EuroGOOS. EuroGOOS Publication No. 1. ISBN 0-904175-22-7.

Franks, P.J.S., 1997: Coupled physical-biological models for the Study of Harmful Algal Blooms. *Ocean Research*, 19, 153-160.

Ginsburg, A. I., A. G. Kostianoy, D. M. Soloview, and S. V. Stanichny, 2000: Remotely sensed coastal/deep-basin water exchange processes in the Black Sea surface layer. In D. Halpern (Ed.), *Satellites, Oceanography and Society*, Elsevier Oceanography Series 63 (pp. 273-285). Amsterdam: Elsevier.

Global Ocean Observing System (GOOS), 1998: The Global Ocean Observing System. GOOS Pub. No. 42. Paris: UNESCO Publications.

Gordina, A. D., U. Niermann, A. E. Kideys, A. A. Subbotin, Y. G. Artyomov, and F. Bingel, 1998: State of summer ichthyoplankton in the Black Sea. In L. Ivanov and T. Oguz (Eds.), *Ecosystem Modelling as a Management Tool for the Black Sea.* NATO Science Series 2/47 (pp. 367-396). Dordrecht: Kluwer Academic Publishers.

Gregoire, M., J. M. Beckers, J. C. J. Nihoul, and E. Stanev, 1998: Reconnaissance of the main Black Sea's ecohydrodynamics by means of a 3-D interdisciplinary model. *Journal of Marine Systems,* 16, 85-106.

Guillaume, A., 1987 : VAG, modèle de prévision de l'état de la mer en eau profonde. Note de travail de l'EERM, 178, Météo-France. 128 pp.

Hankins, P., F. Touchstone, and B. Hanlon, 1999: Oil contingency plans for naval activities. In S. T. Besiktepe,, U. Unluata, and A. S. Bologa (Eds.), *Environmental Degradation of the Black Sea: Challenges and Remedies.* NATO Science Series 2/56 (pp. 337-350). Dordrecht: Kluwer Academic Publishers.

Ibrayev, R. A., and D. I. Trukhchev, 1998: Model study of the seasonal variability of the Black Sea circulation. In L. I. Ivanov and T. Oguz (Eds.), *Ecosystem Modelling as a Management Tool for the Black Sea,* NATO Science Series 2/47, Vol. 2 (pp. 179-196). Dordrecht: Kluwer Academic Publishers.

Intergovernmental Oceanographic Commission, 1998: Health of the Oceans: Panel of the Global Ocean Observing System, Reports of Meetings of Experts and Equivalent Bodies. GOOS Rep. No. 40. Paris: UNESCO Publications.

International GeosphereJournal of Marine Systems Biosphere Programme, 1992: Joint Global Ocean Flux Study (JGOFS) Implementation Plan. IGBP Rep. No. 23, JGOFS Rep. No. 9. Stockholm: JGOFS.

International Geosphere–Biosphere Programme, 1993: Land-Ocean Interactions in the Coastal Zone (LOICZ) Science Plan. IGBP Rep. No. 25. Stockholm: JGOFS.

International Geosphere–Biosphere Programme, 1999. Global Ocean Ecosystem Dynamics Implementation Plan. IGBP Rep. No. 47, GLOBEC Rep. No. 13. Stockholm: GLOBEC.

Ivanov, L. I., and T. Oguz, 1998: *Ecosystem Modelling as a Management Tool for the Black Sea.* NATO Science Series 2/47, Vols. 1 and 2 (774 pp.). Dordrecht: Kluwer Academic Publishers.

Kideys, A. E., A. V. Kovalev, G. Shulman, A. Gordina, and F. Bingel, 2000: A review of zooplankton investigations of the Black Sea over the last decade. *Journal of Marine Systems,* 24, 355-371.

Konovalov, S., S. Tugrul, O. Basturk, and I. Salihoglu, 1997: Spatial isopycnal analysis of the main pycnocline chemistry of the Black Sea. In E. Ozsoy and A. Mikaelyan (Eds.), *Sensitivity to Change: Black Sea, Baltic Sea, and North Sea.* NATO Science Series 2/27 (pp. 197-210). Dordrecht: Kluwer Academic Publishers.

Konovalov, S. K., L. I. Ivanov, J. W. Murray, and L. V. Eremeeva, 1999: Eutrophication: a plausible cause for changes in hydrochemical structure of the Black Sea anoxic layer. In

S. T. Besiktepe, U. Unluata, and A.S. Bologa (Eds.), *Environmental Degradation of the Black Sea: Challenges and Remedies.* NATO Science Series 2/56 (pp. 61-74). Dordrecht: Kluwer Academic Publishers.

Konsulov, A., and L. Kamburska, 1998: Zooplankton dynamics and variability off the Bulgarian Black Sea coast during 1991-1995. In L. Ivanov and T. Oguz (Eds.), *Ecosystem Modelling as a Management Tool for the Black Sea.* NATO Science Series 2/47, Vol. 1 (pp. 281–292). Dordrecht: Kluwer Academic Publishers.

Kovalev, A. V, U. Nierman, V. V. Melnikov, V. Belokopytov, Z. Uysal, A. E. Kideys, M. Unsal, and D. Altukhov, 1998: Long-term changes in the Black Sea zooplankton: the role of natural and anthropogenic factors. In L. Ivanov and T. Oguz (Eds.), *Ecosystem Modelling as a Management Tool for the Black Sea.* NATO Science Series 2/47, Vol. 1 (pp. 221-234). Dordrecht: Kluwer Academic Publishers.

Kovalev, A. V., and S. A. Piontkovski, 1998: Inter-annual changes in the biomass of the Black Sea gelatinous zooplankton. *Journal of Plankton Research*, 20, 1377-1385.

Korotaev, G. K., O. A. Saenko, C. J. Koblinsky, and V. W. Knysh, 1999: Satellite altimetry observations of the Black Sea. In S. Besiktepe, U. Unluata and A. S. Bologa (Eds.), *Environmental Degradation of the Black Sea: Challenges and Remedies.* NATO Science Series 2/56 (pp. 225-244). Dordrecht: Kluwer Academic Publishers.

Kudela, R.M. and Chavez, F.P., 2000. Modelling the impact of the 1992 El Niño on new production in Monterey Bay, California. *Deep Sea Research*. II, 47, 1055-1076.

Lebedeva, L. P., and E. A. Shushkina, 1993: Modelling the effect of *Mnemiopsis* on the Black Sea plankton community. *Oceanology* (English translation), 34, 72-80.

Mee, L., 1992: The Black Sea in crisis: A need for concerted international action. *Ambio*, 21 278-286.

Mikaelyan, A. S., 1997: Long-term variability of phytoplankton communities in open Black Sea in relation to environmental changes. In E. Ossify and A. Michaela (Eds.), *Sensitivity to Change: Black Sea, Baltic Sea, and North Sea.* NATO Science Series 2/27 (pp. 105-116). Dordrecht: Kluwer Academic Publishers.

Moncheva, S., and A. Krastev, 1997: Some aspects of phytoplankton long-term alterations off Bulgarian Black Sea shelf. In E. Ozsoy and A. Mikaelyan (Eds.), *Sensitivity to Change: Black Sea, Baltic Sea and North Sea.* NATO Science Series 2/27 (pp. 79-94). Dordrecht: Kluwer Academic Publishers.

Moncheva, S., G. Shtereva, A. Krastev, N. Bodeanu, A. E. Kideys, and S. Bayraktar, 1998: Vertical distributions of summer phytoplankton in the western Black Sea during 1991-1995 with respect to some environmental factors. In L. Ivanov and T. Oguz (Eds.), *Ecosystem Modelling as a Management Tool for the Black Sea.* NATO Science Series 2/47, Vol. 1 (pp. 327-350). Dordrecht: Kluwer Academic Publishers.

Mutlu, E., 1999: Distribution and abundance of ctenophores and their zooplankton food in the Black Sea. II. *Mnemiopsis leidyi, Marine Biology,* 135, 603-613.

Mutlu, E., E. Bingel, A. C. Gucu, V. V. Melnikov, U. Niermann, N. A. Ostr, and V. E. Zaika, 1994: Distribution of the new invader *Mnemiopsis sp.* and the resident *Aurelia aurita* and *Pleurobrachia pileus* populations in the Black Sea in the years 1991–1993. *ICES, Journal of Marine Science*, 51, 407-421.

Neziin, N. P., A. G. Kostianoy, and M. Gregoire, 1999: Patterns of seasonal and inter-annual changes of surface chlorophyll concentration in the Black Sea revealed from the remote sensed data. *Remote Sensing of Environment (China)*, 69, 43-55.

Niermann, U., A. E. Kideys, A. V. Kovalev, V. Melnikov, and V. Belokopytov, 1999: Fluctuations of pelagic species of the open Black Sea during 1980-1995 and possible teleconnections. In S. T. Besiktepe, U. Unluata, and A. S. Bologa (Eds.), *Environmental Degradation of the Black Sea: Challenges and Remedies,* NATO Science Series 2/56 (pp. 147-176). Dordrecht: Kluwer Academic Publishers.

Oguz, T., P. La Violette, and U. Unluata, 1992: Upper layer circulation of the southern Black Sea: its variability as inferred from hydrographic and satellite observations. *Journal of Geophysical Research,* 97, 12569-12584.

Oguz, T., V. S. Latun, M. A. Latif, V. V. Vladimirov, H. I. Sur, A. A. Makarov, E. Ozsoy, B. B. Kotovshchikov, V. V. Eremeev, and U. Unluata, 1993: Circulation in the surface and intermediate layers of the Black Sea. *Deep Sea Research, I,* 40, 1597-1612.

Oguz, T., D. G. Aubrey, V. S. Latun, E. Demirov, L. Koveshnikov, H. I. Sur, V. Diacanu, S. Besiktepe, M. Duman, R. Limeburner, and V. Eremeev, 1994: Mesoscale circulation and thermohaline structure of the Black Sea observed during HydroBlack '91. *Deep-Sea Research, I,* 41, 603-628.

Oguz, T., P. Malanotte-Rizzoli, and D. Aubrey, 1995: Wind and thermohaline circulation of the Black Sea driven by yearly mean climatological forcing. *Journal of Geophysical Research,* 100, 6845-6863.

Oguz, T., and P. Malanotte-Rizzoli, 1996: Seasonal variability of wind and thermohaline driven circulation in the Black Sea: modelling studies. *Journal of Geophysical Research,* 101, 16551-16569.

Oguz, T., H. Ducklow, P. Malanotte-Rizzoli, S. Tugrul, N. Neziin, and U. Unluata, 1996: Simulation of annual plankton productivity cycle in the Black Sea by a one-dimensional physical–biological model. *Journal of Geophysical Research,* 101, 16585-16599.

Oguz, T., L. I. Ivan, and S. Besiktepe, 1998: Circulation and hydrographic characteristics of the Black Sea during 1992. In L. I. Ivanov and T. Oguz (Eds.), *Ecosystem Modelling as a Management Tool for the Black Sea,* NATO Science Series, 2/47, Vol. 2 (pp. 69-92), Dordrecht: Kluwer Academic Publishers.

Oguz, T., H. Ducklow, P. Malanotte-Rizzoli, J. W. Murray, V. I. Vedernikov, and U. Unluata, 1999: A physical–biochemical model of plankton productivity and nitrogen cycling in the Black Sea. *Deep Sea Research, I,* 46, 597-636.

Oguz, T., and S. Besiktepe, 1999: Observations on the Rim Current structure, CIW formation and transport in the western Black Sea. *Deep Sea Research, I,* 46, 1733-1753.

Oguz, T., and B. Salihoglu, 2000a: Simulation of eddy-driven phytoplankton production in the Black Sea. *Geophysical Research Letters,* 27, 2125-2128.

Oguz, T., H. W. Ducklow, P. Malanotte-Rizzoli, 2000b: Modelling distinct vertical biogeochemical structure of the Black Sea: Dynamical coupling of the oxic, suboxic and anoxic layers. *Global Biogeochemical Cycles*, 14, 1331-1352.

Oguz, T., J.W. Murray, and A.E. Callahan, 2001a: Modelling redox cycling across the suboxic–anoxic interface zone in the Black Sea, *Deep Sea Research, I,* 48, 761-787.

Oguz, T., H.W. Ducklow, J.E. Purcell, P. Malanotte-Rizzoli, 2001b: Simulation of recent changes in the Black Sea pelagic food web structure due to top-down control by gelatinous carnivores. *Journal of Geophycical Research*, 106, 4543-4564.

Ozsoy, E., and A. S. Mikaelyan, 1997: Sensitivity to Change: Black Sea, Baltic Sea and North Sea, NATO Science Series 2/27, 469 pp. Dordrecht: Kluwer Academic Publishers.

Palshin, G., 1998: Black Sea in crisis. In *Proceedings of the 23rd Session of the International Seminars on Planetary Emergencies.* August 19-24, 1998. ICSC World Laboratory Rep. No. 23. Erice, Sicily. World Federation of Scientists.

Petranu, M. A., N. Bodeanu, A. S. Bologa, C. Dumitrache, M. Moldoveanu, G. Radu, and V. Tiganus, 1999: Status and evolution of the Romanian Black Sea coastal ecosystem. In S. T. Besiktepe, U. Unluata, and A. S. Bologa (Eds.), *Environmental Degradation of the Black Sea: Challenges and Remedies,* NATO Science Series 2/56 (pp. 175-196). Dordrecht: Kluwer Academic Publishers.

Prodanov, K. and G. Daskalov, 1992: Stock assessment of sprat (Sprattus sprattus) along Bulgarian Black Sea coast (1976 - 1990). Rapp. et Proces-Verbaux des Reunions, 33, 305.

Prodanov, K., K. Mikhailov, G. Daskalov, K. Maxim, A. Chashchin, A. Arkhipov, V. Shylakhov, and E. Ozdamar, 1997: Environmental impact of fish resources in the Black Sea. In E. Ozsoy and A. Mikaelyan (Eds.), *Sensitivity to Change: Black Sea, Baltic Sea, and North Sea.* NATO Science Series 2/27 (pp. 163-182). Dordrecht: Kluwer Academic Publishers.

Rachev, N. H., and E. V. Stanev, 1997: Eddy processes in semi-enclosed seas: a case study for the Black Sea. *Journal of Physical Oceanography*, 27, 1581-1601.

Rigaini, R. C., 1999: Monitoring Black Sea environmental conditions: Workshop summary. Proceedings of the Working Group on Water and Pollution, Proceeding Series, Vol. 3 (pp. 5-26). World Federation of Scientists Publications. Lausanne, Switzerland.

Robinson, A.R., 1999. Forecasting and simulating coastal ocean processes and variabilities with the Harvard ocean prediction system. Coastal Ocean Prediction, *AGU Coastal and Estuarine Studies,* 56, 77-99.

Shiganova, T. A., 1998: Invasion of the Black Sea by the ctenophore *Mnemiopsis leidyi* and recent changes in pelagic community structure. *Fisheries Oceanography,* 7, 305-310.

Shiganova, T. A., A. E. Kideys, A. C. Gucu, U. Niermann, and V. S. Khoroshilov, 1998: Changes in species diversity and abundance of the main components of the Black Sea pelagic community during the last decade. In L. Ivanov and T. Oguz (Eds.), *Ecosystem Modelling as a Management Tool for the Black Sea.* NATO Science Series 2/47, Vol. 1 (pp. 171-188). Dordrecht: Kluwer Academic Publishers.

Shulman, G. E., Y. A. Stolbov, E. V. Ivieva, Y. A. Shchepkin, and G. S. Minyuk, 1999: Influence of anthropogenic impact on the physiology of some Black Sea fish species. In S. T. Besiktepe, U. Unluata, and A. S. Bologa (Eds.), *Environmental Degradation of the Black Sea: Challenges and Remedies,* NATO Science Series 2/56 (pp. 257-272). Dordrecht: Kluwer Academic Publishers.

Shushkina, E. A., M. E. Vinogradov, L. P. Lebedeva, T. Oguz, N. P. Neziin, V. Yu. Dyakonov, and L. L. Anokhina, 1998: Studies of structural parameters of planktonic communities of the open part of the Black Sea relevant to ecosystem modelling. In L. Ivanov and T. Oguz (Eds.), *Ecosystem Modelling as a Management Tool for the Black Sea, Symposium on Scientific Results.* NATO Science Series 2/47, Vol. 1 (pp. 311-326). Dordrecht: Kluwer Academic Publishers.

Small Pelagics and Climate Change Programme, 1996: GLOBEC International, SPACC Implementation Plan, *Report of the First SPACC Modelling Meeting Workshop,* October

14-16, 1996, Ispra, Italy. GLOBEC Publications, Rep. No. 11.

Stanev, E. V., 1990: On the mechanisms of the Black Sea circulation. *Earth-Science Review*, 28, 285-319.

Stanev, E. V., V. M. Roussenov, N. H. Rachev, and J. V. Staneva, 1995: Sea response to atmospheric variability: model study for the Black Sea. *Journal of Marine Systems*, 6, 241-267.

Stanev, E. V., J. V. Staneva, and V. M. Roussenov, 1997: On the Black Sea water mass formation: model sensitivity study to atmospheric forcing and parameterizations of physical processes. *Journal of Marine Systems*, 13, 245–272.

Stanev, E. V., and J-M. Beckers, 1999: Numerical simulations of seasonal and inter-annual variability of the Black Sea thermohaline circulation. *Journal of Marine Systems*, 22, 241-267.

Stanners, D., and P. Bourdeau, 1995: Europe's environment: the Dobris assessment. European Environment Agency Task Force. *Newsletter* 5, ISBN 92-826-5409-5; ECU: 55. Luxembourg: Office for Official Publications of the European Communities.

Stelmakh, L. V., O. A. Yunev, Z. Z. Finenko, V. I. Vedernikov, A. S. Bologa, and T. Y. Churilova, 1998: Peculiarities of seasonal variability of primary production in the Black Sea. In L. Ivanov and T. Oguz (Eds.), *Ecosystem Modelling as a Management Tool for the Black Sea, Symposium on Scientific Results.* NATO Science Series 2/47, Vol. 1 (pp. 93-104). Dordrecht: Kluwer Academic Publishers.

Sur, H. I., E. Ozsoy, and U. Unluata, 1994: Boundary current instabilities, upwelling, shelf mixing, and eutrophication processes in the Black Sea. *Progress in Oceanography*. 33, 249-302.

Sur, H. I., E. Ozsoy, Y. P. Ilyin, and U. Unluata, 1996: Coastal/deep ocean interactions in the Black Sea and their ecological/environmental impacts. *Journal of Marine Systems*, 7, 293-320.

Thompson, M. K., 1999: Monitoring transboundary issues and environmental initiatives. *Working Group Proceedings on Water and Pollution Proceeding Series*, Vol. 3 (pp. 259-262). World Federation of Scientists Publications. Proceeding Series Vol. 3. Lausanne, Switzerland.

Unluata, U., D. G. Aubrey, Z. Belberov, A. Bologa, V. Eremeev, and M. Vinogradov, 1993: International Programme investigates the Black Sea, *EOS*, 74 (36), 401-412.

United Nations Development Programme, 1993: Saving the Black Sea. Programme for the Environmental Management and Protection of the Black Sea. Rep., 28 pp. New York: World Bank.

Vinogradov, M.E., V.V. Sapoznikov, and E.A. Shushkina, 1992: Ekosistema Chernogo moria (The Black Sea Ecosystem), Moscow, Nauka.

Walstad, L.J. and McGillicudy, D.J., 2000: Data assimilation for coastal observing systems. *Oceanography*, 13, 47-53.

Vinogradov, M. E., E. A. Shushkina, A. S. Mikaelyan, and N. P. Neziin, 1999: Temporal (seasonal and inter-annual) changes of ecosystem of the open waters of the Black Sea. In S. T. Besiktepe, U. Unluata, and A. S. Bologa (Eds.), *Environmental Degradation of the Black Sea: Challenges and Remedies.* NATO Science Series 2/56, 109-129. Dordrecht: Kluwer Academic Publishers.

Yakushev, E. Y., 1998: Mathematical modelling of oxygen, nitrogen, sulfur, and manganese cycling in the Black Sea. In L. Ivanov and T. Oguz (Eds.), *Ecosystem Modelling as a Management Tool for the Black Sea.* NATO Science Series 2/47, Vol. 2 (pp. 373-384). Dordrecht: Kluwer Academic Publishers.

Yakushev, E. V., and L. N. Neretin, 1997: One-dimensional modelling of nitrogen and sulfur cycles in the aphotic zone of the Black and Arabian Seas. *Global Biogeochemical Cycles*, 11, 401-414.

Yilmaz, A., O. A. Yunev, V. I. Vedernikov, S. Moncheva, A. S. Bologa, A. Cociasu, and D. Ediger, 1998: Unusual temporal variations in the spatial distribution of chlorophyl in the Black Sea during 1990-1996. In L. Ivanov and T. Oguz (Eds.), *Ecosystem Modelling as a Management Tool for the Black Sea.* NATO Science Series, 2/47, Vol. 1 (pp. 105-120). Dordrecht: Kluwer Academic Publishers.

Zaitsev, Yu., 1993: Impacts of eutrophication on the Black Sea fauna. General Fisheries Council for the Mediterranean, Studies and Reviews, 64, 63-86. Rome: FAO

Zaitsev, Yu., and V. Mamaev, 1997: Marine biological diversity in the Black Sea: a study of change and decline. GEF Black Sea Environmental Programme, 208 pp. Black Sea Environmental Series, Vol. 3. New York: United Nations Publications.

ANNEX I

COMPONENTS OF THE NATIONAL OPERATIONAL MARINE HYDROMETEOROLOGICAL SERVICES

1. FORECASTING CAPABILITIES OF BULGARIA AND ROMANIA: THE ALADIN PROJECT

The acronym ALADIN (Aire Limitée Adaptation Dynamique Développement International) describes several facets of an international project (on limited-area mesoscale modelling) involving up to 160 people from 14 national meteorological services. The project goal is to develop a limited-area version of the ARPEGE forecasting system of Météo-France. Bulgaria and Romania are the members of the South-Eastern Limited-Area Model (SELAM) group. The SELAM project currently involves technical collaboration. The main development and maintenance of the code is carried out by Météo-France in Toulouse. Bulgaria and Romania have local operational applications with high resolution in a domain covering the territory of the state and some parts of the neighbouring countries. Initial and boundary conditions are provided from the output of the parent global model of Météo-France. The local operational forecast is a short-range one only up to 48 hours of integration. The products are distributed and used at a national level. The performance of the model around the Black Sea coast is very good and can be successfully used for various purposes (Cordoneanu and Geleyn, 1998) .

The ALADIN model covers only Bulgaria and Romania, including the adjacent Black Sea domain. Thus, low-resolution data for the entire Black Sea domain are available with a frequency of 6 hours for the forecast period of 48 hours and only for the basic dynamical variables (surface pressure, horizontal wind, temperature and moisture). More precise data (with higher resolution and more frequent data, as often as desired) are available for the adjacent waters of the Black Sea from the output of ALADIN. They are used to supply the source term of the wind input in solving the wave model.

Advanced atmospheric fine-resolution models are used for the description of the atmospheric input to the wave models. The third-generation wave model WAM (Gunther, 1992) and second-generation French wave model VAG (Guillaume, 1987) are used by the national meteorological services of Bulgaria and Romania, supplying wind-wave and swell parameters (height and period) and wave spectra. They have a resolution of 0.25×0.25 degrees and cover the whole Black Sea; at the National Meteorological Service in Bucharest a higher-resolution wave model (5’×5’) integrated over the western basin of the Black Sea gives very good results. However, deeper verification and calibration, as well as initialization improvement of the wave model over the Black Sea, are necessary and it is the improvement of the observational network, one of the main BS–GOOS objectives, that could allow this.

2. COASTAL HYDROMETEOROLOGICAL NETWORK OF GEORGIA

The Georgian coastal zone encompasses 326 km of the Black Sea coast between Russia and Turkey, from the mouth of the River Psou to Kelenderi Cape. Until the early 1990s, there were 32 meteorological stations, 6 tide gauges, shipboard observations at 35 hydrographic stations, and 45 observation stations for marine-pollution monitoring along the coast of Georgia. Collection, systematization and processing of data from this network were carried out at the Hydrometeorological Observatory of Batumi.

Since the 1990s, the socio-economic and political circumstances in Georgia have had a negative effect on the hydrometeorological observation network. Presently, only five meteorological stations and three tide gauges are functioning. The shipboard observations have almost stopped and hydrochemical measurements are made only episodically.

The initial network of the Georgian Black Sea GOOS will include meteorological and tide-gauge measurements at Batumi, Kobuleti, Poti, Supsa and Kulevi. Near-future plans are to include the hydrometeorological stations of Abkhazeti: Sokhumi, Bichvinta and Gagra. Future improvement of the network may allow recovery of all the observations that were available before 1990.

3. OPERATIONAL MARINE HYDROMETEOROLOGICAL SERVICES OF RUSSIA

The Hydrometeorological Service of Russia prepares and disseminates various kinds of oceanographic products, both for general and specialised use. Products of the Service cover all Russian marginal seas, particularly the Black Sea. The developed products are based on:

- Marine hydrometeorological and hydrochemical observations (ground and satellite-based);
- Collection, processing and archiving of the marine hydrometeorological data;
- Data assimilation, preparation and presentation of the diagnostic and prognostic products and their delivery to the end users.

The major task of the Service is to provide data and other information on the marine environment to support social, economic, defence, and nature-protection activities, including warnings of severe hydrometeorological events, supplying information on the actual and expected (forecast) states of various components of the marine environment, such as pollution, consultations and recommendations on the actual and/or expected impact of weather conditions on everyday activity, and reference information on marine climate, etc.

The marine hydrometeorological information is presented mainly in the form of daily bulletins that may be supplemented with various graphs and other materials describing the features of the marine climate.

The routine hydrometeorological monitoring of the marine environment is the basis of forecasts and warnings. Four times a day the Service performs an objective analysis of the pressure, precipitation, cloud, air-temperature and wind-velocity fields on a grid 150 km by 150 km using hydrodynamic atmospheric models. The diagnostic fields are accumulated in an operational data base and are subsequently delivered to the regional forecasting centre. There they serve as a background and/or boundary conditions for detailing the objective analysis and regional or local forecasting. The Russian Hydrometeorological Service possesses an operational database which contains all necessary types of data for meteorological and oceanographic analysis and forecasts.

4. THE TURKISH STATE METEOROLOGICAL SERVICE

The main objectives of the TSMS are:

- To make observations;
- To provide forecasts;
- To provide climatological data, archive data and other information;
- To communicate these to the public;
- To meet the meteorological needs of the army and civil aviation.

Marine meteorology provides support for shipping, sailing, fishing, tourism, harbour planning and management, transport and marine-pollution studies.

The Turkish Marine Forecasting Office prepares marine reports and forecasts. Daily analysis maps and weather forecasts come from the Analysis and Forecasting Division. The Numerical Weather Prediction Section, in the Analysis and Forecasting Division, provides all ECMWF outputs to the TSMS.

The Research Division of the Research Department supports marine forecasting using a third-generation wave model METU3. Currently, the programme undertakes daily routine forecasting at the Marine Forecasting Office. This model has a resolution of 0.5° E–W by 0.36° S–N for the Black Sea. The model output includes three maps: the first one gives wind speed (in m/s) and direction at 10 m height; the second gives significant wave height (in metres) and direction; and the third gives mean wave period (in seconds).

There are seven marine stations along the Turkish Black Sea coast. These stations make sea observations at 06:00, 08:00, 10:00, 12:00, 14:00, 16:00, 18:00 UTC every day and the observations are transferred on-line to the Marine Forecasting Office. Observed parameters are cloudiness, wind direction, speed and gust, air temperature, marine sea-level pressure, present and past weather, sea-surface temperature (observed only at 0600), sea state and visibility over the sea.

5. OPERATIONAL MARINE HYDROMETEOROLOGICAL SERVICES OF THE UKRAINE

The Ukrainian national system of marine coastal observations consists of 36 hydrometeorological stations of different types on the Ukrainian coasts of the Black Sea, the Sea of Azov, in straits and mouths of rivers (Fig. 9). Observed variables are routine meteorology, river run-off, sea level, water temperature, salinity, waves and ice conditions, marine chemistry and pollutants.

Seven stations have small research vessels implementing the regular hydrometeorological and chemical observations in coastal waters within the distance from 1–2 to 5–10 miles. Regular shipboard observations are executed as follows:

Southern seashore of the Crimea, port of Yalta. Oceanographic surveys are carried out: at 30 stations in the 5-mile band of coastal water between the towns Alushta and Alupka; 10-mile “secular” sections from the port of Yalta towards the south-east; a “secular” roadstead station 1 mile from Yalta.

South-western coast of the Crimea, port of Sevastopol. Oceanographic surveys are carried out: at 15–30 stations in a 5-mile band of coastal water between Cape Lukull and Cape Sarytch; at 10–15 stations in the Sevastopol Bight or at 5–7 stations along the Bight's axis.

The Danube river mouth, port of Izmail. Oceanographic surveys are carried out: at 50 stations in a 50-mile band of coastal water from the Danube's mouth to the island Zmeiny; and 20-mile "secular" sections at 9 stations along the latitude 45°20'N.

Dnieper–Bug estuary and marine coastal waters, port of Nikolaev. Surveys are carried out: in the Dnieper–Bug estuary at 25–30 stations; at 3–9 stations in coastal water.

Kertch Strait, village of Opasnoye. Surveys of the Kertch Strait are carried out: at 15–20 stations; a "secular" section across the strait at 8 stations; a "secular" roadstead station in the centre of the strait.

Northern seashore of the Taganrog Bay in the Sea of Azov, port of Mariupol. Surveys of coastal water are carried out near Mariupol at 15 stations; an 8-mile "secular" section from the port of Mariupol towards the south-south-east at 6 stations; a "secular" roasted station 1 mile from Mariupol.

Western seashore of the Sea of Azov, city of Genichesk. Surveys are carried out: of the Utliuk Firth and Lake Sivash at 12 stations; a "secular" roadstead station in the Tonkiy Strait.

Water temperature, salinity, transparency (Secchi-disk depth) and colour (on the standard scale) are measured, as well as standard meteorological observations, during the nearshore oceanographic work on small vessels. Occasionally, marine current speed and direction are recorded. Distributions of oceanographic properties with depth are obtained by means of Nansen-bottle samples or CTD-probes (the latter are used occasionally, during joint work with research institutes). Water samples are taken for chemical analysis and pollutant control. Oceanographic and meteorological observational data are processed using standard methods.

Regular roadstead observations are made every 10 days all year round, except under harsh meteorological conditions.

Oceanographic and chemical surveys for water-quality control, as well as "secular" sections, are conducted, basically, once per season (4 times per year), except for Yalta, where such surveys and sections are conducted every month.

Four forecasting units of the National Hydrometeorological Service provide operational marine services in Ukraine:

- *Hydrometeorological Centre for the Black Sea and the Sea of Azov in Odessa* is the main marine forecasting and methodological entity. It prepares and transmits one- and two-day weather and wave forecasts, storm and gale warnings for the Black Sea, short-term sea-water temperature and ice forecasts for the north-western coast of the Black Sea and Kertch Strait, weather and wave forecasts for waterways in the Black

Sea and the Azov Sea, forecasts and real-time information for the ports of Odessa, Nikolayev and Yuzhny.

- *Hydrometeorological Bureau of Ilyichevsk* prepares one-day weather and wave forecasts, storm warnings for the Ilyichevsk area, forecasts for the ferry route Ilyichevsk–Varna.

- *Danube Observatory in Izmail* prepares weather forecasts and storm warnings for the Danube region of the Ukraine, including the ports of Reni, Izmail, Kiliya and Ust-Dunaysk.

- *Hydrometeorological Bureau of Sevastopol* prepares one-day weather and wave forecasts, storm warnings for the Sevastopol area and the ports of Evpatoriya, Yalta and Feodosiya, and for the offshore oil and gas platforms in Karkinitskiy and Kalamitskiy Bays.

ANNEX II

LIST OF ACRONYMS

ALACE	Autonomous Langrangian circluation explorer
ALADIN	Aire Limitée Adaptation Dynamique Développement International model (of Météo-France)
ARENA	A Regional Capacity Building and Networking Programme to upgrade Monitoring and Forecasting Activity in the Black Sea Basin
AVHRR	Advanced very high-resolution radiometer
BOD	Biological oxygen demand
BSBP	Black Sea Buoy Programme
BSC	Black Sea Commission
BS–DIMS	Black Sea Data and Information Management System
BSEP	Black Sea Environment Programme (of UNEP)
BS–GOOS	Black Sea Global Ocean Observing System (of IOC)
CESUM	Centre for Sustainable Development and Management of the Black Sea Region (Bulgaria)
CFC	Chlorofluorocarbon
CTD	Conductivity–temperature–depth meter
CZMA	Coastal-Zone Management and Analysis (of BS–GOOS)
DBCP	Data-Buoy Co-operation Panel (of IOC and WMO)
DDT	Dichloro-diphenyl-trichloroethane
ECMWF	European Centre for Medium-Range Weather-Forecasting
EGOS	European Group of Ocean Stations
ERS	Earth Remote-sensing Satellite (of European Space Agency)
ESAD	Earth Sciences Applications Directorate (of NASA)
EU	European Union
EuroGOOS	European Global Ocean Observing System (of GOOS)
FTP	File-transfer protocol
GEF	Global Environment Facility
GIWA	Global International Waters Assessment (of UNEP–GEF)
GLOBEC	Global Ocean Ecosystem Dynamics project (of the International Council of Science)
GLOSS	Global Sea-Level Observing System (of IOC)
GNP	Gross national product
GOOS	Global Ocean Observing System
HAB	Harmful Algal Blooms programme (of IOC)
HRPT	High-resolution picture transmission
ICZM	Integrated Coastal-Zone Management
IGBP	International Geosphere–Biosphere Programme
IMS	Institute of Marine Science (of METU)
IOC	Intergovernmental Oceanographic Commission (of UNESCO)
JGOFS	Joint Global Ocean Flux Study (of GLOBEC)
LANDSAT	Land satellite (of NASA)

LME	Large Marine Ecosystems
LMR	Living marine resources
LOICZ	Land–Ocean Interactions in the Coastal Zone (of IGBP)
MARPOL	International Convention for the Prevention of Pollution from Ships, 1973, as Modified by the Protocol of 1978 Relating Thereto
MEDGLOSS	Mediterranean Global Sea-Level Observing System (of IOC)
MedGOOS	Mediterranean Global Ocean Observing System (of GOOS)
METU	Middle Eastern Technical University (Turkey)
MHI	Marine Hydrophysical Institute (Ukraine)
MSM	Marine Service Module (of BS–GOOS)
NASA	National Aeronautics and Space Administration (USA)
NASU	National Academy of Science of the Ukraine
NATO	North Atlantic Treaty Organization
NOAA	National Oceanic and Atmospheric Administration (USA)
NSCAT	NASA six-antenna scatterometer
NWS	North-western shelf (Black Sea)
OGCM	Ocean general circulation model
OOSD	Optimal observation system design
OSMA	Open-Sea Management and Analysis (of BS–GOOS)
PALACE	Profiling autonomous Langrangian circluation explorer
PAR	Photosynthetically available radiation
RAC	Regional Analysis Centre (of BS–GOOS)
RAS	Russian Academy of Science
RMAM	Regional Management and Analysis Module
SDAS	Sea-Data Analysis System
SeaWiFS	Sea-viewing Wide Field-of-view Sensor (of NASA)
SELAM	South-eastern limited-area model (of BS–GOOS)
SfP	Science for Peace (of NATO)
SPACC	Small Pelagic Fishes and Climate Change programme (of GLOBEC)
SST	Sea-surface temperature
TOC	Total organic carbon
TSMS	Turkish State Meteorological Service
TUE	Transuranic element
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USD	United States dollar
UTC	Universal Time Co-ordinate
WAM	Wave model
WG	Working Group
WMO	World Meteorological Organization
XBT	Expendable bathythermograph
XCTD	Expendable Conductivity Temperature Depth