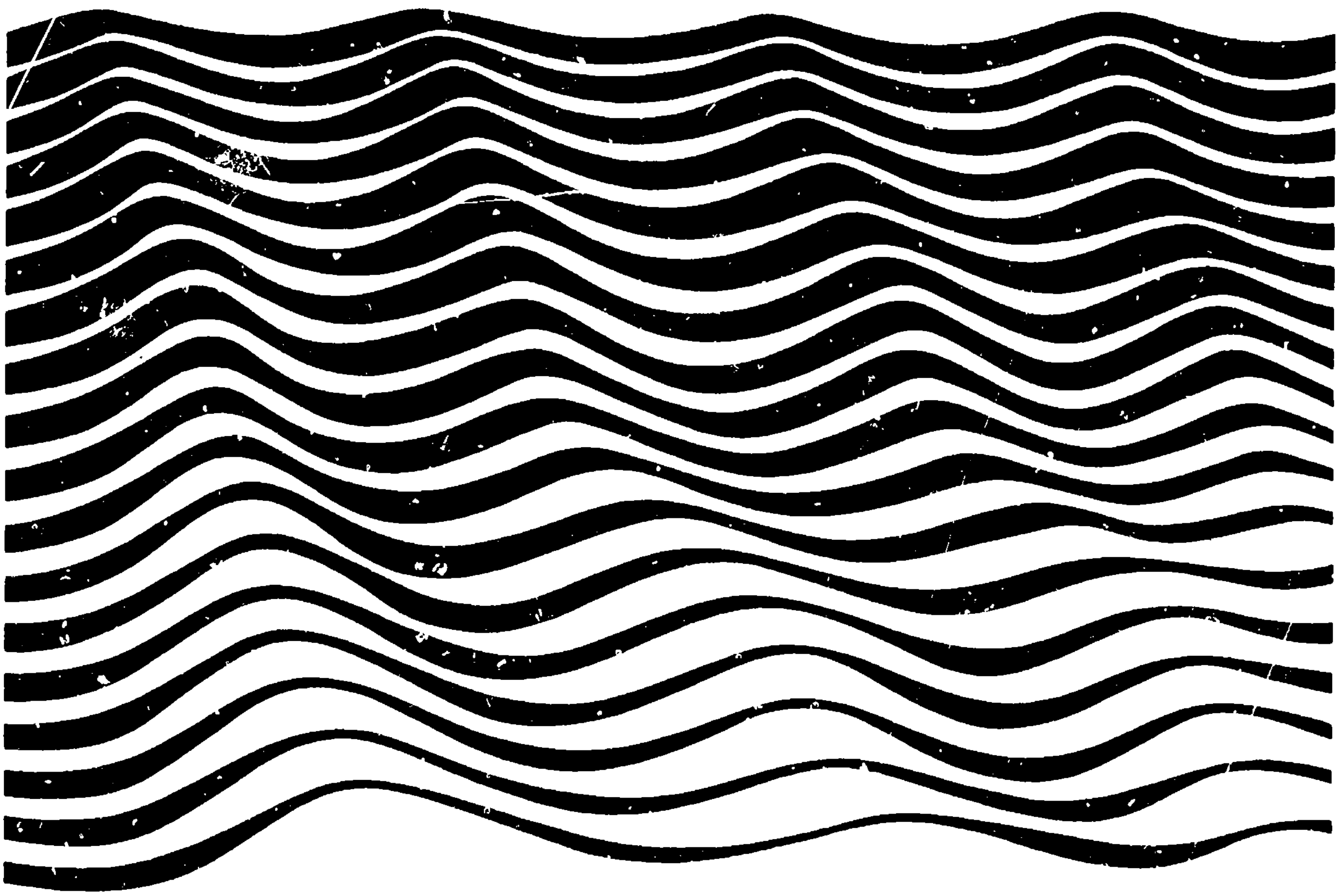
Unesco reports in marine science 30

Physical oceanography of the Eastern Mediterranean: an overview and research plan

Report of a workshop
held in Lerici, La Spezia (Italy),
September 1983



Unesco, 1984

UNESCO REPORTS IN MARINE SCIENCE

No.		Year
1	Marine ecosystem modelling in the Eastern Mediterranean Report of a Unesco workshop held in Alexandria, Egypt, December 1974 English only	1977
2	Marine ecosystem modelling in the Mediterranean Report of the Second Unesco Workshop on Marine Ecosystem Modelling English only	1977
4	Syllabus for training marine technicians Report of an IOC/Unesco workshop held in Miami, Florida, 22-26 May 1978 Available in English, French, Russian and Spanish	1979
5	Marine science syllabus for secondary schools Report of an IOC workshop held at United World College of the Atlantic, United Kingdom, 5-9 June 1978 Available in Arabic, English, French, Russian and Spanish	1979
6	Organization of marine biological reference collections in the Mediterranean Arab countries Expert meeting held in Tunis, 20-23 September 1978 Available in Arabic, English and French	1979
7	Coastal ecosystems of the southern Mediterranean: lagoons, deltas and salt marshes Report of a meeting of experts, Tunis, 25-27 September 1978 Available in Arabic, English and French	1979
8	The mangrove ecosystem: Human uses and management implications Report of a Unesco regional seminar held in Dacca, Bangladesh, December 1978 English only	1979
9	The mangrove ecosystem: scientific aspects and human impact Report of the seminar organized by Unesco at Cali, Colombia, 27 November-1 December 1978 Available in English and Spanish	1979
10	Development of marine science and technology in Africa Working Group of Experts sponsored by ECA and Unesco, Addis Ababa, 5-9 May 1980 Available in English and French	1980
11	Programa de Plancton para el Pacífico Oriental Informe final del Seminario-Taller realizado en el Instituto del Mar del Perú, El Callao, Perú, 8-11 de septiembre de 1980 Spanish only	1981
12	Geología y geoquímica del margen continental del Atlántico Sudoccidental, Informe final del Taller de Trabajo organizado por la Unesco en Montevideo, Uruguay, 2-4 de diciembre de 1980 Spanish only	1981
14	Marine science and technology in Africa: present state and future development Synthesis of Unesco/ECA survey missions to African coastal states, 1980 Available in English and French	1981
15	Fishery science teaching at the university level Report of a Unesco/FAO workshop on university curricula in fishery science, Paris, May 1980 Available in Arabic, English, French, Russian and Spanish	1981
16	Marine and coastal processes in the Pacific: ecological aspects of coastal zone management Report of a Unesco seminar held at Motupore Island Research Centre, University of Papua New Guinea, 14-17 July 1980 English only	1981
17	The coastal ecosystems of West Africa: coastal lagoons, estuaries and mangroves A workshop report, Dakar, 11-15 June 1979 Available in English and French	1981
18	Coral reef management in Asia and the Pacific: some research and training priorities Report of a Unesco workshop held in Manila, Philippines 21-22 May 1981 English only	1982
19	Mareas rojas en el Plancton del Pacífico Oriental Informe del Segundo Taller del Programa de Plancton del Pacífico Oriental, Instituto del Mar, Callao, Perú 19-20 de noviembre de 1981 Spanish only	1982
20	Quantitative analysis and simulation of Mediterranean coastal ecosystems: The Gulf of Naples, a case study Report of a workshop on ecosystem modelling Ischia, Naples, Italy, 28 March to 10 April 1981 Organized by the United Nations, Educational, Scientific and Cultural Organization (Unesco) and the Stazione Zoologica, Naples English only	1983
21	Comparing coral reef survey methods A regional Unesco/UNEP workshop, Phuket Marine Biological Centre, Thailand, December 1982 English only	1983
22	Guidelines for marine biological reference collections Prepared in response to a recommendation by a meeting of experts from the Mediterranean Arab countries Available in English, French and Arabic	1983
23	Coral reefs, seagrass beds and mangroves: their interaction in the coastal zones of the Caribbean Report of a workshop held at West Indies Laboratory, St. Croix, U.S. Virgin Islands, May, 1982 English only	1983
24	Coastal ecosystems of Latin America and the Caribbean The objectives, priorities and activities of Unesco's COMAR project for the Latin America and Caribbean region Caracas, Venezuela, 15-19 November 1982 Available in English and Spanish	1983
25	Ocean engineering teaching at the university level Recommended guidelines from the Unesco/IOC/ECOR workshop on advanced university curricula in ocean engineering and related fields, Paris, October 1982 Available in English, French, Spanish, Russian, Arabic and Chinese	1983
26	Global survey and analysis of post-graduate curricula in ocean engineering English only	1984
27	Productivity and processes in island marine ecosystems. Recommendations and scientific papers from the Unesco/IOC sessions on marine science co-operation in the Pacific, at the XVth Pacific Science Congress, Dunedin, New Zealand, February 1983 English only	1984
28	Oceanographic modelling of the Kuwait Action Plan (KAP) Region. Report of simposium/workshop; University of Petroleum and Minerals, Dhahran, Kingdom of Saudi Arabia 15-18 October 1983 English only	1984
29	Eutrophication in coastal marine areas and lagoons: a case study of 'Lac de Tunis' Report prepared by Dr M. Kelly and Dr M. Naguib English only	1984
30	Physical oceanography of the Eastern Mediterranean: an overview and research plan Report of a workshop held in Lerici, La Spezia (Italy), September 1983 English only	1984

Unesco reports in marine science 30

Physical oceanography of the Eastern Mediterranean: an overview and research plan

Report of a workshop
held in Lerici, La Spezia (Italy),
September 1983

Unesco, 1984

Published in 1984 by the United Nations
Educational, Scientific and Cutural Organization
Place de Fontenoy, 75700 Paris
Printed in Unesco's workshops

PREFACE

Unesco Reports in Marine Science are designed to serve specific programme needs and to report on developments in projects conducted by the Unesco Division of Marine Sciences, including those involving collaboration between the Division and the Intergovernmental Oceanographic Commission, particularly in the field of training, education, and mutual assistance in the marine sciences.

Designed to serve as a complement to the *Unesco Technical Papers in Marine Science*, the *Reports* are distributed automatically to various institutions and governmental authorities. Individuals may, at their request, receive copies of specific titles, but cannot be included on the automatic distribution list. Both the *Reports* and the *Technical Papers* series are free of charge.

Requests for copies of specific titles or for additions of institutions or authorities to the mailing list should be addressed, on letterhead stationery if possible, to:

Marine Information Centre
Division of Marine Sciences
Unesco
Place de Fontenoy
75700 Paris
France.

ABSTRACT

This report presents the results of the workshop "Physical Oceanography of the Eastern Mediterranean: An Overview and Research Plan", held in Lerici, La Spezia, September 1983. It summarizes the scientific plan and scientific objectives of the International Cooperative Program for the Exploration of the Eastern Mediterranean.

RESUME

Le présent rapport expose les résultats de la réunion de travail qui s'est tenue à Lerici, La Spezia, en septembre 1983 sur le thème : "Océanographie physique de la Méditerranée orientale : aperçu général et plan de recherche". Il récapitule le plan et les objectifs scientifiques du Programme international de coopération pour l'exploration de la Méditerranée orientale.

RESUMEN

El presente informe expone los resultados de la reunión de trabajo sobre el tema: "Oceanografía Física del Mediterráneo Oriental: panorama general y plan de investigación", que se celebró en Lericia, La Spezia, en septiembre de 1983. Recapitula los objetivos y el plan científicos del Programa Cooperativo Internacional para la Exploración del Mediterráneo Oriental.

РЕЗЮМЕ

В настоящем докладе излагаются итоги работы состоявшегося в сентябре 1983 г. в Леричи /Специя/ семинара по теме "Физическая океанография восточной части Средиземного моря: общий план проведения исследований", приводятся основные данные о научных целях и плане Международной кооперативной программы исследований восточной части Средиземного моря.

ملخص

يستعرض هذا التقرير نتائج ورشة العمل حول موضوع "علوم البحار الفيزيائية لحوض شرقي البحر المتوسط : نظرة عامة وخطة بحث"، الذي عقد بمدينة ليريتشي - لاسبتسيا (ايطاليا) في سبتمبر/أيلول من العام ١٩٨٣ ، ويلخص التقرير الخطة العلمية وكذلك الأهداف العلمية للبرنامج التعاوني الدولي لاستكشاف شرقي البحر الأبيض المتوسط .

摘　　要

这项报告介绍了1983年9月在拉斯佩齐亚的莱里奇举行的“东地中海的物理海洋学：一项综述和研究规划”讲习班的成果。它概述了国际考察东地中海合作计划的科学规划和科学目标。

FOREWORD

This report presents the results of the workshop "Physical Oceanography of the Eastern Mediterranean: An Overview and Research Plan" held in Lerici, La Spezia, September, 1983. The report constitutes an extensive development and syntheses of the material originally discussed in the Round Table held at the 28th Plenary Assemble of ICSEM, France, December 1982. The summary document "Recommendation of the Eastern Mediterranean Round Table" is given in Appendix II.

The scientific discussion leading to the present report was undertaken to develop the ultimate phenomenological and theoretical knowledge of the Eastern Mediterranean, a basin very poorly know compared to other interesting regions of the world's ocean. Enough is known about this region, however, to recognize the importance of its study:

i) for modern ocean science, as the Eastern Mediterranean is an ideal test basin to study fundamental physical processes common to the world ocean,
ii) for the benefits such knowledge will bring to the nations which border the sea itself.

From a general and global scientific viewpoint the Eastern Mediterranean is of great interest because of the occurrence of intermittent but powerful convective processes which are critical to the thermohaline circulation but extremely poorly known. They are very difficult to study because such convection occurs over only a tiny fraction of the ocean's surface, in regions which are mostly located in the polar seas. In these regions experimental work is extremely arduous and almost impossible. Air-sea interaction processes are responsible for the convection phenomena. They are an extremely strong signal in the Eastern Mediterranean which constitutes an ideal test basis for their study. Additional scientific interest lies in the fact that Mediterranean water exits into the Atlantic and influences the general circulation of the world ocean.

The study of the Eastern Mediterranean is timely because of its importance and because of the feasibility of making a substantial step forward in understanding the region by means of a coordinated international research effort. Physical oceanography has made rapid advances scientifically and technically in recent years. By combining the classical techniques of oceanographic research with powerful modern concepts and methods, it is possible in a few years to change to one of the better known parts of the world ocean.

The report constitutes a summary of the unsolved scientific questions and important physical processes occurring in the Eastern Mediterranean. The scientific plan is developed for the investigation of these questions as well as the detailed field plan leading to the acquisition of the data base relevant to the project.

The workshop was convened by Professors Allan R. Robinson and Paola Malanotte- Rizzoli. They were assisted by the Organizing Committee of the Program (Appendix I). The report in its preliminary form was discussed and

commented by the International Oceanographic Community participating in the workshop. Thanks are due to Dr. Makram Gerges for the expert editing of the final version of the text. Thanks are also due to Dr. Nadia Pinardi who cooperated in the final writing of the report and to Ms. Debra Block for careful and expert typing.

Allan R. Robinson
Harvard University
Cambridge, Mass.

Paola Malanotte-Rizzoli
MIT
Cambridge, Mass.

Laboratorio Per lo Studio Della
Dinamica Delle Grandi Masse
Venice, Italy

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This executive summary is divided in three parts. Part I is an overview of the intentions and purpose of the Eastern Mediterranean Program, and of its overall scientific objectives. Part II presents the methodology of approach which bears upon the most powerful modern concepts, methods and techniques. Part III summarizes the research recommendations for the Program.

Part I: Purpose and Scientific Objectives

The purpose of the Eastern Mediterranean Program is to reach the ultimate knowledge of its phenomenology; to understand the dynamics, variability and energetics of its general circulation; to explain fundamental physical processes like deep convection and water mass formation there occuring and common to different areas of the world ocean. This knowledge is essential to understand chemical and biological transport processes and distributions; to quantify surface and coastal regional exchanges of heat, fresh water dissolved substances. This knowledge is required for the efficient utilization of marine resources, the study of regional climatology and for the management of the environment and the control of pollution.

The ultimate scientific goal for the planned Eastern Mediterranean research is to construct a general circulation model of the Eastern Mediterranean adequate for biological and chemical transport processes and for climate study. The overall scientific objectives are (Fig. 1):

1) What are the fundamental driving mechanisms of the circulation.
2) What are the surface wind stress and flux distribution; their seasonal, annual and interannual variabilities and budgets.
3) What are the major features of the circulation, its energetics and variabilities.
4) What are the detailed processes of open ocean convection, mixing and spreading.
5) What are the implications of the circulation for the distribution of biological and chemical properties.

Part II: Methodology of Approach

New techniques, advanced instrumentation and models now exist which will be used for the program in the optimal combination of modern scientific methodology. The methodology to be brought to bear on the systematic investigation includes (Fig. 2):

- Field measurements from shipboard, moored and free floating instruments.
- Tracer studies.
- Satellite and other remotely sensed data.
- Models for the general circulation, intermediate scale phenomena, and physical processes.
- Combination of models and data via efficient new techniques including data assimilation, optimal field estimates, inverse techniques etc.
- Synthesis of existing data, data sharing and pooling, synthesis of program accomplishments.

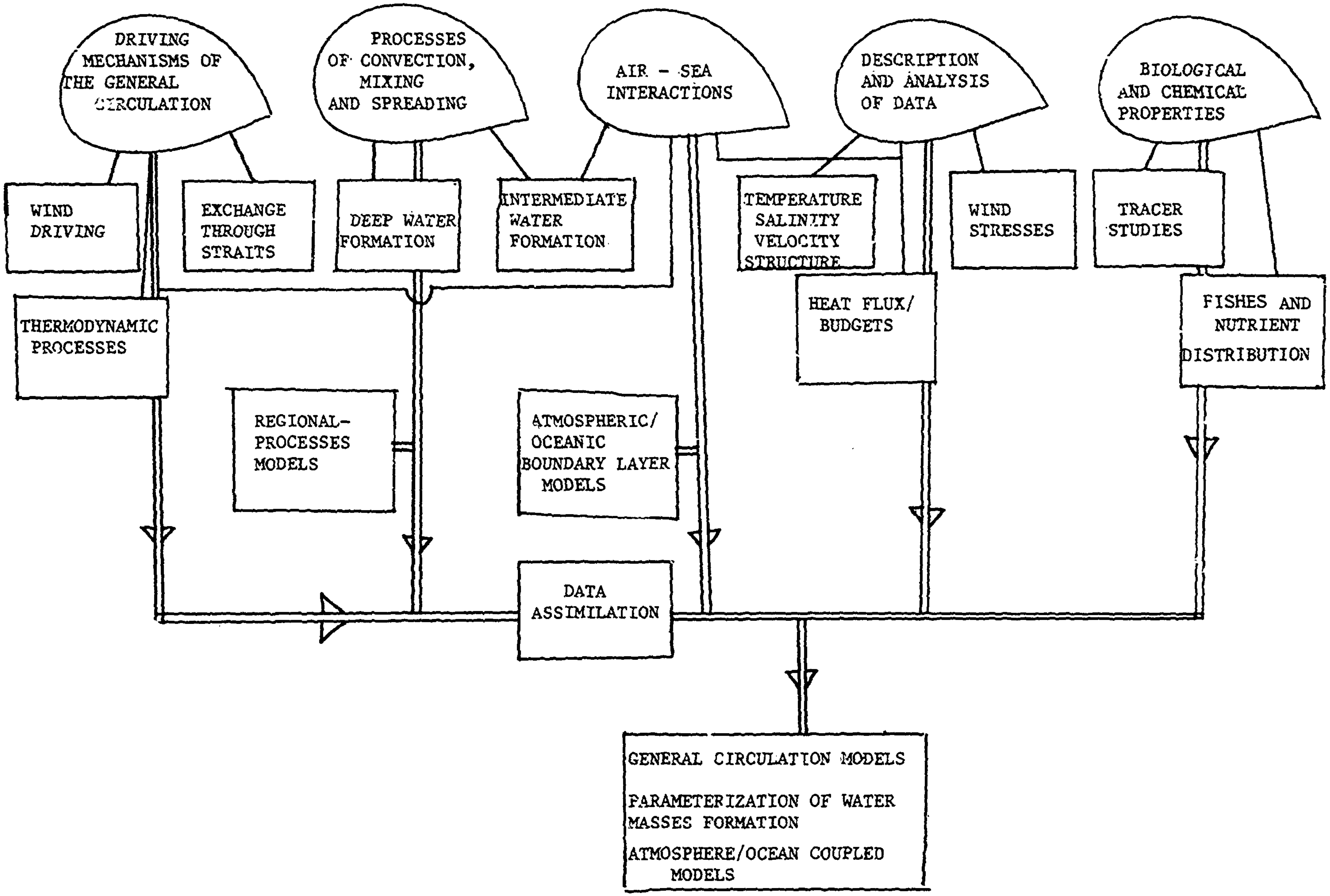


FIG. 1 Summary of scientific objectives

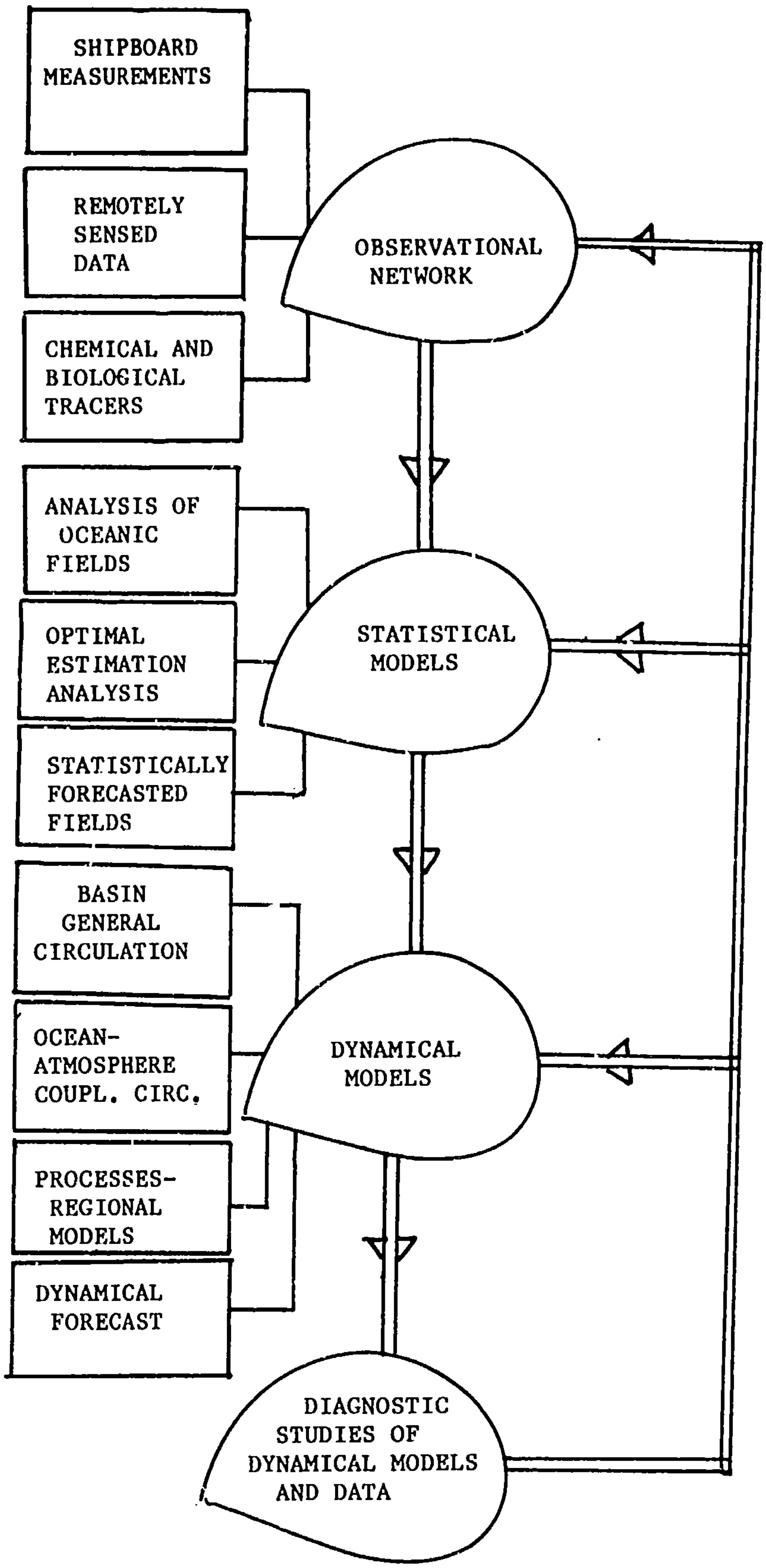


Fig. 2 Methodological flow-chart

Part III: Recommendations

The recommendation for the field plan of the Program, synthesis of the activities of the Working Groups, are the following:

- Quasi synoptic survey of the circulation of the Ionian and Levantine Basins

  6 Surveys, 50 km spacing
  Prior partial surveys required
- Intensive studies of intermediate water formation
- Detailed observations of preconditioning phase and spreading phase of intermediate water and spreading phase of deep-water
- Deep-Water tracer survey
- Synoptic/mesoscale surveys of selected areas for internal dynamical processes
  200-300 sq.km regions, 2-4 studies, 8 km. spacing
- Time series measurements of fluxes through straits and sills (Sicily, Otranto, Aegeans)
- Time series of satellite observed sea surface temperature
- Tide gauge array
- Meteorology
- General circulation modelling
  originally for determining driving mechanisms
  ultimately for biological/chemical transports and climate studies
- Meso/synoptic scale models for internal dynamics and data assimilation
- Detailed modelling and parameterization studies for water mass formation and transformation processes
- Models for the interactions and fluxes at the sea surface and coastal boundaries

1. INTRODUCTION AND SUMMARY

1.1 Scientific Basis and Approach

The Eastern Mediterranean Sea which lies eastward of the Straits of Sicily is comprised of the Ionian and Levantine Basins and the Adriatic and Aegean Seas. Compared to other interesting regions of the world's ocean, little is known about the Eastern Mediterranean. Enough is known about this region however, to recognize the importance of its study, i) for modern ocean science generally and ii) for the benefits such knowledge will bring to the nations which border the sea itself.

In the Eastern Mediterranean intermediate and deep waters are formed which subsequently spread and mix. The physical processes of water formation, dispersion and transformation are believed, for the most part, to be general to many other parts of the world ocean and these processes are poorly understood but of critical importance. In the Eastern Mediterranean the signal of such processes is strong and their investigation is logistically relatively convenient. Furthermore, these waters are exchanged through the Sicily Straits and ultimately in part through the Straits of Gibraltar whence they importantly affect the general circulation of the Atlantic Ocean.

A knowledge of the circulation, its variability and dynamics is of obvious importance regionally. It is essential for an understanding of chemical and biological transport processes and distributions, and of the surface and coastal regional exchanges of heat, fresh water, dissolved substances, etc. Thus it is required for the efficient utilization of marine resources, the study of regional climatology and for the management of the environment and the control of pollution.

The study of the Eastern Mediterranean is timely because of its importance and because of the feasibility of making a substantial step forward in understanding the region by means of a coordinated international research effort. Physical oceanography has made rapid advances scientifically and technically in recent years. By combining the classical techniques of oceanographic research with powerful modern concepts and methods, it is possible in a few years to change this region from a poorly understood sea to one of the better understood regions of the world ocean. The geographical coincidence of the interests of oceanographers generally in physical processes with the interests of regional oceanographers is fortuitous.

The ultimate scientific goals for the planned Eastern Mediterranean research are to construct a general circulation model of the Eastern Mediterranean adequate for biological and chemical transport processes and for climate study, and to answer the following five questions:

1) What are the fundamental driving mechanisms of the circulation.
2) What are the surface wind stress and flux distribution; their seasonal, annual and interannual variabilities and budgets.
3) What are the major features of the circulation, its energetics and variabilities.
4) What are the detailed processes of open ocean convection, mixing and spreading.
5) What are the implications of the circulation for the distribution of biological and chemical properties.

The methodology to be brought to bear on this systematic investigation includes:

- Field measurements from shipboard, moored and free floating instruments.
- Tracer studies.
- Satellite and other remotely sensed data.
- Models for the general circulation, intermediate scale phenomena, and physical processes.
- Combination of models and data via efficient new techniques including data assimilation, optimal field estimates, inverse techniques etc.
- Synthesis of existing data, data sharing and pooling, synthesis of program accomplishments.

1.2 The Overall Scientific Objectives

In the document "Recommendations from the Eastern Mediterranean Round Table", Results of the Round Table Discussion held at the 28th Plenary Assembly of ICSEM, Cannes, France, December 6-8, 1982 (Appendix II), six main scientific objectives were identified for the research programs in the Eastern Mediterranean, namely:

i) Fundamental driving mechanisms of the Mediterranean circulation.
ii) Wind stress and surface fluxes distributions, their seasonal, annual and interannual variabilities and budgets.
iii) Major features of the circulation, its energetics and variability.
iv) Detailed processes of open ocean convection, mixing and spreading.
v) Implications of the circulation for the distribution of biological and chemical properties.
vi) Construction of a general circulation model originally for determining the driving mechanisms, ultimately adequate for biological and chemical transports and climate studies.

With the above objectives in view, we consider the following:

a.) It is well known that the Mediterranean is an evaporation basin, with the peak of evaporation fluxes concentrated in the Levantine basin. No attempt however has been made until now to give quantative estimates of the importance of:

- wind forcing,
- exchanges through straits,
- thermodynamic processes

in driving the Mediterranean circulation, in particular in the Eastern Basin.

The correct identification and quantification of the basic driving force or forces is crucial for the modelling of the circulation and of the physical property distributions. The associated field work will provide the tool for the validation of the model's hypothesis.

b.) For the proper identification of the circulation driving mechanisms, it is fundamental to obtain the meteorological information necessary as input to the models and to understand detailed dynamical processes such as open ocean convection. With this we mean:

- wind stress and surface fluxes distributions,
- their seasonal, annual and interannual variabilities, and,
- the surface flux budgets.

Reliable estimates of the above quantities are extremely important, in particular in the Eastern Mediterranean where evaporation dominates. The sensitivity of the above estimates both to the quality of measurements, to variation in the empirical coefficients of the standard bulk formulae has been pointed out by Bunker, Charnock and Goldsmith (1982).

They show that even the sign of the total flux budget in the Mediterranean can be reversed for slight variations of the above coefficients.

c.) The commonly accepted knowledge of the general features of the Mediterranean circulation is of rather qualitative nature. The phenomenological evidence based upon historical data allows the distinction of 4 main vertical layers:

- surface Atlantic water
- intermediate Levantine water
- transition layer
- deep and bottom water

(Lacombe and Tchernia 1960, 1972; Wust, 1961; Bethoux, 1980).

On the basis of this phenomenology, a general pattern for the circulation in each layer has been qualitatively established.

The need is imperative, however, for a definitive phenomenology based not only upon all the existing historical data or theoretical models but upon more modern measurements. Moreover, basic questions remain unsolved and need to be understood, quantified, and modelled (space and time scales of the circulation kinematics, local internal dynamical processes, oscillation of thermocline, (frontal activity and baroclinic instability).

Once the major driving mechanisms have been identified, the distribution of currents and hydrological properties can be explored in a quantitative way:

- on a seasonal, annual, interannual scale
- as response to transients
- evaluating the details of the energetics and mesoscale variability.

A further problem of basic scientific importance is the annual and interannual variability in the volume of Levantine salty water formed and in its outflow into the Atlantic. The well known tongue of Mediterranean salty water intruding into the intermediate Atlantic layer and spreading in cross-basin direction influences and determines the general circulation and property distribution in the Atlantic ocean and, as a consequence, in the world ocean.

In future modeling investigations, it is feasible to envision studies of the two coupled systems: Atlantic and Mediterranean.

d.) Two distinct types of convection processes have been identified:

- Convection on the shelf (Weddell and Ross Sea in the Antarctica, Northern Adriatic, etc.). This type of convection is well understood and modeled.
- Open ocean convection (Ligurian Sea, Labrador Sea, Levantine Basin, etc.)

Big areas can be involved in the open ocean convection (Ligurian Sea) (MEDOC Group, 1970; Sankey, 1973) as well as small sinking regions of horizontal dimensions of the order of local Rossby deformation radius. The details of the open ocean formation process, and subsequent mixing and spreading, are not yet well understood or properly modeled. Open, unsolved questions remain concerning the frequency and patchiness of the sinking regions; the total volume of intermediate and/or deep water formed; its residence times, etc. The first problem concerns the correct identification of the sinking regions of newly formed Levantine water. This will be one of the first crucial tasks of the experimental plan.

Further unsolved questions specifically related to the eastern Mediterranean concern the deep convection processes and formation of the deep-bottom layer in the Eastern basin (Ionian Sea). It is a generally accepted view that the deep and bottom water in the Ionian Sea is of Southern Adriatic origin. This phenomenological evidence (Pollak, 1951) is far from being definitively proved.

Neither has it been quantitatively established whether the Aegean Sea contributes to the formation of this bottom water, and, in this case in which proportions. A further unsolved problem is the possible contribution of the Aegean Sea to the formation of Levantine intermediate water. Monitoring of the straits (Otranto Straits, Straits between the Greek Islands) connecting the Eastern Mediterranean with the adjacent, regional seas is thus of crucial importance as well as the monitoring of the Sicily Strait for communication with the Western basin. Current measurements for long time intervals with fixed moorings, when possible, would be crucial in establishing the entity and variability of the deep flow.

e.) The following block diagram roughly schematizes the importance of establishing a quantitative circulation pattern for inferring the distribution and time evolution of properties such as transient tracers, chemical and biological parameters.

FIELD WORK (transient tracers, biological and chemical properties) ---> CIRCULATION FEATURES

MODELLING

Good circulation models for quantitative estimates of property distributions

Byproducts of great social and economic importance for development can emerge from the investigation of the above scientific objectives.

- Implications of air-sea fluxes and wind stress patterns and estimates for agriculture and commerce.
- Implications of a good description and quantitative pattern of the general circulation for the proper utilization of marine resources and fishery.
- Influence of the circulation upon pollution and waste disposal problems.
- Implications for coastal areas management.

1.3 Research Recommendations

- Quasi synoptic survey of the circulation of the Ionian and Levantine Basins
  6 Surveys, 50 km spacing
  Prior partial surveys required
- Intensive studies of intermediate water formation
- Detailed observations of preconditioning phase and spreading phase of intermediate water and spreading phase of deep-water
- Deep-Water tracer survey
- Synoptic/mesoscale surveys of selected areas for internal dynamical processes
  200-300 sq.km regions, 2-4 studies, 8 km. spacing
- Time series measurements of fluxes through straits and sills (Sicily, Otranto, Aegeans)
- Time series of satellite observed sea surface temperature
- Tide gauge array
- Meteorology
- General circulation modelling
  originally for determining driving mechanisms
  ultimately for biological/chemical transports and climate studies
- Meso/synoptic scale models for internal dynamics and data assimilation
- Detailed modelling and parameterization studies for water mass formation and transformation processes
- Models for the interactions and fluxes at the sea surface and coastal boundaries

2. SYNOPSIS OF THE WORKSHOP

In the course of the Workshop three Working Groups (WG's) were formed to deal with the specific components of the proposed research plan as follows: WG I: Descriptive Oceanography; WG II: Physical Processes (Convection, Dispersion and Mixing); and WG III: Models and Dynamics. The following are the reports of the respective WG's.

2.1 WG I: Descriptive Oceanography

A group of oceanographers interested in the subject, met to discuss the potential for cooperative work in the Eastern Mediterranean over the next five years.

After exchanging information on existing national and international programs, it has been agreed that a joint project, involving both observations at sea and numerical modelling, was timely.

The major interest was in the formation and transformation of water masses, processes which are especially suitable for study in the Eastern Mediterranean. The first priority was the study of the formation and distribution of the Levantine intermediate water, the second was the study of the formation and distribution of deep water, the third, the collection and interpretation of observations to augment our knowledge of the climatology of the Eastern Mediterranean.

The most important season for the observations at sea is the late fall, when the characteristics of the surface water are modified following the breakdown of the summer thermocline, and late winter, when by atmospheric cooling exchanges makes the water so salty that its density becomes high enough to bring about general sinking. Accordingly, a series of cruises was recommended starting in October 1985 and being repeated and extended in March 1986, October 1986 and March 1987.

A good geographical coverage seemed possible by the giant efforts of several countries, notably Yugoslavia, Italy, Greece, Turkey, Israel, and Egypt. Enquiries would be made of the possible contributors, especially France, England, and the United States.

During these cruises, observations would be made of temperature, salinity, and oxygen, together with appropriate inorganic tracers and biological variables of interest. Suitable arrangements would be made for the intercalibration of instruments and standards so as to achieve the high accuracy needed for definitive observations.

Details of cruise tracks, station spacing, etc. would be discussed, but particular attention would be paid to the conditions at sea straits and sills.

To complement the seagoing work there is a need for current meter moorings to measure the source-sink flows which contribute so markedly to the flow patterns of the region.

As well as the several nations that it is hoped will contribute to the work at sea during the special cruises, there is a need for contributions by many of the nations whose territory borders the Eastern Mediterranean. A particular need is for observations of sea-level. It is sharply recommended that the network of sea level gauges used in the Medalpex project be maintained, if possible reinforced. Some open-sea tide gauges would also be valuable.

It is also hoped that all nations will, during the period of this project, do all they can to provide suitable meteorological observations from coastal and island stations. Offshore meteorological buoys would also be particularly useful. It may also be possible to acquire useful oceanographic observations (XBT, surface salinity) as well as meteorological reports, from specially selected ships of opportunity perhaps reinforced by specially embarked observers.

Arrangements will be made to take advantage of all relevant satellite observations and imagery; some special cruises and aircraft flights may be desirable to validate the satellite input; the experience gained will be of particular value to those planning the post-1988 series of remote sensing oceanographic satellites.

Many nations are already making oceanographic observations in their coastal waters in connection with applied studies (pollution, ocean-engineering, etc.)

and it is recommended that whenever possible such hydrographic sections be coordinated with the water-mass transformation project so as to provide relevant information on the distribution of temperature, salinity, oxygen and other tracers.

2.2 WG II: Physical Processes

2.2.1: Scientific Objectives

The Mediterranean, in general, and the Eastern Mediterranean, in particular, is an area of relatively small extension and easy to investigate. A number of remarkable oceanographic phenomena and meteorologic-oceanographic-coupling take place which can be considered as models for the world ocean.

The main regime of the sea, in the western as well as in the eastern basin, is controlled by intense surface transfers and exchanges across the sea surface. In the concentration basins that each of the sections of the Mediterranean constitute, there occurs a typical mechanism of transformation of the inflowing water from the Atlantic into a number of typical water masses whose total volume is about 3/4 of the total volume of the sea. These waters are more saline, somewhat colder and more dense than the inflowing water through the Strait of Gibraltar. Thus, the Mediterranean is a system in which the enclosing water suffers drastic modifications which gives it the typical Mediterranean character. The transformation which is rather slow and shallow in the warm season takes place with focal or even "catastrophic" intensity in winter in a number of areas in the sea. Some of these areas are, more or less, closed basins of relatively small volume, submitted to winter meteorological conditions which vary largely from place to place and year to year due to the character of the meteorological forcing which is very unequally distributed in time and space on rather small scales. In these areas the surface waters under the influence of intense cooling by evaporation taking place at the surface of a sea over which dry and cold winds (often 10°C colder than the sea surface) blow, reach a near surface density which is such that convective motions are started down to depth ranging from 200-250m for Levantine intermediate water (LIW), to 1000-1200m in the Adriatic Sea and the Northern Aegean Sea and up to 2000m in the NW Mediterranean.

The formation of the intermediate and deep waters takes place in rather limited areas (a few % of the sea surface). The "convection" which takes place is certainly not at all "simple" because it occurs in areas where currents and current shears exist which can generate a variety of dynamic instabilities, intensifying the "convection".

After the formation of these winter water types in February-March, varying in intensity from one place of formation to another and from one year to another, some "blobs" of intermediate or deep water reach a mixing and spreading phase during which they invade the deep area of the basins and mix with each other to form the deep water of the Eastern Mediterranean. Part of the LIW flows over the Strait of Sicily sill and expands in the Western Basin where it plays a major role in forming deep water in the West Mediterranean.

In no other place of the world ocean (except perhaps the Red Sea) do occur as many phenomena within a sea area whose size makes it possible to study them with relatively limited facilities.

As is well known the same kind of processes but on a much larger scale, occur in the world ocean, mainly in polar or sub-polar areas which are difficult to work in.

Thus, it appears that the fundamental problems of formation, and spreading and mixing of water masses which takes place in all parts of the world ocean, can be studied, with relatively limited facilities, in the Mediterranean and in the Eastern Mediterranean in much more detail than elsewhere.

The supply and spreading of the water masses formed in a sea area with a succession of straits with sills, gives place to very conspicuous phenomena over these sills, which are critical sections coupling the basins on either sides. Over the sills, very intense shearing and eddying flows, as well as density flows, occur which are modulated by tide and meteorological situations. Many sills in the Mediterranean have typical sill and strait dynamics phenomena and may be models of ocean sills.

The areas of Intermediate Water Formation in the Mediterranean, as well as the areas of great bottom slope, irregular topography of the coast, inducing irregularities in the winds, give rise to strong frontal and dynamic phenomena which can be rather easily detected from satellite, thanks to the relative high proportion of clear skies.

Then it appears that the study of the oceanographic phenomena in the Mediterranean are good models for those happenings in the world ocean and can be relatively easily studied due to the limited extent of the sea.

In addition, the knowledge of the hydrographic and dynamic behavior of the sea could be of great benefit in the bordering contours for the fisheries as well as for the prevention of pollution in an almost closed sea whose general regime tends to "trap" the pollutants.

2.2.2 Levantine Intermediate Water Formation and Circulation

Regions of formation of LIW have been already more or less identified in the eastern Mediterranean Sea (Morcos, 1972; Ozsoy et al., 1981). The formation of this water mass is so important for the global understanding of this region that we really need to know more about it: the (complex) nature of the process; when and where formation occurs; under what specific conditions it occurs (general variable conditions); how much water mass is formed; and at which rate; and finally how this water spreads or circulates once it is formed.

A. Methods

Our strategy will be:

(a) To analyse the actual available data. (mainly hydrographic data).

- to incorporate them in numerical or/and analytical models in order to understand for instance, how and where, under specific meteorological forcing, the ocean can store potential energy which can be converted later on into kinetic energy during the formation process.
- to make a survey experiment which would allow us both to check for

the quality of the models and to identify more clearly the fundamental parts of the problem mainly: the preconditioning phase (ocean general circulation, meteorological forcing and circulation, meteorological forcing and water masses characteristics defined synoptically- synoptic time scale means an order of magnitude lower than seasonal time scale so around 15 days) on a large scale (seasonal and basin wide) with a resolution down to the internal radius of deformation (or close to it)).

(b) To make an intensive experiment specifically studying the formation processes; to check the nature of the process, the different scales involved, the relative role of one dimensional mixed layer process and a quasi two dimensional thermo-dynamic model from which we can objectively analyse our data.

(c) To collect information using long term tracers both geochemical and artificial to study the spreading of the LIW throughout the Eastern Mediterranean Sea.

B. Schedule

We intend to begin in 1984 (a) incorporating actual data in existing models and to begin in 1985 (b) the synoptic survey.

The intensive experiment (b) is planned for the March of 1986 (see the next section).

The tracers experiment (c) is planned for 1985 to 1987.

C. Field Program

(a) Synoptic survey for the preconditioning phase (see descriptive group) in addition to the contributions of the descriptive group, we can mention that we need to tighten the (24 kms) CTD network (64 CTDs) (grid spacing 30 kms) as closely as possible to the intensive experiment and that we intend to launch surface drifters in order to map some elements of surface circulation in and around the area of formation and to moor current meters on shelf and along the continental slope of Turkey for studying shelf waves and topographic Rossby waves.

(b) Intensive survey - in addition to a CTD network of a smaller grid spacing (10 km) than the synoptic survey (30 kms) in particular in frontal regions we need to launch subsurface floats (15) tracked by acoustic, to map the convective features. These floats are of two types: SOFAR floats and VCMs for measuring vertical currents. They are tracked permanently with autonomous listening stations (ALS) and from time to time (in real time) with shipborne receivers.

D. Research Requirements and Logistics

Most of the shiptime is available from Turkey and Israel for the LIW synoptic survey. For the intensive survey, in addition, we will rely on a French ship for launching floats of different sort and tracking them.

(c) A tracer survey to study intermediate water spreading (tritium, 3H2, freon), 1° to 2° grid spacing 0-1000 m depth, preferably connected with the intensive survey according to b) or shortly later. There should also be additional, non restricted tracer surveys along the presumed axis of LIW - flow (i.e. west and south of Crete and then north-west across the Ionian Sea).

2.2.3 Deep-Water Formation

There are two sources for the waters below the Levantine intermediate water, i.e. the Aegean Sea and the Adriatic. The Adriatic appears to be the major source. It seems to contribute most of the water found at depths exceeding 1500 m but possibly also some shallow water. The role of the Aegean, presumably, is restricted to depths less than 1500 m, but is not very clear at all.

The objectives in regard to the deep water are to study the formation processes and rates of formation, as well as the subsequent spreading of the deep water once formed, and its pathways back up into strata when it rejoins the non vigorous circulation and eventually leaves the Eastern Mediterranean through the Sicily Channel.

Both mentioned deep-water sources are related to marginal basins, and are separated from the main volume of the Eastern Mediterranean by ridges, i.e., the Strait of Otranto sill in the case of the Adriatic, and the sill on the deep channel that joins the Levantine Basin and the Sea of Crete in the Kasos Channel. Therefore, both the original formation of dense water in the Adriatic and in the Aegean, and its problem modification (entrainment) upon entering the main volume will have to be studied.

A. Methods

The fact that the deep water enters the main volume of the Eastern Mediterranean in well-defined places, i.e. the mentioned sills, calls for recording its flow in these places by current meter measurements. To study the formation processes, detailed hydrographic surveys should be made in the presumed areas of original dense water formation and during peak formation periods (late winter,usually), and furthermore, sections should be run across the mentioned sites to study the subsequent modification. These sections should include measurements of transient tracers and possibly further properties, in order to enable to quantify the contributing water (e.g., by entrainment) in the process. It is to be expected that deep water formation in particular has considerable interannual variability. A study of the preconditioning and of the thermodynamic forcing that leads to the formation of dense water is therefore essential if the results of the operational period are to be generalized.

As for the study of the further spreading and circulation of the deep waters, transient tracers have shown great potential. One detailed survey of these tracers (tritium, 3H2, and the freon F11 and F12) should therefore be carried out through the entire Eastern Mediterranean. The tracer data should be accompanied by hydrographic data, which must, however, be of the highest possible quality in view of the relative uniformity of deep-water hydrographic characteristics. Nutrient data, again necessarily of top quality, would be a very useful complement for such a study.

A special item is the study of the final depths of stabilization of deep water formed by the Adriatic. It has been suggested, e.g., that there is flow of such water at mid-depth towards the outflow area off the Sicilian Channel. Sections across the Continental Slope, south of Otranto, off Calabria, and off Sicily, again including tracers, should be carried out in this connection.

B. Schedule

The formation and transformation processes should be studied in two subsequent years (1986, 1987) near the peak formation time (about March) on the sites and the current meter moorings should cover the same period. One general deep water survey, without restriction to any specific season, should be sufficient to obtain the general tracer distributions in the deep water.

C. Field Program

One general survey of deep-water hydrography T, S, ρ and tracers (tritium, 3He, freons), at about a 2° x 2° grid spacing throughout the Eastern Mediterranean. These are measured aboard ship, therefore this survey should preferably be done by one ship covering the entire area.

Sections across the Kasos and Otranto Strait sills, hydrography and tracers, station distance 10-50 km, dense vertical spacing. These sections should preferably be run twice near the peak formation season, in 1986 and 1987.

Current meter moorings on the same sills for at least the full formation period during these years. High sensitivity current meters would be important.

Sections across the Continental slope between south of Otranto down to the Sicily-Malta escarpement in both years. Station distance no more than 10 km in 600m to 1500m water depth, hydrography and tracers. A moderate section program in the first year (1986) with an option for enlargement in the second year.

Dedicated studies in the original formation areas in both years. These studies would primarily be carried out within the national programs of these areas.

D. Research

It appears that the relationship of the deep-water formation rates and the preconditioning as well as thermodynamic forcing in the original areas would require specific attention.

2.2.4 Timing of field work

See Table 1

2.3 WG III: Models and Dynamics

2.3.1 Scientific Objectives (As Stated By Modelling Group)

The objectives listed below are a consensus, though some may reflect primarily interest on the part of some individuals and/or countries.

Table 1

	1985	1986		1987
	October	March	October	March
1) General Hydrographic Surveys	Pre-conditioning Phase	Mixing-Spreading Phase	Precondi-tioning Phase	Mixing-Spreading Phase
2.) Physical Processes Exp. (Intermediate Deep Water Formation)	Intensive Survey Preconditioning Area (CTD's; Surface Drifters)	Intensive Survey Convection Area (SOFAR floats; C.M. Moorings; CTD's)	Intensive Survey Precondi-tioning Area (CTD's Surface Drifters	Intensive Survey Convection Area (CTD's; SOFAR floats; C.M. Moorings)
3.) Mesoscale Experiment		High Resolution Synoptic Survey Over Selected Areas (Fig. 3)	High Resolu-tion Over Selected Areas (Fig. 3)	
4.) Tracer Studies	One General Survey Over The Whole Mediterranean Sea			
5.) Monitoring of the Straits	September ----> March C.M. Moorings Tidal Gauges Strait of Sicily		October ----> March C.M. Moorings Tidal Gauges Strait of Otranto	

i) Determination of the relative contributions to the general circulation and T/S structure evolution by the three driving forces:
   a) Straits source-sink flow
   b) Atmospheric momentum and heat fluxes
   c) Deep convective processes

ii) Determination of the (possible) general circulation of the Eastern Mediterranean and its seasonal variation.

iii) Modelling of important dynamic/thermodynamic processes using process models in regions of suspected/known strong dynamical/thermodynamical activity to investigate, e.g., baroclinic instabilities, water mass formations, etc.

iv) Description of the upper layer thermal structure and its diurnal/synoptic/seasonal variability. Use atmospheric fluxes to investigate mixed layer evolution, surface currents, surface front formation, Ekman pumping and advection etc.

v) Use of models in an interactive mode with data. Use of models for data assimilation to give quasi-synoptic pictures. Fill in data blanks in time and space. Generate simulated data sets to help in the planning of observations.

vi) Investigation of shelf dynamics on the continental shelf of various nations; couple the shelf circulation to that of the deep water as obtained from the basin General Circulation Model.

vii) One-way interactive regional models. For various national and/or scientific interests, certain geographical regions should be modeled at high resolution with an open/partially closed regional model.

viii) Parameterization of water mass formations for use in models.

ix) Development of a (E,W,E-W) Mediterranean GCM capable of coupling with the atmospheric GCM.

x) Use of coupled models for the study of feedback mechanisms between the East Mediterranean and the overlying atmosphere.

2.3.2 Timing of Scientific Research

See Table 2

Comments on Table 2

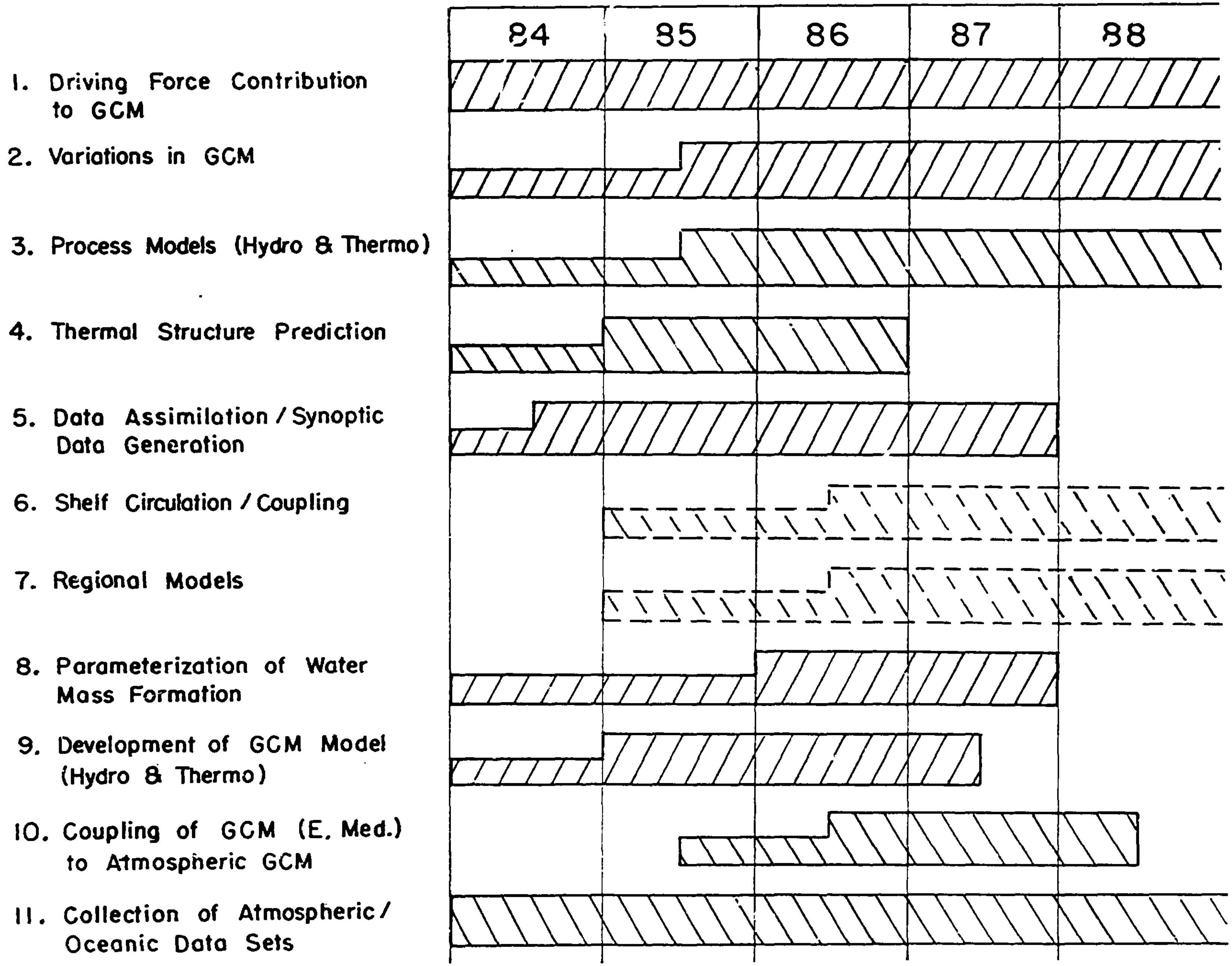
1. Items 1 and 9 are related - initial model testing and comparisons are to be carried out in (1), then a full-scale modeling effort should take off to produce a realistic model suitable for air-sea coupling. At each stage, existing models are to be used with the different driving forces and their combinations to extract science and to compare with data becoming available.

One key step will be to embed mixed layer models into hydrodynamic models; another, the parameterization of deep convective processes (see no. 8).

2. This can only start, or get in full swing, after initial modeling effort in (1) (and possibly (8)) have been successful at producing some realistic basin-wide current patterns.

3. We envisage models along the Harvard quasigeostrophic open ocean models in investigating important dynamical processes in selected regions. Turbulence closure models (possible 2.5D) adapted to include penetrative convection will

TABLE 2


84
85
86
87
88
1. Driving Force Contribution to GCM
2. Variations in GCM
3. Process Models (Hydro & Thermo)
4. Thermal Structure Prediction
5. Data Assimilation / Synoptic Data Generation
6. Shelf Circulation / Coupling
7. Regional Models
8. Parameterization of Water Mass Formation
9. Development of GCM Model (Hydro & Thermo)
10. Coupling of GCM (E. Med.) to Atmospheric GCM
11. Collection of Atmospheric / Oceanic Data Sets

also be tested.

4. This can be done with existing models, provided the atmospheric fluxes can be obtained. Preferably 6-12 months of fluxes at 6-hourly intervals is desired, to study synoptic and seasonal variations. Likely sources are the European Medium Range Weather Forecasting Center and FNOX at Monterey, CA. An objective analysis must be performed to interpolate the fluxes from (18-20) global mesh points of the atmospheric model located over the Mediterranean area to the much finer grid of the ocean model.

5. Numerical models are very useful tools in providing 4-D space-time interpolation of data by carrying information forward and absorbing new data in a consistent fashion. They can be used to provide data in data sparse areas, and in all locations between observations. Outside strong frontal or eddy activity, mixed layer models can provide a good
d description of the thermal structure in the top 300m if the atmospheric fluxes are reasonably known, the produced field far exceeds climatology and is correlated with weather events.

6 & 7. These modeling efforts represent interest on the part of several countries in specific circulations close to their shores. They will need as input boundary conditions provided by the Eastern Mediterranean General Circulation Model.

8. A lot of theoretical and analytical work related to convection and turbulence will be needed before reasonable models reproducing deep convection can be built. Further simplifications of these models will be necessary to imbed them into hydrodynamic ocean models.

9 and 10. The most advanced hydrodynamic/thermodynamic.

2.3.3 Field Data Requirements

A. Surface forcing: Wind stress
Wind speed (U x 3)
Heat flux components (IR, Evaporative, solar insolation, sensible)
Precipitation
Sea-Surface Temperature

Also of use in initializing/verifying models is surface height elevation from tidal gauges and altimetry; also wave heights/breaking waves/ foaminess from microwave, altimeter pulse shape, tidal gauges, SAR radar; satellite data for SST.

B. Horizontal boundary fluxes: for open regional models, T/S/ρ and height or currents on all four boundaries For basin models, inflow through straits needs to be known for relatively long times; through current meters, currents throughout cables, density field plus tidal gauges for total flux measurements.

C. High resolution synoptic data in selected areas: such data should be taken only in regions where most important dynamic/thermodynamic processes are known/ suspected of taking place. Propose 2-4 such sites, see attached map (Fig.3); the numbers are somewhat reflective of the priorities mentioned. The proposed

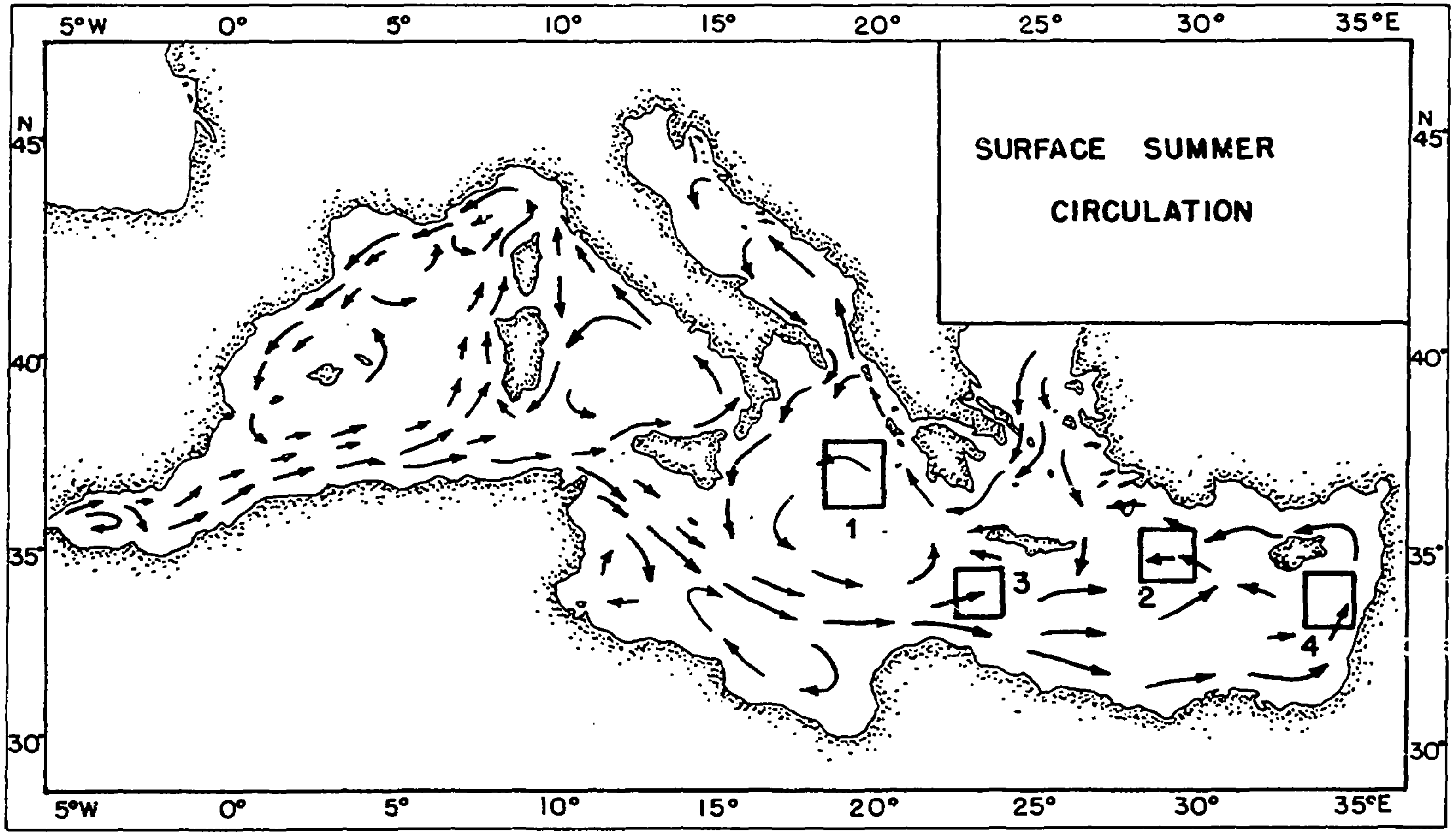


Fig. 3. Proposed areas for high resolution synoptic surveys.

size of these areas was 240 x 240 km, with a fine resolution of $\Delta x = 8$ km. It was then proposed to drop XBTs at each of the 31°x 31° grid points, but perform CTD casts only at every 4th point, i.e. the CTD mesh would consist only of 8 X 8 = 64 points. A ship with 3 hour stops at each stations would need 12 days to survey such a site.

D. Quasi-synoptic T/S data for the OGCM. The largest separation that would be allowed from the model point of view is $x = 50$ km, which is 3 times the baroclinic radius of deformation, a good estimate of the horizontal correlation length. It happens also to be almost almost equal to the distance between the hydrographic data points of the US Naval Oceanographic Office (1/2° x 1/2° , or 55 km x 40 km). From the dynamic point of view, however, $x = 20$ km would be preferable.

E. Monitoring of the mouths of the Adriatic and Aegean Sea. For purposes of directly incorporating the deep water transport from the Southern Adriatic we may want to put a boundary at mid-Adriatic. In this case, fine sources of data would be needed, with tracks repeated every 3-4 weeks if possible, to show any synoptic (weather-caused) and seasonal variation. A similar statement applies to the openings between the Aegean islands.

F. Atmospheric/mixed layer buoy: At least one, but preferably 2 buoys with atmospheric sensors and thermistor chains should be placed in regions of intense thermodynamic activities, in order to

a) follow evolution of mixed layers and heat content
b) follow evolution of convection-caused deepening
c) follow corralations with atmospheric events
d) time mixed layer models from Pacific constants to possibly different, Mediterranean' constants
e) help in parameterizing deep convection.

3. DISCUSSION AND CONCLUSIONS

In the final plenary meeting the outcome and recommendations of the three working groups were further discussed and commented. Additional questions were raised concerning the specific following topics:

Ships of opportunity.
This includes the possibility of carrying out XBT and surface salinity measurements from tankers, ferry boats and touristic ships along routes of importance for the Eastern Mediterranean. The participants were asked to gather information in the respective countries and to send it to Prof. Charnock.

Remote sensing and dissemination of information.
The discussion focused upon the necessity of collecting satellite remotely sensed data in conjunction with the planned hydrographic surveys. Dr. R. La Violette expressed his willingness to make available to the participants the first set of satellite images taken by his group in the Eastern Mediterranean.

Eastern Mediterranean newsletter.
The idea was discussed of issuing a regular series of newsletter type

of publications containing information on the ongoing activities. The participants were asked to further elaborate the idea and to send their suggestions in this regard to Professor Robinson.

Data exchange, banks, synthesis.

Prof. Lacombe informed the meeting that in the Paris Laboratory of Physical Oceanography all the data collected in the Mediterranean Sea is available in a listing form up to 1980. He will also explore the accessibility of this data and/or summaries for the program. Prof. M. Gerges informed the meeting the Mediterranean data are stored in two World Data Centers: A in Washington and B in Moscow. He was asked to inquire whether the data existing in Center B are also available in A. For each country a meeting participant was chosen to explore the existence of national data not stored in World Data Center A and their accessibility to the program.

The following members were chosen for each country:

Drs. Franco & Bregant	Italy
Dr. Gerges	Egypt
Dr. Hecht	Israel
Dr. Oguz	Turkey
Dr. Piaczek	USA
Dr. Zore-Armanda	Yugoslavia
Dr. Cruzado	UNEP
Dr. Gergos	IOC
Dr. Morcos	UNESCO

Bibliography.

To update and complete the available bibliographies already existing for the Mediterranean (M. Gerges, 1980; Dr. Gascard 1982) each participant was asked to send a list of new publications known to him/her to Dr. Gascard. This definitive updated bibliography could be made available to the participants at a later date.

Moorings.

The possibility was discussed and scientific importance was stressed of positioning some fixed current-meter moorings at depth in the Straits of Sicily and Otranto. Dr. Rizzoli and Italian Colleagues will explore and discuss this possibility for the Strait of Sicily and Otranto Strait. These would be provided by Prof. La Combe and the French Colleagues and positioned by an Italian ship during one of the planned hydrographic surveys. The importance was also stressed to have analogue moorings in the Aegean Straits.

The final program was discussed and an unanimous consensus of support was adopted for the general scientific program

REFERENCES

Bethoux, N. 1980. Mean water fluxes across sections in the Mediterranean water and salt budgets and of observed salinities. Oceanologica Acta, 2: 157-163.

Bunker, A. F., H. Charnock and R. A. Goldsmith. 1982. A note on the heat balance of the Mediterranean and Red Seas. J. Mar. Res., 40(Suppl.): 73-84.

Lacombe, H. and P. Tchernia. 1960. Quelques traits généraux de l'hydrologie Méditerranéenne d'après diverses campagnes hydrologiques récentes en Méditerranée dans la poche Atlantique et dans le détroit de Gibraltar. Cahiers Océanographiques, COEC, 12(8): 527-547.

Lacombe, H. and P. Tchernia. 1972. Caractères hydrologiques et circulation des eaux en Méditerranée. In: The Mediterranean Sea: A Natural Sedimentation Laboratory, Ed. D. J. Stanley, p. 25-36, Dowden, Hutchinson and Ross, Inc., Stroudsburg, Pennsylvania.

MEDOC Group. 1970. Observations of formation of deep water in the Mediterranean Sea. Nature, London, 227(5262): 1037-1040.

Morcos, S. A. 1972. Sources of Mediterranean intermediate water in the Levantine Sea. In: Studies in Physical Oceanography. A Tribute to Georg Wust on his 80th Birthday, A. L. Gordon (Ed.), 2: 185-206, Gordon and Breach, Science Pub. Inc., New York.

Ozsoy, E., M. A. Latif and U. Unluata. 1981. On the formation of Levantine Intermediate Water. Rapp. Comm. Int. Mer Médit., 27(6): 51-66.

Pollak, M. J. 1951. The sources of the deep water of the Eastern Mediterranean Sea. J. Mar. Res., 10(1): 128-152.

Sankey, T. 1973. The formation of deep water in the northwestern Mediterranean. In: Progress in Oceanography, B. A. Warren (Ed.), 6: 159-179, Pergamon Press.

Wust, G. 1961. On the vertical circulation of the Mediterranean Sea. J. Geophys. Res., 66(10): 3261-71.

Appendix I

A. Venue

The Workshop was held on 10 and 11 September 1983 at the Centro ENEA di Santa Teresa, Lerici (La Spezia), Italy.

B. Participants

33 Scientists from 11 countries, and representatives from 3 international organizations were present. The following is the list of participants:

ASTRALDI M.	CNR, Stazione Oceanografica, La Spezia, Italy
BARALE, V.	CNR, ISDGM, Venezia, Italy
BERGAMASCO, A.	CNR, ISDGM, Venezia, Italy
BREGANT, D.	CNR, 1st Talassografico, Trieste, Italy
CATTLE, H.	Meteorological Office, Bracknell Berks, England
CHARNOCK, H.	University of Southampton, Dept. Oceanogr., England
CREPON, M.	Lab. d'Ocean. Phys., Paris, France
CRUZADO, A.	UNEP, Athens, Greece
FRANCO. P.	CNR, 1st. Biol. del Mare, Venezia, Italy
*GASCARD, J.C.	Lab. d'Ocean. Phys., Paris, France
GRANCINI	SNAM-PROGETTI Max. Techn. Dept. Fano-Pesaro Italy
GERGES, M.	Inst. Ocean. & Fisheries, Alexandria, Egypt
*HECHT, A.	Oceanogr. & Limn. Res. Ltd., Haifa, Israel
HOPKINS, T.	Brookhaven Nat. Lab., Upton, L.I., New York, USA
JEFTIC, L.	Dept. Plann. & Environ. Protect., Zagreb, Yugoslav.
KOURAFOLOU, V.	Univ. of Miami, Miami, Florida, USA
LACOMBE, H.	Lab. Ocean. Phys., Paris, France
LASCARATOS	Univ. of Athens, Dept. of Applied Physics, Athens
LAVIOLETTE, P.E.	NORDA, NSTL Station, Bay St. Louis, Mississippi,
MANZELLA, G.	CNR, Stazione Oceanografica, La Spezia, Italy
MICHELATO	OGS, Trieste-Italy
MILLOT, C.	BOM du CNEXO, La Seyne sur Mer, France
MOLCARD, R.	SACLANT Res. Center, La Spezia, Italy
MORCUS, S.	UNESCO, Div. Mar. Science, Paris, France
OGUZ, T.	Middle. E. Tech. Univ., Erdemly, Icel, Turkey
*PIACSEK, S.	NORDA, NSTL Station, Bay St. Louis, Mississippi
PINARDI, N.	Harvard Univ., Cambridge, MASS., USA
PURINI, R.	IFA., Rome, Italy
*RIZZOLI, P.	Mass.Insti. Tech., Cambridge, Mass., USA
*ROBINSON, A.	Harvard Univ., Cambridge, Mass., USA
*ROETHER, W.	Inst. fur Umweltphys., Heidelberg, W. Germany
SANSONE, E.	1st Univ. Navale, Napoli, Italy
*SHARAF EL-DIN, S.H.	University of Alexandria, Egypt (Not Present)
STRAVISI	CNR, 1st. Talass., Trieste, Italy
THEOCARIS	Inst. Ocean & Fish, Res., Athens, Greece
UNLUATA, U.	Middle E. Tech. Univ., Icel, Turkey
ZORE-ARMANDA	Inst. Ocean. i Ribarstio, Split, Yugoslavia

* Organizing Committee

C. Agenda

Saturday, 10 September, 1983

Opening of the Workshop:

Co-Chairpersons: A.R. ROBINSON
P. MALANOTTE-RIZZOLI

1. Introductory remarks:

   Scientific basis
   Program objectives — A.R. ROBINSON
   Work plan — P. MALANOTTE-RIZZOLI

2. UNESCO-IOC Presentation — S.A. MORCOS

3. Brief Scientific Presentation
   Morcos
   Charnock
   Gascard
   Hecht
   Lascaratos
   Unluata
   Roether
   Zore-Armanda
   Jeftic
   La Combe
   Piacsek
   Gerges
   Kourafalou
   Purini
   Crepon
   La Violette

Presentations and discussions are built on the Round-Table Discussions held at Cannes ICSEM Meeting

4. Detailed Scientific Working Groups (WG):

   Organization of Working Groups

   i. Descriptive Oceanography
      Co-Chairmen: H. CHARNOCK
      A. HECHT

   ii. Physical Processes (Convection, Dispersion, Mixing)
      Co-Chairmen: J.C. GASCARD
      W. ROETHER

   iii. Dynamics and Modelling:
      Co-Chairmen: S. PIACSEK
      M. GERGES

Sunday, 11 September, 1983

- Plenary Meeting: Summary of activities of 10 September
- Continuation of Working Group Discussion
- Plenary: Presentation of Working Group Reports and Recommendations
- Further Discussions on Additional Topics
- Melding and Co-ordination of Recommendations of the WGs.
- Adoption of the Research Program and Future Plans
- Closure of the Workshop

D. Terms of Reference for the Working Groups

The Working Groups are charged with the following topics:

Group I: DESCRIPTIVE OCEANOGRAPHY
Hydrography, surface fluxes, remote sensing, biological chemical and climatic influences;
Coastal coupling, others

Group II: PHYSICAL PROCESSES (CONVECTION, DISPERSION AND MIXING)
Deep and intermediate water formation;
Air-sea interactions, spreading, mixing, transformation, tracers, others

Group III: DYNAMICS AND MODELLING
General circulation, driving mechanisms.
Internal dynamical processes, analytical and numerical approaches.

Each Working Group will address the following main questions:

i. Overall Research Program:
- Specific scientific objectives
- Methods
- Tentative Schedule

ii. Field Program and Plan
- Objectives
- Techniques, intercalibration
- Resource requirements
- Logistics

iii. Existing and Historical Studies
- Plans for synthethis

iv. Data Management
- Data banking and exchange
- Co-ordinated and cooperative analysis

v. Research Implications
- Research Ships

APPENDIX II

28th CONGRESS & PLENARY ASSEMBLY of the ICSEM

ROUND TABLE

on the

EASTERN MEDITERRANEAN

Cannes, France
December 6-8, 1982

Table of Contents:

RECOMMENDATIONS FROM THE EASTERN MEDITERRANEAN ROUND TABLE:

AN INTERNATIONAL COOPERATIVE SCIENTIFIC PROGRAM FOR THE EASTERN MEDITERRANEAN

Among the various Mediterranean areas, the Eastern basin is undoubtedly the most poorly investigated. Although enough is known to indicate important scientific problems, the fundamentals of the descriptive, kinematical and dynamical processes are still controversial and ill defined. A scientific program focusing on the full Eastern Mediterranean Oceanography is therefore timely and desirable.

The fundamental properties of the Eastern Mediterranean and related scientific questions can be summarized as follows:

a. Problems of Deep and Intermediate Water Formation

b. Influence of the Mediterranean Water on The North Atlantic and World Ocean Formation

c. Problems of Mixing and Spreading

d. Air-sea Exchanges and Budgets of Properties

As a consequence of these problems basic scientific objectives can be summarized as follows:

a. What is the fundamental driving force of the Mediterranean circulation? (Atmospheric forcing, exchanges through straits, thermodynamic processes)

b. What are the major features of the circulation, its energies and variability?

c. What are the details of the dynamics of the open ocean convection processes?

d. What are the most important implications of the circulation for the distribution of biological and chemical properties distributions?

The scientific problems and related objectives have consequences of important social and human impact:

a. The prediction of changes in weather and climate of the nations bordering the Eastern Mediterranean is fundamental for the planning of Agriculture and Commerce.

b. The description and prediction of the circulation is fundamental for the utilization of resources, fishery, energy and transportation.

c. The description and prediction of the ocean environment is fundamental for resolving pollution and waste disposal problems.

d. The prediction of changes in the coastal zone is fundamental for the zone management as related to tourism, recreation and industry.

The previous considerations point out the timeliness, importance and urgency of a Scientific Program focusing on the proposed questions and objectives, and requests the CIESM to promote it.

A workshop is required for developing details of the two scientific objectives, a specific plan and the schedule and methods for implementation.

A.R. Robinson Co-chairperson
P. Malanotte-Rizzoli Co-Chairperson

S.H. Sharaf El-Din Panelist
J-C. Gascard Panelist

A. Hecht
S. Piacsek
W. Roether

ANNEX I

CIRCULATION AND DYNAMICS OF THE EASTERN MEDITERRANEAN: AN OUTLINE OF RESEARCH PROBLEMS AND THEIR IMPLICATIONS

CIRCULATION AND DYNAMICS OVERVIEW OF AN IMPORTANT RESEARCH PROBLEM

1. Sufficient knowledge exists to identify important, interesting and feasible SCIENTIFIC PROBLEMS

    a. Deep Water Formation

    b. Intermediate Water Formation and Transport

    c. Mixing and Spreading of Water Masses

    d. Air-Sea Exchanges including Evaporation

2. Yet Fundamentals of the description and physics are unknown: SCIENTIFIC QUESTIONS

    a. Wind, Source-Sink or Thermodynamic Driving?

    b. Features of the Circulation and their Variability?

    c. Physical Processes and Statistics of Water Formation?

    d. Biological and Chemical Implications?

3. Knowledge and Models of the Region are essential and have important PRACTICAL IMPLICATIONS for societal problems

    a. Weather and Climate

    b. Resource Development and Utilization

    c. Environmental Management

SCIENTIFIC PROBLEMS, QUESTIONS AND PRACTICAL IMPLICATIONS

1. SCIENTIFIC PROBLEMS

    a. Deep Water Formation in the Adriatic which feeds the Eastern Mediterranean and reaches directly or by diffusion to the Western Mediterranean

    b. Levantine Intermediate Water is formed in the Eastern Mediterranean and reaches the Western Mediterranean and the North Atlantic (in a mixture with deep Mediterranean water) and influences the General Ocean Circulation

c. The Mixing of Water Masses

   i. Cross Isopycnal Mixing

   ii. Along Isopycnal Spreading (advection-stirring-mixing?)

   iii. The fate of the North Atlantic Water

   iv. Important Regionally and Generally for the Oceans

d. Air-Sea Exchange Processes (especially Evaporation) which effect Atmosphere, Weather and Climate

2. SCIENTIFIC QUESTIONS

   a. Are Wind, Source-Sink or Thermodynamics Driving Forces most important?

   b. What are major features of the circulation?

      i. Scales, Energetics

      ii. Variabilities including Synoptic and Mesoscale

   c. What are detailed physical processes of deep and intermediate water formation?

      i. Location(s), Intermittency, Statistics

   d. What are most important implications of Physical Circulation for biological and chemical processes?

3. PRACTICAL IMPLICATIONS

   a. Provides the scientific basis for addressing weather and climate effects for nations bordering the Eastern Mediterranean and their relation to agriculture and commerce

   b. Description and Prediction of the Circulation for development and utilization of Marine Resources

      i. Fisheries, Transportation

      ii. Mineral exploration and extraction

      iii. Energy from the sea and from under the sea

   c. Management of the total Mediterranean environment

      i. Pollution Disposal

      ii. Recreation and Coastal Zone Management

ANNEX II

PANELISTS & VENUE
Cannes, France, December 6-8, 1982

Co-Chairpersons (Animateurs):

Prof. Allan R. Robinson
Harvard University
Center for Earth and Planetary Physics
Pierce Hall
Cambridge, Massachusetts 02138, USA
Office Tel.: 617/495-2819
Telex: 921496 HARVARD

Prof. Paola Malanotte-Rizzoli
Laboratorio Pero Studio Della
Dinamica Delle Grandi Masse
Venice 30125, VENICE

M.I.T.
Dept. of Meteorology and Physical Oceanography
Building 54-1622
Cambridge, MA 02139, USA
Office Tel.: 617/253-2451

Panelists (Moderateurs):

Dr. S.H. Sharaf El-Din
University of Alexandria
Faculty of Science
Alexandria, EGYPT

Dr. Jean-Claude Gascard
Museum National D'Histoire Naturelle
Physical Oceanography Laboratory
43-54 Rue Cuvier
75005 Paris, FRANCE
Office Tel.: 707-8544
Home Tel.: 012-0861
Telex: (842) 270686 LOPMNHN

Dr. Arthur Hecht
Israel Oceanographic and Limnological Research
Tel Shikmona
Haifa, P.O. Box 8030, ISRAEL
Office Tel.: 04-515202
Cable: RESOCHAIFA
Telex: 46400 BXHA IL Ext: 8848

Dr. Steven Piacsek
NORDA
Code 322
NSTL, Building 1100
Bay St. Louis, Mississippi 39529, USA
Office Tel.: 601/688-5433

Dr. W. Roether
Institut fur Umweltphysik der Universitat Heidelberg
Heidelberg, FEDERAL REPUBLIC OF GERMANY
Telex: (841) 4615151 UNIHD

UNESCO REPORTS IN MARINE SCIENCE

Title of numbers which are out of stock

No.		Year
3	Benthic ecology and sedimentation of the south Atlantic continental platform Report of the seminar organized by Unesco in Montevideo, Uruguay, 9-12 May 1978	1979
13	Seminario Latinoamericano sobre Enseñanza de la Oceanografía Informe final del Seminario organizado por la Unesco en São Paulo, Brasil, 17-20 de noviembre de 1978	1981