Intergovernmental Oceanographic Commission

Workshop Report No. 43

IOC Workshop on the Results of MEDALPEX and Future Oceanographic Programmes in the Western Mediterranean

Venice, Italy, 23-25 October 1985

SC-86/WS-42

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No.	Title	Publishing Body	Languages
1	CCOP-IOC, 1974, Metallogenesis, Hydrocarbons and Tectonic Patterns in Eastern Asia (Report of the IDOE Workshop on); Bangkok, Thailand 24-29 September 1973 UNDP (CCOP), 138 pp.	Office of the Project Manager UNDP/CCOP c/o ESCAP Sala Santitham Bangkok 2, Thailand	English
2	CICAR Ichthyoplankton Workshop, Mexico City, 16-27 July 1974 (Unesco Technical Paper in Marine Sciences, No. 20).	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock) Spanish (out of stock)
3	Report of the IOC/GFCM/ICSEM International Workshop on Marine Pollution in the Mediterranean, Monte Carlo, 9-14 September 1974.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish (out of stock)
4	Report of the Workshop on the Phenomenon known as "El Niño", Guayaquil, Ecuador, 4-12 December 1974.	FAO Via delle Terme di Caracalla 00100 Rome, Italy	English (out of stock) Spanish (out of stock)
5	IDOE International Workshop on Marine Geology and Geophysics of the Caribbean Region and its Resources, Kingston, Jamaica, 17-22 February 1975.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock) Spanish
6	Report of the CCOP/SOPAC-IOC IDOE International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Suva, Fiji, 1-6 September 1975.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
7	Report of the Scientific Workshop to Initiate Planning for a Co-operative Investigation in the North and Central Western Indian Ocean, organized within the IDOE under the sponsorship of IOC/FAO (IOFC)/Unesco/EAC, Nairobi, Kenya, 25 March-2 April 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
8	Joint IOC/FAO (IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters, Penang, 7-13 April 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)
9	IOC/CMG/SCOR Second International Workshop on Marine Geoscience, Mauritius, 9-13 August 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
10	IOC/WMO Second Workshop on Marine Pollution (Petroleum) Monitoring, Monaco, 14-18 June 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish (out of stock) Russian
11	Report of the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain Trinidad, 13-17 December 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish (out of stock)
11 Suppl.	Collected contributions of invited lecturers and authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain, Trinidad, 13-17 December 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
12	Report of the IOCARIBE Interdisciplinary Workshop on Scientific Programmes in Support of Fisheries Projects, Fort-de-France, Martinique 28 November-2 December 1977.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
13	Report of the IOCARIBE Workshop on Environmental Geology of the Caribbean Coastal Area, Port of Spain, Trinidad, 16-18 January 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
14	IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas, Abidjan, Ivory Coast, 2-9 May 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French
15	CPPS/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific, Santiago de Chile, 6-10 November 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)
16	Workshop on the Western Pacific, Tokyo, 19-20 February 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Russian
17	Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS), Moscow, 9-11 April 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
17 Suppl.	Papers submitted to the Joint IOC/WMO Seminar on Oceanographic Products and the IGOSS Data Processing and Services System, Moscow, 2-6 April 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
18	IOC/Unesco Workshop on Syllabus for Training Marine Technicians, Miami, 22-26 May 1978 (Unesco reports in marine sciences, No. 4)	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
19	IOC Workshop on Marine Science Syllabus for Secondary Schools, Llantwit Major, Wales, U.K., 5-9 June 1978 (Unesco reports in marine sciences, No. 5).	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian Arabic
20	Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources, Bandung, Indonesia, 17-21 October 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
21	Second IDOE Symposium on Turbulence in the Ocean, Liège, Belgium, 7-18 May 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
22	Third IOC/WMO Workshop on Marine Pollution Monitoring, New Delhi, 11-15 February 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
23	WESTPAC Workshop on the Marine Geology and Geophysics of the North-West Pacific, Tokyo, 27-31 March 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Russian
24	WESTPAC Workshop on Coastal Transport of Pollutants, Tokyo, 27-31 March 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)
25	Workshop on the Intercalibration of Sampling Procedures of the IOC/WMO UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open-Ocean Waters, Bermuda, 11-26 January 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (superseded by IOC Technical Series No. 22)
26	IOC Workshop on Coastal Area Management in the Caribbean Region, Mexico City, 24 September-5 October 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
27	CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Nouméa, New Caledonia, 9-15 October 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
28	FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes Lima, 20 April-5 May 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
29	WESTPAC Workshop on Marine biological methodology Tokyo, 9-14 February 1981.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
30	International Workshop on Marine Pollution in the South-West Atlantic Montevideo, 10-14 November 1980.	IOC, Unesco Place de Fontenoy, 75700 Paris, France	English (out of stock) Spanish
31	Third International Workshop on Marine Geoscience Heidelberg, 19-24 July 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
32	UNU/IOC/Unesco Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime Paris, 27 September - 1 October 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish

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FOREWORD

This Report summarizes the main outcomes of the Workshop on the Results of MEDALPEX and Future Oceanographic Programmes in the Western Mediterranean. As far as scientific presentations are concerned, one will find relevant abstracts in Annex II. The full texts of the presentations are published as a special issue of Annales Geophysicae, the official organ of the European Geophysical Society. Anyone interested in receiving this issue is kindly requested to contact either:

IOC Secretariat
Unesco
7, place de Fontenoy
75700 Paris
France

or:

Annales Geophysicae
C.D.R. Centrale des Revues
11, rue Gossin
F-92543 Montrouge Cédex
France.

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1. OPENING

The Director of the host Agency (Istituto per lo Studio della Dinamica delle Grandi Masse - ISDGM - of the Italian Consiglio Nazionale delle Ricerche - CNR), Prof. R. Frassetto, called the session to order at 09.00 on 23 October 1985. He welcomed the participants in Venice and at Papadopoli Palace which houses the ISDGM. He then recalled that the idea of studying in the fullest detail the flow of air-masses over and around mountains was conceived in the same room in 1971-1972, as a means to better predict storm surges in Venice. The idea grew up and finally led to the design of the Alpine Experiment (ALPEX) as a sub-programme of the Global Atmospheric Research Programme (GARP) undertaken under the co-sponsorship of the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU). ALPEX was aimed at studying the effects of mountains on the general stream of the atmosphere and took place from 1 September 1981 to 30 September 1982, with a Special Observing Period (SOP) from 1 March to 30 April 1982.

Through Resolutions EC-V.4 and XI-2, the IOC decided that oceanographers should become engaged in this study and decided to support the development of an oceanographic programme in the Mediterranean Sea during ALPEX (MEDALPEX). MEDALPEX was aimed at understanding the effect of wind forcing on the dynamics of the western part of the Mediterranean and the Adriatic Sea. National contributions to MEDALPEX were provided by Belgium, France, Italy, Monaco, Spain, USSR and Yugoslavia.

A first "quick look" at the scientific results of MEDALPEX was made at the Meeting on the Preliminary Results of MEDALPEX (Santa Teresa, 9 September 1983). Now, time was mature to have a more general and comprehensive overview of the scientific results of the experiment and to think of future oceanographic programmes to be undertaken in the western Mediterranean.

Prof. Frassetto concluded in wishing the participants in the Workshop every success in their endeavours. (A List of Participants is attached as Annex VIII).

The Assistant Secretary IOC, Mr. Y. Tréglos, expressed the thanks of the Commission to the CNR and Prof. Frassetto for holding the Workshop. He then presented a draft time-table for the Workshop (see Annex I), along which the first two days would be devoted to MEDALPEX-related scientific presentations followed by a round table, and the third day to discussions on future programmes in the western Mediterranean. The Workshop agreed on this schedule.

2. SCIENTIFIC RESULTS OF MEDALPEX

2.1 SCIENTIFIC LECTURES

Abstracts of the scientific presentations are reproduced in Annex II. It was considered unfortunate that the scientists from USSR were unable to give their lectures, due to last minute administrative problems.

Prof. Nihoul proposed, and the Workshop gratefully accepted, that presentations made at the Workshop and at the Santa Teresa Meeting be published in a special issue of Annales Geophysicae, the official organ of the European Geophysical Society. The IOC Secretariat was requested to ensure that speakers be informed of ways and means of submitting their papers to that end.

2.2 GENERAL CONCLUSIONS

Prof. Frassetto agreed to sum up ALPEX (as far as oceanographers may be concerned) and MEDALPEX progresses and results. His contribution appears as Annex III.

During the round table on this topic, the Workshop reached the following conclusions:

(i) If MEDALPEX was to be considered exclusively as an international co-operative programme, it should be recognized that the experiment was not fully successful, for national contributions did rather reflect the scientific interests of several groups of oceanographers than a common will to reach a common goal;

(ii) On the other hand, the great variety of results contributes to a better knowledge of several mechanisms that drive the complex water movements in the western Mediterranean and the Adriatic Sea;

(iii) In addition, this variety by itself allows for an in-depth reflection on what could be the grounds for future oceanographic undertakings in this part of the world ocean;

(iv) MEDALPEX occurred at a very important transitional period aiming at dealing with the western Mediterranean in a modern oceanographic style; such a work has to be continued. To that end, the general framework provided for by IOC was considered as convenient.

3. FUTURE OCEANOGRAPHIC PROGRAMMES IN THE WESTERN MEDITERRANEAN

In introducing this item, the Assistant-Secretary IOC emphasized the last afore-mentioned conclusion: in such a context, the role of IOC is to provide a framework for co-operative oceanographic studies. This follows from its Statutes which read (Article 1, para.2): "The purpose of the Commission is to promote scientific investigation with a view to learning more about the nature and resources of the oceans through the concerted action of its members". He also recalled that "in carrying out its functions, the Commission shall bear in mind the special needs and interests of developing countries, including in particular the need to further the capabilities of these countries in marine science and technology" (in IOC Statutes, Article 2).

The Workshop acknowledged this explanation. It also agreed that any proposal for co-operative studies had to bear a strong scientific interest and to be fully adhered to by the scientific community involved. Participants therefore agreed to express their views on the main scientific topics to be addressed with regard to western Mediterranean.

In this connection, it was considered useful to review on-going programmes in the Mediterranean. Participants involved in these programmes presented some of them (see Annex IV).

As a starting point, the Workshop was presented with a proposal put forward by Dr. C. Millot: a reasonably good scientific objective for future co-operative studies in the western Mediterranean would be the better understanding of the "circulation" of the three water masses in the region (the

water of Atlantic origin, the Levantine intermediate water and the Mediterranean deep water) and of the roles played by the diverse forcings that drive them (wind forcing, atmospheric forcing, river discharge forcing, deep water formation forcing, etc.). The wording "circulation" was made explicit by defining the space and time scales of the phenomena of interest, i.e., respectively the Rossby's radius of deformation (about 12 km in the Mediterranean) and a few days. More details about the proposal can be found in Annex V.

The Workshop agreed that a scientific programme could be built up on this basis, even though new thoughts might slightly modify the original goal. The building up phase was laid out as follows:

- to synthetize and analyse the current knowledge and the diverse hypotheses on the circulation of water masses in the western Mediterranean;

- to define specific scientific objectives relating to the aforementioned core-goal;

- to set up an observational strategy (taking into account existing data sets);

- to develop a modelling strategy that fits the scientific questions raised in the western Mediterranean (Prof. A. Robinson agreed to provide guidance on this item; his contribution appears as Annex VI);

- to prepare for the scientific evaluation of the results.

The Workshop considered that a Group of Experts should be established to "steer" the building up phase with the following Terms of Reference:

(i) to develop a scientific programme aiming at a better knowledge of the structure of the western Mediterranean, of its dynamics and of the processes that drive them;

(ii) to specify the observational, data handling and computational facilities needed to that aim;

(iii) to assess the extent to which the needs are being met by existing national and international programmes;

(iv) to identify the need for additional activities;

(v) to consider and recommend an organizational structure by which such activities can be provided through a co-operative international project.

The Workshop recommended that the Group of Experts be made up of:

C. Millot (France), Chairman
M. Astraldi (Italy)
A. Chouikhi (Algeria)
M. Crépon (France)
G. Heburn (USA)
M. Kuzmič (Yugoslavia)
C.J. Nihoul (Belgium)
L. Rickards (UK)
J. Salat (Spain)

In addition, Prof. H. Charnock, Prof. R. Frassetto and Prof. A. Robinson would be considered as advisers for the project.

The Workshop agreed that the work of the Group of Experts could include the preparation of an issue paper on future oceanographic programmes in the western Mediterranean along the lines of the attached draft lay-out (see Annex VII).

The Workshop also wished to point out the following:

- any oceanographic programme in the western Mediterranean would definitely need a strong input from meteorologists, to provide wind stress, air temperature and humidity, etc.;

- a foreseen or expected important source of data would be the ships of opportunity (merchant or fishing vessels that take and transmit oceanographic observations for international exchange); present transmission problems between ships at sea and entry points to the Global Telecommunication System (GTS) of WMO should be overcome, probably by using satellite communications;

- one of the main problems to be solved in undertaking such a co-operative project is that of data centres. Experience gained during MEDALPEX showed that some participants did not follow established rules and forgot to send their data to the RNODC-MEDALPEX. Other participants, such as those interested in modelling, were unable to get some MEDALPEX data. It was stressed that data management should be carefully considered in future and IOC was requested to help solving this problem.

4. CLOSURE

In closing, the Workshop requested the Assistant-Secretary IOC to bring its views to the attention of the forthcoming Nineteenth Session of the IOC Executive Council. It also wished to express its thanks to Prof. Frassetto and his team for their kind, traditionally Italian, hospitality.

The Workshop closed at 17.00 on 25 October 1985.

ANNEX I

PROGRAMME FOR THE WORKSHOP

WEDNESDAY 23 OCTOBER CHAIRMAN : H. Charnock

09.00 - 09.15	Opening
	Currents and water masses of the Western Mediterranean Basin
09.15 - 09.45	Oceanographic research of the Ligurian Sea and other regions of the Mediterranean Sea during field phase of MEDALPEX P. Gudz, F. Terziev, Y. Vakaljuk and V. Zatc
10.00 - 10.30	Report on sea level data collected during the MEDALPEX Experiment from 1st September 1981 to 30th September 1982 L.J. Rickards
10.45 - 11.00	Coffee
11.00 - 11.30	The Ligurian Sea budgets during MEDALPEX Bethoux and Prieur
11.45 - 12.15	Seasonal and mesoscale variability in the Ligurian Sea C. Millot
12.30 - 14.30	Lunch
14.30 - 15.00	Transient circulation in the Tyrrhenian Sea and Sicily Channel Grancini and Iovenitti
15.15 - 15.45	Spectral characteristics of wind waves in the North Adriatic Gacic and Smircic
16.00 - 16.15	Coffee
16.15 - 16.45	Water mass structure near and offshore the Catalan coast during winter of 1982 and 1983 J. Sadat and J. Font

THURSDAY 24 OCTOBER CHAIRMAN : A.R. Robinson

Modelling Mediterranean phenomena

09.00 - 09.15	Introductory remarks
09.15 - 09.45	MEDmodel in a hydrodynamic model of the Western Mediterranean Basin P.M. Lehucher, G. Chabert d'Hières, M. Crépon and C. Millot
10.00 - 10.30	Application of a three-dimensional mathematical model to the study of synoptic and mesoscale processes in the MEDALPEX Mediterranean area J. Nihoul
10.45 - 11.00	Coffee
11.00 - 11.30	Effects of wind stress forcing on the dynamics of the Liguro-Provencal Basin G.W. Heburn
11.45 - 12.15	Effects of Bura on the current field. On the basis of MEDALPEX and some other data effect of Bura will be analysed M. Zore-Armanda and M. Gacic
12.30 - 14.30	Lunch
14.30 - 15.00	Wind-induced vertical shearing : MEDALPEX data and modelling exercise M. Kuzmic and M. Orlic
15.15 - 15.45	WAM - The third generation wave model in the Mediterranean Sea : a challenge for oceanographers and meteorologists L. Cavalieri
16.00 - 16.15	Coffee

CHAIRMAN : R. Frassetto

The results of MEDALPEX : conclusions

16.15 - 17.00	Round Table

FRIDAY 25 OCTOBER CHAIRMAN : C. Millot

Future oceanographic programmes in the Western Mediterranean

09.00 - 09.15	Introductory remarks
09.15 - 10.45	The scientific questions raised in the Western Mediterranean : the general circulation . Invited papers on :
	1. Overview of the general circulation in the Western Mediterranea and its characteristics
	2. Forcings relevant to the general circulation : 2.1 Wind forcing 2.2 Atmospheric forcing 2.3 River discharge forcing 2.4 Deep water forcing
	3. Modelling efforts in the Western Mediterranean
10.45 - 11.00	Coffee
11.00 - 12.00	Brief presentations of on-going programmes and round table
12.00 - 12.30	Summary of the morning session : a consolidated scientific programme in the Western Mediterranean?
12.30 - 14.30	Lunch
14.30 - 16.45	Preparation of an issue paper on Future Oceanographic Programmes in the Western Mediterranean
16.45 - 17.00	Closure of the Worshop

ANNEX II

ABSTRACTS OF SCIENTIFIC PRESENTATIONS

OCEANOGRAPHIC RESEARCH OF THE LIGURIAN SEA AND OTHER REGIONS OF THE MEDITERRANEAN SEA DURING FIELD PHASE OF MEDALPEX

(P. Gudz, F. Terziev, Y. Vakaljuk, V. Zatc)

During the Special Observing Period of MEDALPEX (March-April 1982) Soviet research vessels "V. Bugaev", "Prof. Vodjanitsky" and "Zodiak" conducted the meteorological and oceanographic research in the Provencal Basin, the Ligurian and Adriatic Seas, the Otranto and Tunisian Straits.

Hydrological conditions in the Genova Gulf is one of the important cause of formation and development of cyclones.

The problems, connected with the processes of winter convection in the Mediterranean Sea, the sea-air interaction, the conditions of development of atmospheric cyclones in the Ligurian Sea, the water transfer through straits are investigated.

Convective mixing reached the bottom, it promoted to the deep-water formation in this region of the Mediterranean Sea.

The northern winds with speed of 15-20 m/s caused heat loss through the sea surface of 30-50 mj/m^2 per day and promoted to maintenance of cyclonic circulation of the Ligurian Sea waters.

In future, the measurements of thermodynamic conditions of the Mediterranean Sea, investigation of air-sea interaction as well as water exchange between the Mediterranean Sea and surrounding regions will be continued.

REPORT ON SEA LEVEL DATA COLLECTED DURING THE MEDALPEX EXPERIMENT FROM 1st SEPTEMBER 1981 TO 30th SEPTEMBER 1982

(L.J. Rickards)

Hourly values of sea level from 29 sites in the western Mediterranean were collected as part of the Mediterranean Alpine Experiment (MEDALPEX). The management, quality control and analysis of these data were carried out by the UK Marine Information and Advisory Service (MIAS) on behalf of the Permanent Service for Mean Sea Level (PSMSL).

The paper describes the methods used to compile the MEDALPEX sea level data into a uniform data set and includes a comprehensive collection of data analysis presentations. The data were both tidally analysed and low pass filtered, and non-tidal fluctuations were investigated using principal components analysis. The low pass filtered data show a fairly good correlation with the passage of meteorological events particularly the Adriatic Sea data. Principal components analysis suggests that the non-tidal variations in sea level in the western Mediterranean and the Adriatic Sea were decoupled over the period of the MEDALPEX experiment.

A magnetic tape copy of the data set, including documentation, is available from PSMSL in GF-3 format, the IOC's general format for the exchange of oceanographic data.

THE STRUCTURE OF MESOSCALE PHENOMENA IN THE LIGURIAN SEA INFERRED FROM THE DYOME EXPERIMENT

(C. Millot)

General hydrodynamical features in this region of the northwestern Mediterranean Sea have already been described, mainly from the analysis of 30 one-year current meter records (Taupier-Letage and Millot, 1986). Mesoscale currents measured in the vicinity of the Ligurian Current in the north and of the Western Corsican Current in the south displayed marked differences. The mesoscale activity -as defined by the variance over 20-day periods- was quasi permanent in the south while it markedly increased during the winter season in the northern and central zones: in the latter one it reached maximum values at depths ranging from 100m to at least 1100m. These seasonal variations of the mesoscale activity led us to define a quiet and a stormy period.

This information is complemented in the present paper by results from auto- and cross-spectral analysis during the two periods. Features foreseen in the former paper, such as the vertical structure of the mesoscale currents, the dependence of their intensity on both space and season and the generation of deep wintertime mesoscale phenomena by the Liguro-Provençal Current are supported by these computations. They also show that energy densities are relatively large in the central zone at the lowest frequencies, a feature which can be due to phenomena having different time scales and/or different phase speeds. It is natural to imagine that mesoscale phenomena, and specially the biggest ones, generated by instability processes affecting the coastal currents, tend to settle more in the central zone than elsewhere.

SPECTRAL CHARACTERISTICS OF WIND WAVES IN THE NORTH ADRIATIC

(M. Gačić, A. Smirčić)

On the wind wave data collected during the MEDALPEX SOP period and some other data from the North Adriatic, the JONSWAP parametric presentation of wave spectra has been tested. This presentation has been examined separately on the waves generated by the NE-wind ("bora") and SE-wind ("jugo"). Phillips' constant and peak enhancement factor were calculated for each data set. Overall 250 spectra were analysed.

In addition to the JONSWAP parametric presentation a new formula was proposed which respected the fact that the high-frequency part of the spectrum in the North Adriatic had a -4 slope. The formulae were compared with the measured spectra and their validity was discussed.

WATER MASS STRUCTURE NEAR AND OFFSHORE THE CATALAN COAST DURING WINTER OF 1982 AND 1983

(J. Salat, J. Font)

Oceanographic data from CARON cruises (40°30' - 43°N, 1° - 6°30'E) obtained by CTD casts and continuous surface TS analysis, during March 1982 and February-March 1983 are presented. The water mass structure found and geostrophic circulation is described. Some ideas about the processes involved in the origin of water masses and their evolution, especially concerning Winter Intermediate Water and Deep Water, are discussed:

The results obtained seem to confirm that Water formed by convection over the edge of the continental shelf is spreading southwards and offshore being one of the main sources of Winter Intermediate Water. On the other hand, deep convections found around parallel 41°N, in the central part of the Catalan Sea, suggest a propagation of the Deep Water formation mechanism to the South following a divergence line across the center of the cyclonic circulation.

THE MEDMODEL PROJECT

(P.M. Lehucher, G. Chabert d'Hières, M. Crépon, C. Millot)

The MEDMODEL Project is devoted to the hydrodynamical study of the whole Western Mediterranean Basin. Its objective is to build a tool able to give a quantitative evaluation of transfer of water masses at a basin scale and between the coastal zones and the open sea.

It focuses primarily on process studies together with the analysis of available data sets in theoretical physical models. Three study areas have been chosen on the basis of good available data and relevance to the general circulation. These are:

(i) Gibraltar Strait-Alboran Sea System,

(ii) the Algerian Basin,

(iii) the Ligurio-Provencal Basin.

Upon completion of these sub-models, a general circulation three dimensional (3-D) model will be constructed by taking into account results from the in situ data sets, physical and quasi-geostrophic models.

This project is co-ordinated by the CETE (Centre d'Etudes Techniques de l'Equipment) - Méditerranée and is planned on a 4-year basis.

APPLICATION OF A THREE-DIMENSIONAL MATHEMATICAL MODEL TO THE STUDY OF SYNOPTIC AND MESOSCALE PROCESSES IN THE MEDALPEX MEDITERRANEAN AREA

(J. Nihoul)

The three-dimensional mathematical model developed at the School for Geohydrodynamics and Environmental Research (GHER) of Liège University is presented. The state variables are the three components of the velocity vector, pressure, buoyancy and the turbulent kinetic energy. The basic equations are written in σ- coordinates with horizontal eddy diffusivities proportional to the four thirds power of the mesh size and vertical eddy diffusivities functions of the turbulent kinetic energy and the Richardson number.

The parameterization of eddy coefficients and boundary conditions is based on observations made during the MEDALPEX Experiment and the model is calibrated for the Western Mediterranean Sea and the Adriatic Sea.

Applications are described and a comparison is made of the model's predictions with observations.

EFFECTS OF BORA ON THE CURRENT FIELD

(M. Zore-Armanda, M. Gačić)

Bora wind is an offshore wind typical for the eastern Adriatic coast. It is characterized by the strong alongshore variability due to the topography of the mountains along the coast.

Consequently a strong vorticity input to the current field is expected.

As it was shown earlier on the basis of MEDALPEX data the vorticity of the current field in the North Adriatic shows large spatial changes. In this paper we tried to explain these vorticity changes in terms of the alongshore shear in the wind field. The cyclonic barotropic gyre in the northernmost part of the Adriatic is intensified during a strong bora event which appears to be due to the strong cyclonic vorticity of bora wind in that part of the Adriatic. The alongshore distribution of bora-wind shows maximum in the Gulf of Trieste decreasing southward with a local minimum probably near Rovinj. Then bora-wind speed increases reaching another maximum south of Pula. From this it follows that south of Rovinj there is an anticyclonic vorticity input which results in the change of sign of vorticity in the current field. Southern limit of the northernmost part of the Adriatic is characterized by the thermal front. Its existence is studied also from the horizontal distribution of phytoplankton data collected during the MEDALPEX experiment.

The nearshore circulation induced by the bora wind in several semi-closed bays of the eastern Adriatic coast is also analysed in terms of the alongshore distribution of the wind speed. Similar response to the wind forcing, i.e., a similar pattern of cyclonic and anticyclonic gyres has been noticed in a number of semiclosed bays like, e.g., Bay of Kaštela, Virsko more, Rijeka Bay, etc.

WIND-INDUCED VERTICAL SHEARING: MEDALPEX DATA AND MODELLING EXERCISE

(M. Kuzmić, M. Orlić)

A three-dimensional numerical hydrodynamical model has been used to study the wind-driven flow in the Northern Adriatic. The model, employing the integral transformation to predict the vertical distribution of velocity, has been utilized to reproduce the wind-induced motion during winter. The hydrographic, sea-level and current data collected in the Northern Adriatic during the MEDALPEX have been used to verify the model predictions. Analysis of the empirical data has suggested that the bura wind induces the most pronounced, albeit transient, contribution to the Northern Adriatic current field. The model predictions have clearly shown the controlling influence of the shallower bottom topography along the Italian coast. The model to data comparison revealed the necessity to change the expected values of the eddy viscosity coefficient and the coefficient of bottom friction by an order of magnitude in order to rectify the predicted vectors direction and magnitude. Some discrepancies in magnitude and direction, as well as in "surface" to "bottom" current ration, persisted after the adjustment of the two coefficients. The horizontal variability of the wind-stress, vertical variability of the eddy viscosity coefficient and the non-linear formulation of the bottom friction have been identified and further studied as possible areas for amelioration of the noted inadequacies.

WAM - THE THIRD GENERATION WAVE MODEL IN THE MEDITERRANEAN SEA A CHALLENGE FOR OCEANOGRAPHERS AND METEOROLOGISTS

(L. Cavaleri)

One year ago the wave international scientific community decided to go ahead with the development and implementation of a new, third generation, wave prediction model. The aim is to provide a reliable wave forecast in all the European seas, including the Baltic Sea, the North Sea, the Atlantic Ocean and the Mediterranean Sea. The input will be the ECMWF weather forecast with a daily adaptation of the model output to the available experimental data, both directly from the sea as from satellite like the expected ERS-1. It is immediate that the length of the reliable forecast will be strictly depending on the correctness of the wind forecast. Nowadays this seems to be sufficiently correct up to 4-5 days, but the conditions worsen drastically when we limit our concern to the Mediterranean basin, and in particular to the Italian Seas.

That the weather forecast is here more challenging than at other locations is proven by the existence of the ALPEX experiment itself!

It is clear that I am not contributing to the solution of the meteorological problem. Rather I want to stress the necessity of collapsing the ALPEX scientific results in a better understanding of the complicated phenomena happening here. This should allow the formulation of better models for the area, and consequently the capability of good wind and wave forecast in the Mediterranean basin.

This seems a very good problem, both scientific and practical, suitable for a large co-operation of the meteorological and scientific communities. We expect to be ready in five years. We would like the meteorologists to be the same.

ANNEX III

ALPEX - MEDALPEX SUMMARY

by R. Frassetto

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INTRODUCTION

This report on the combined experiment of ALPEX and MEDALPEX which took place in 1981-82 is addressed, inter alia, to the community of meteorologists and oceanographers interested in the geophysical fluid dynamics of the Mediterranean region.

The objective is to sum up problems and findings of both experiments and to contribute to the on-going oceanographic programmes in the western and the eastern Mediterranean Sea, as well as to provide guidelines for the preparation of research activities which should be undertaken during the nineties when several marine satellites are in orbit.

The Mediterranean Sea has a scientific role to play in the several global programmes which have been proposed for the period up to the end of this century; this role should be recognized and properly defined.

1. BACKGROUND

It is well known that momentum, heat and moisture fluxes are the principal forcings on the Mediterranean Sea and that gravitational forces have little and well-predicted effects on this geometrically complicated marginal sea.

Sea-level variations, monitored by precision tide gauges, are therefore significant indicators of the effects of meteorological and climatological forcings. ALPEX/MEDALPEX has given new evidence of the importance of long series of synoptic meteo-oceanographic measurements from strategically distributed tide gauges and moored buoys together with ship-of-opportunity data and remotely sensed data from satellites.

With a well-planned set of routine measurements of this kind, new mathematical models could resolve, simulate and predict a variety of oceanographic processes which occur in the Mediterranean on a reduced scale and in the world ocean on a large scale. MEDALPEX has demonstrated that a great benefit to oceanographic sciences could be obtained if a reasonable measurement system was set up in the Mediterranean Sea or at least if the present disorderly systems were re-organized and implemented. This would be particularly important for the decade 1990 during which a second generation of sea observing satellites will routinely monitor the Mediterranean Sea.

The Alpine Experiment, together with MEDALPEX, its western and central Mediterranean counterpart, have provided however an important new set of data in both fluids, air and water, during the AOP (Annual Observing Period) from October 1981 to October 1982, and a unique set of data during the SOP (Special Observing Period), in March-April 1982.

The SOP, in fact, coincided with frequent meteorological perturbations (see Figure 1) which were successfully monitored during the Intensive Observation Periods (IOPs). At these periods, during which several research aircrafts were flying over the Alps and the Mediterrranean and all other measurements were intensified, several cases of cyclogenesis and Bora were observed, together with their effects over the western Mediterranean and the Adriatic Seas. A preliminary analysis of these cases has been made but a more complete study is expected when all sets of ALPEX meteorological data, including surface wind fields, heat and vapour fluxes and satellite data are available.

The success of the Alpine Experiment was due to a careful and professional planning and management of the field operation, supported by WMO and ICSU since 1978. Figure 2 shows the basic scheme adopted for planning and implementing ALPEX and Figure 3 the fied of operation.

The idea of carefully studying the flow of air masses over and around mountains was conceived, however, in Venice, Italy, in 1971-1972 at a CNR Summar School directed by the late Prof. Jules Charney. It was evident at the time that to predict storm surges in Venice the wind field forcing and character over the Mediterranean was needed with more than six hours' forecast, and that to provide this information numerical models had to include the effects of orography of the surrounding lands.

Oceanographers, solicited since 1972, moved only in 1980 and thanks to the initiative of IOC, a MEDALPEX Experiment design was published in the GARP-ALPEX series as an oceanographic contribution to ALPEX.

The plan on the whole has served as a triggering mechanism to stimulate a renewed interest of oceanographers in the study of the western Mediterranean and the Adriatic seas, which so far have been considered convenient model areas for the observation and understanding of a variety of mesoscale phenomena occurring in the world ocean but which occur here on a reduced, easier to observe, scale. ALPEX was a new opportunity to start a long wished co-operation between meteorologists and oceanographers, in particular in view of the importance of air-sea interaction studies for the global and regional experiments of the World Climate Research Programme.

2. ALPEX-SOP

About one hundred people participated in the SOP of ALPEX (March-April 1982) including meteorologists, atmospheric scientists, aircraft crews and technicians operating from the airport of Geneva. The Operation Centre, headed by Dr. J. Kuettner, was installed next to the airport with the necessary communications and computer facilities to produced and display the real time information and the up-to-6 days' forecasts needed for the daily plans, and to co-ordinate the field activity of the several research aircrafts and gliders displaced around the Alpine region, of the several ad hoc and conventional networks of meteorological stations and of the research vessels and ships of opportunity operating in the Mediterranean Sea.

The Workshop on the ALPEX results, held in Venice from 4 to 6 November 1985, has collected the significant material for a report by WMO on the results of ALPEX to be issued in early 1986. From this material, several topics and described atmospheric events are of great interest to oceanographers.

The weather events encountered during the SOP of ALPEX can be splitted into 3 periods: the first one was characterized by strong westerly-northwesterly flow with cyclonic disturbances, the second one was more quiescent and the last one was characterized by northerly flow connected with Atlantic blocking. Repeated cyclogenesis occurred in the first and third periods. The sequence of events is shown in Figure 1 which demonstrates how the weather was highly favourable for the ALPEX scientific objectives. Ten cyclones, several of which were orographically induced, about 17 days of Bora and at least 20 Mistral days were encountered, many of which, even if occurring in "clusters" (frontal passages, lee cyclones, Mistral, Bora), were thoroughly probed.

A great deal of research is still needed after the Venice meeting to exploit the large mass of ALPEX data for their use in a variety of scientific and practical fields and above all as input in the mathematical models in continuous evolution.

3. ALPEX DATA

The ALPEX data sets available as on November 1985 are shown in Appendix 1 (extracted from the WMO report). Four major gaps still exist in the processing of data:

- MEDALPEX data archive is not yet completed.
- Radar data are not available in a uniform format.
- Quite a number of satellite products are still missing.

These products should be processed to a final stage to make them easily available to the users. A general recommendation was made at the ALPEX Workshop to produce a "user-oriented" (rather than a producer oriented) master catalogue of data sets. Errors in data sets should also be listed altogether and procedures to upgrading the data established. However, despite unavoidable shortcomings, the ALPEX data sets are unique. Never before was data of comparable quality and in comparable quantity produced for such an experiment.

Most unique is the archive of the 3 hourly visible, IR and water vapour satellite images available throughout the SOP, except for the period 19-23 March 1982. ESA is considering printing an "ALPEX Image Set" of the European region from March 1 to May 5, 1982, from the sets of data still now in a digital form. This is a costly operation which could not be afforded by research institutes.

Correction of Level II-b data produced by IADC is under consideration by the US ALPEX Panel, particularly with regard to the intercomparison between different station data obtained from different sensors.

Dropsonde data over the Mediterranean during surveys of the cyclogenesis or Bora developments will be of great value to the Mediterranean air-sea interaction studies as well as surface wind and precipitation over the sea. These forcing factors on the thermodynamics of the Mediterranean have never been available before. This will contribute to a significant progress in creating or tuning a large variety of analytical and numerical oceanographic and climatological models.

4. ALPEX PRELIMINARY FINDINGS

Preliminary general findings of ALPEX which are of interest to oceanographers may be summarized as follows:

Latent heat release, unimportant during the early stages of lee cyclone developments, plays a substantial role during the mature stage of the system but more so at upper levels, where condensation is more likely to take place. Heat and moisture fluxes from the northwestern Mediterranean are significant for the evolution of the cyclogenesis of the Ligurian Sea as well as of the transient Atlantic cyclones, but substantial air-water temperature differences are needed to generate disastrous precipitations over the land (from Italy to the Balkans).

Very intense observation of Mistral cases were made on 4-5 and 20-22 March and 23-24 April 1982. The study of numerical models of these cases shows that the flux follows different mechanisms above the sea and in the Rhone valley. In the latter case, the structure of the flow results both from the katabatic component and from large scale waves, induced by the airflow over the mountains. From these meteorological findings it appears possible to improve the forecasting of Mistral and its evolution over the sea which has such an impact on dynamics of the western Mediterranean Sea and on the large scale diffusion of pollution. A typical aircraft survey of a cyclogenesis is shown in Figure 4 and a visual display of a Mistral field in Figure 5.

ALPEX gave a unique set of information on Bora, which allows a better understanding of the generation and evolution of the phenomenon. It appears that Bora accelerates not only when falling to the sea but also upstream of the mountain crest. Its generation occurs with combined cold air from the northeast and a sufficiently low pressure in the Adriatic Sea. Figure 6 shows a simplified scheme of Bora structure.

5. MEDALPEX-SOP

Despite a late start, and many difficulties in mobilizing the required support, MEDALPEX had important aspects of success and provided some unique sets of measurements.

About 10 oceanographic ships, involved in national experiments of physical and biological oceanography contributed to the MEDALPEX-SOP the best way they could. The large oceanographic ships of the USSR devoted most of their time to measurements for MEDALPEX, making hydrological stations even during stormy conditions, along with the recommendations of the MEDALPEX operation plan. The USSR scientists must be credited with their ability to make measurements from a ship, which, in the past, were only made from the "Bouée Océanographique de Recherches Habitée (BORHA)" of France, moored offshore, south of Toulon. It was unfortunate, in fact, that this precious manned buoy could not be operating during MEDALPEX, because of a prohibitive cost of operation.

For the first time, a successful series of BT drops with surface meteorology measurements every 10 miles were routinely made during the SOP from two ferry boats, during crossings from Italy to Corsica. The Italians contributed with the equipment and IOC supported two scientists from Turkey for the observations.

Unique were also: the long time series of measurements from about 20 oceanographic buoys moored or drifting in different locations of the Liguro-Provencal area; the series of digitized tidal data from about 40 stations; the series of upper air soundings forwarded by the USSR ships to GTS at synoptic times; and the intensified marine meteorological measurements from commercial ships transiting in the Mediterranean.

Appendix 2 gives the schedule and areas of ship and buoy operations during the SOP (March and April 1982).

6. MEDALPEX DATA

The MEDALPEX data sets stored in data banks are divided in time series extending to the major part of the AOP, such as tides, buoy and ship-of-opportunity data, and in episodic meteo-oceanographic data sets collected by oceanographic ships during the SOP. The PSMSL (Permanent Service for Mean Sea Level, in Bidston) succeeded in assemblying digitized tide data on magnetic tapes from 40 stations of different countries bordering the western Mediterranean and Adriatic Seas. Rickards analyzed the data series.

The Deutscher Wetterdienst Seewetteramt in Hamburg succeeded in intensifying, to a certain extent, the ship-of-opportunity reports on surface meteorological data and the IADC (International ALPEX Data Centre, at the ECMRWF in Reading) stored 3 hourly synoptic data sets and maps. The synoptic time was taken plus or minus 1.5 hours.

About 20 buoys were moored or released to drift over periods ranging from few hours or days (the USSR ones) to few months (the French, Italian and Belgian ones) mostly in the Ligurian Sea and in the Mistral area (USSR). The resulting current measurements from surface (Lagrangian and Eulerian) to 1,000 metres' depth, depending on the location, were analyzed by each institute that deployed the buoys. The data have not yet been forwarded to the RNODC (Responsible National Oceanographic Data Centre) of the USSR to be archived and distributed but have been used for national reports. These buoys were in fact funded for national research programmes.

Data from 2,000 hydrographic stations, 500 XBTs and sea surface meteo-observations transmitted to GTS are available at the RNODC in GF-3 on magnetic tapes or in tabulated form. The apparent lack of co-ordination and the missing intercalibration exercises are due to the fact that MEDALPEX was not a centralized oceanographic experiment (like the previous MEDOCs), but an aggregation of national on-going programmes partially suited to contribute to MEDALPEX. The RNODC has made however all efforts to gather the most reliable data to make up a data set as coherent as possible.

In conclusion, the marine meteorology data are now in the ALPEX data set at the US International Data Center and at the ECMRWF in Reading. The tide gauge data and their analysis have been published in the IOS (Institute of Oceanographic Sciences of UK) Report No.209. The hydrographic casts are stored at the RNODC, USSR; the current data have not been forwarded yet to the RNODC but can be found through Millot and Manzella.

7. MEDALPEX MAJOR FINDINGS

The set of oceanographic observations made during MEDALPEX AOP and SOP periods and later measurements gave the opportunity to check with greater precision several mesoscale synoptic phenomena and provided new data for the development of models of general circulation, coastal dynamics and processes induced by meteorological forcings such as convection, surface fluxes and current patterns which will be described separately for the Ligurian and the Adriatic Seas.

In general, the ALPEX-MEDALPEX SOP tooks place during the transition between the winter cooling (March 1982) and the spring warming (April 1982) as the USSR measurements demonstrated.

The major findings of MEDALPEX were presented and discussed together with other present on-going fied programmes at the IOC Workshop on the Scientific Results of MEDALPEX and Future Oceanographic Programmes in the Western Mediterranean at CNR Institute, in Venice, from 23 to 25 October 1985.

7.1 THE LIGURO-PROVENCAL SEA CONVECTION

This phenomenon, well known to take place in the Artic and Antarctic through an increase in salinity, hence in density, during the respective winter freezings, occurs in the Liguro-Provencal Sea each winter with diverse extensions and durations because of yearly climatic variability. After a precondition of winter cooling and homogeneity, cold dry winds, such as Mistral or Tramontana, can trigger the mechanism of convergence and deep water formation.

Evaporation rates during March 1982 have unusually increased the salt content of the Liguro-Provencal Sea, according to Bethoux.

The USSR oceanographers also reported that the average value of the March 1982 air temperature was about 11.5°C compared to a statistical value of 12.6°C. They reported that the average temperature in the Ligurian Sea in March changed from 11°C to 12°C and that eight short term Mistral cases, lasting no more than 12 hours each, generated sea surface cooling discretely and randomly distributed, giving place to dense surface water spots and consequently to a sinking of water in chimney structures (Figure 7) rather than in large zones of convergence as reported in the MEDOC 1970 experiment.

It is possible that a number of chimney-like convections with typical diameters of 5 to 7 miles and of short duration may have occurred. Because of their size and duration, they are difficult to be detected by oceanographic ships even during dense hydrographic surveys. Similar features have been reported by the Spanish oceanographers to occur during MEDALPEX in the Catalan Sea, and by Frassetto during MEDOC 1969 in the Ligurian Sea. One can presume that these chimney-like convections occur with random distribution every year from February to April, after the necessary precondition of instability of the surface layers (500 metres or more) has taken place.

Figure 5, a satellite image of the Gulf of Lion and the Catalan Sea, shows the roughness of the sea created by orographically induced winds over a sun glitter area, using the visible part of the spectrum. More advanced thermal images of the sea by means of IR or microwave sensors of future satellites may contribute to verify the theory of the chimney-like convection process, as well as the time-space distribution and size of such convergences.

7.2 THE LIGURO-PROVENCAL SEA FLUXES

The classical equation used for the calculation of heat loss or gain by the sea is:

$$Q_s(1-A) + Q_a = Q_n + Q_c + Q_e$$

where s = sun heating, a = marine advection, n = IR back radiation, c = convection and e = evaporation.

According to Bethoux, the heat loss during March 1982 was about 44 $kJ.cm^{-2}$, Q_e being 20 $kJ.cm^{-2}$. About 62% of the evaporation from the western Mediterranean is claimed to be transported by the atmosphere and about 23% return to the sea in form of rain. The atmosphere heat gain during March would have been 31 $kJ.cm^{-2}$:

$$G = Q_n + Q_c + 0.38\ Q_e = 31\ kJ.cm^{-2}$$

Vakelyak, Gudz and Popov reported that the heat loss by the sea during March in the Ligurian Sea was 27 $kJ.cm^{-2}$ and the average heat gain of the sea during April was 35 $kJ.cm^{-2}$.

Bethoux calculated the average monthly heat loss by the Ligurian Sea also with the Lagrangian budget, by measuring the heat loss of a mass of water 100 m thick transported by the cyclonic current from the west side of Corsica to the Nice coastline in about 20 days (Figure 8). In March 1982 the decrease in temperature would have been 0.4°C and the average heat loss for the month 42 $kJ.cm^{-2}$.

7.3 THE LIGURO-PROVENCAL CURRENT REGIME

The general cyclonic circulation of the Ligurian Sea, in which the eastern and western currents of Corsica merge, is strictly connected to synoptic mesoscale variability. The two Corsican currents (east and west) have different structures which lead to different kinds of unstable phenomena in their flow towards the Ligurian gyre. The interrelationship between instabilities, meanders and eddies is subject to seasonal variability.

During the French oceanographic programme DYOME (Dynamique océanique à moyenne échelle), part of which was simultaneous to the ALPEX-SOP, the several current measurements made from moored buoys in strategical positions (large black points in Figure 8) and few drifting buoys released northwest of Corsica, in addition to a series of hydrographic stations (small points in Figure 8) and to the Italian current measurements from 4 moored buoys in the eastern and north-eastern side of Corsica (ODAS, V, C, E, Figure 9), provided a unique set of synoptic data from surface to near bottom which have been analyzed by Millot, Prieur, Bethoux and Manzella.

The Corsican mesoscale activity is restricted to the surface layers and is clearly baroclinic through the year. The eddies and plumes, associated with the western Corsican current as shown in several IR thermal images from satellites, have a limited vertical extent and dissipate in a relatively short time (few days).

The Ligurian current which nearly doubles the speed of the two Corsican currents that merge into it, is suspected to play an important role in the precondition of convection processes as suggested by the occurrence of meanders. The homogeneization of the water masses is the most active at the outer edge of the Ligurian current (dark line in Figure 8). From this front the mesoscale activitiy extends to the weakly stratified slow moving, dome-shaped, central part of the Ligurian Sea, generating barotropic currents which reach 20 cm/s from 100 to 1,000 m depth around December-January, and creating the necessary conditions for deep water formation.

Other observations made after MEDALPEX by Prieur and Bethoux concern the interannual variability and interrelationship of heat content, salt content and precipitation. How these variabilities are associated with atmospheric forcings remains to be verified, perhaps through a co-operative work by oceanographers and meteorologists in future programmes. Bethoux demonstrated however that the interannual precipitation variability affects directly the Ligurian current in a quantitative way.

7.4 THE ADRIATIC SEA MESOSCALE PROCESSES

The shallow north Adriatic Sea with its geometry, its flat bottom gently sloping from north (30 m) to south (100 m), the dynamics of several river estuaries, among which the Po River exerts a significant hydraulic forcing, the wind forcings from Sirocco and Bora, is an excellent field for many oceanographic studies. A variety of mesoscale processes occur through the

year and in winter the cooling and homogeneization of the overall water mass creates the dense deep water that flows gradually all the way down to the deep (4,000 m) Ionian Sea. This part of the Mediterranean Sea plays this way a significant role in the budget of the rest of the Mediterranean Sea.

From the ALPEX-MEDALPEX measurements of wind and currents, it appears that the circulation of the northern Adriatic Sea under the stress of Bora splits in cyclonic gyre north to the Po River and in an anticyclonic gyre south of it, as shown in Figure 10. Satellite images show this pattern by means of temperature and turbidity and models are in progress to simulate the process to which tides may also contribute.

A constant southward current along the Italian coast exhibits meanders and plumes in satellite images. Its mesoscale variability needs more investigation particularly in correlation with winds and tide flows.

Sirocco and Bora are both, in different ways, responsible for sea level variations along the north Adriatic coast, as well as of rapid wave build up, all of which have been for several years the subject of intense studies to obtain effective forecasts for the Venice and Trieste storm surges.

Several investigators from Italy (Bergamasci - Rizzoli and Cavaleri - Michelato - Mosetti), from Yugoslavia (Kuzmic - Orlic) and Belgium (Nihoul) are developing different kinds of circulation models as new inputs become available from sparse measurements in situ or from visible and IR data from satellites. Wave models are under continuous development by Cavaleri, and pollution diffusion models by Nihoul for JRC, Ispra, and by Bergamasci - Rizzoli (Figure 11). High frequency mesoscale phenomena and their residuals on the general circulation of the northern Adriatic Sea are just emerging.

An interesting description of the possible occurrence of convection in the southern and deep (1,200 m) part of the Adriatic Sea, separated from the deep Ionian Sea by a sill (800 m), has been given by USSR scientists, comparing data collected in winter 1977 (February and April) with those collected in late March 1982 during the ALPEX-SOP. On this series of hydrographic casts, a clear convection to mid depths is indicated (Figure 12).

8. CONCLUSIONS AND RECOMMENDATIONS

Conclusions may be drawn on the major topics concerning the Mediterranean which MEDALPEX helped to reappraise.

(i) Tides

The newest result of MEDALPEX is the analysis of data from 26 tide gauges of a network reactivated for MEDALPEX (Figure 13). The IOS prepared the study (Report No.209, 1985) from which sea level events were identified in correspondence with meteorological perturbations (storms) for the first time in the western Mediterranean.

Rickards reports that in the western Mediterranean the astronomical and meteorological components of the tide are independent from those of the Adriatic Sea. Similar studies had been made since 1970 for the Adriatic Sea by the ISDGM of CNR, Italy, for the forecasts of floods generated in Venice by storm surges.

Dynamical studies are now possible using these time series of data provided the network is properly activated and calibrated and the data are digitally recorded on magnetic tapes. The PSMSL could probably continue working out a special archive for the entire Mediterranean Sea selecting the key stations in agreement with modellers.

(ii) Convection

The complex structure of deep convection in which different water masses intermingle has been identified. The preconditioning mechanisms, however, need further verification through quantitative evaluation of fluxes and space/time distribution of convection chimneys of different sizes. The dependence of atmospheric forcing should be better demonstrated. A parametrization of air-sea interactive processes is needed for modelling.

(iii) Circulation

The kinematics of the vigorous mesoscale cyclonic circulation of the Ligurian Sea, with its seasonal structure and variability, can now be better studied and simulated in models, as the general mechanism is identified. New research programmes are proposed, including the French MEDmodel, and underway at the oceanographic laboratories of Villefranche and La Spezia.

(iv) Wind forcing

The space-time distribution and effects of transient winds, as the major thermodynamic forcing of winter convections and their accurate forecast for marine meteorology applications should be better studied. The satellites to be in operation in the early nineties (NROSS, TOPEX, ERS 1) will be able to provide wind and wave data at low cost. In particular, scatterometers will provide the wind stress field on a Mediterranean grid of 50 x 50 km or less.

The preparation of models for using these data for scientific and practical applications is the subject of on-going research programmes supported by ESA and EARSEL (European Association of Remote Sensing Laboratories) members.

(v) Air-sea interactions

Energy fluxes are the least studied ones so far. The MEDALPEX objective was to stimulate the study of momentum, heat and vapour fluxes and the feedback to the atmosphere. The various air-sea interaction processes occurring in the Liguro-Provencal basin and in the Adriatic Sea are only identified. Similar processes in the eastern Mediterranean will be the subject of research during the POEM experiment. It is time to start considering coupled atmosphere-ocean models both in the east and west Mediterranean with particular relation to climatic variability.

A more detailed meteorology is required for these purposes. Boundary layer studies in the Mediterranean Sea are totally neglected. Combined efforts of meteorologists and oceanographers are highly desirable. One possible study group could be found at the Institute of Physics of the University of Bologna, Italy, and at the IMGA-CNR, Via Campi 213, Modena, Italy. Account should also be taken of the international Centre for Meteorological Studies of the Western Mediterranean (CEMMO), which is being established at the Balearic Area Meteorological Centre in Palma (Majorca), Spain.

(vi) Hydraulic forcing

The hydraulic forcings from the Straits of Gibraltar and the Channel of Sicily are one of the major subjects of research of the on-going WMCE. Important results may be available. The Po River forcing, combined with Bora stress in the Adriatic Sea, has been identified and needs refining in the various models under study. Tides, winds, optical and IR stallite images should be used as model inputs or for verification.

Recommendations

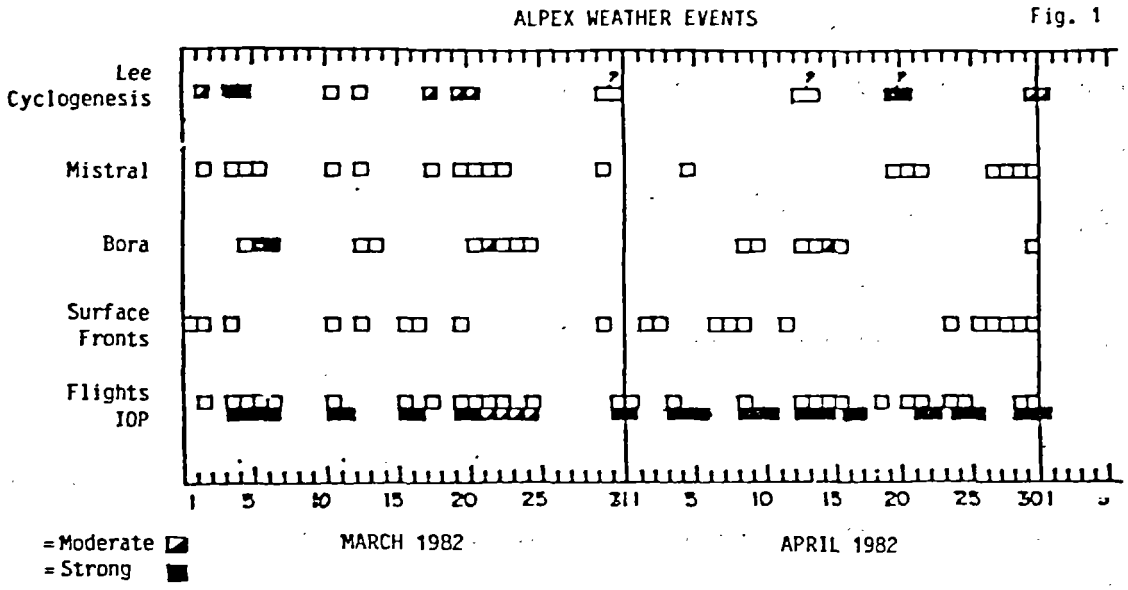
(a) A study should be undertaken on the role of the Mediterranean mesoscale processes and thermodynamics in a better understanding of the world ocean climate processes, perhaps through a SCOR Working Group. Such a study would contribute to the development of research programmes in the Mediterranean Sea, in particular to take the opportunity of the new satellites to be launched in the early nineties.

(b) Tide gauges in the entire Mediterranean Sea should be upgraded (digital recordings) and a consistent network of tide gauges, made up of the minimum indispensable number of strategical stations, be designed and implemented.

(c) The system of commercial ships making synoptic surface meteorological measurements should be re-organized. At present, the major defect of the system in the Mediterranean Sea lies with ship-to-GTS entry points communication links. Mediterranean countries should be urged to improve these links, and WMO to help finding solutions to the problem. The most effective results could probably be obtained in instrumenting the several ferry boats of the Mediterranean Sea with automatic satellite telemetering instruments.

(d) These surface data will allow for validation of the new set of synoptic data to be provided by ERS 1, NROSS, TOPEX and other satellites designed for marine observations mainly by means of all-weather microwave sensors. The question of satellite data and their relationship to in situ data is a critical one and should be dealt with by IOC and SCOR in close collaboration with satellite operators, especially ESA. In particular, in situ observing systems should be fully operational when the satellites are launched in the early nineties. The afore-mentioned SCOR Working Group might assist in a proper network designing to that effect.

List of Figures



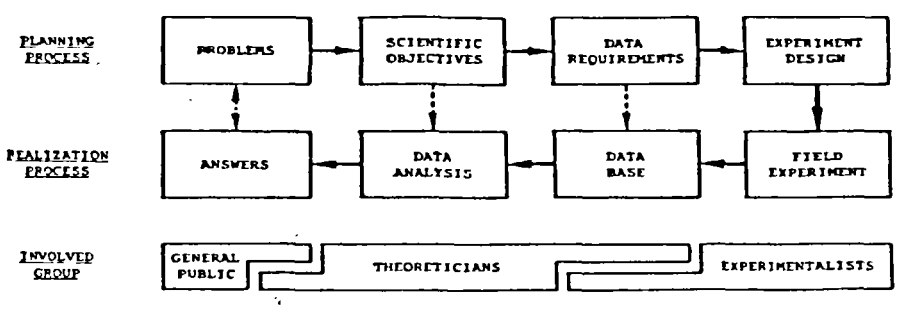


Fig. 2. Basic steps involved in the planning and realization of Alpex scientific experiment.

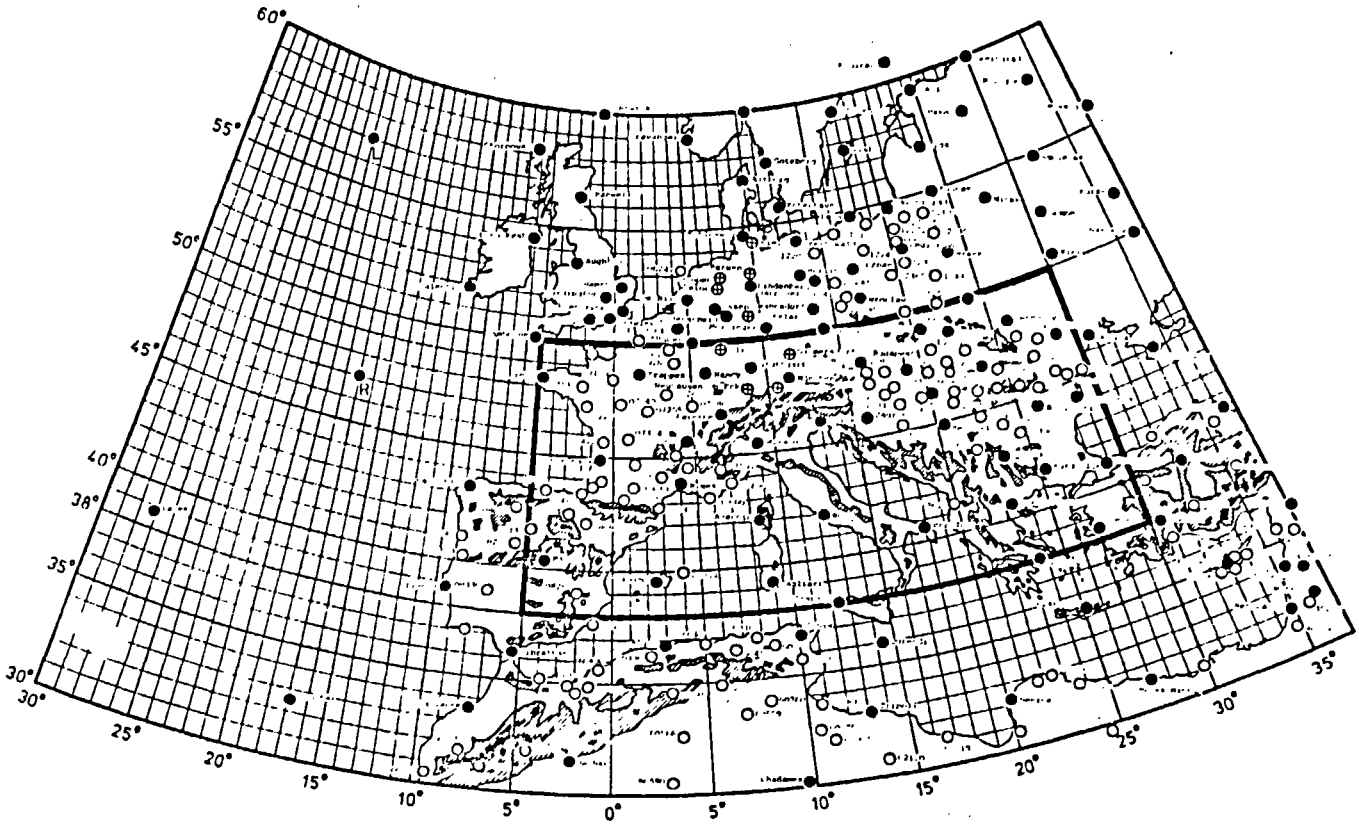


Figure 3. Outer and inner experiment area of ALPEX

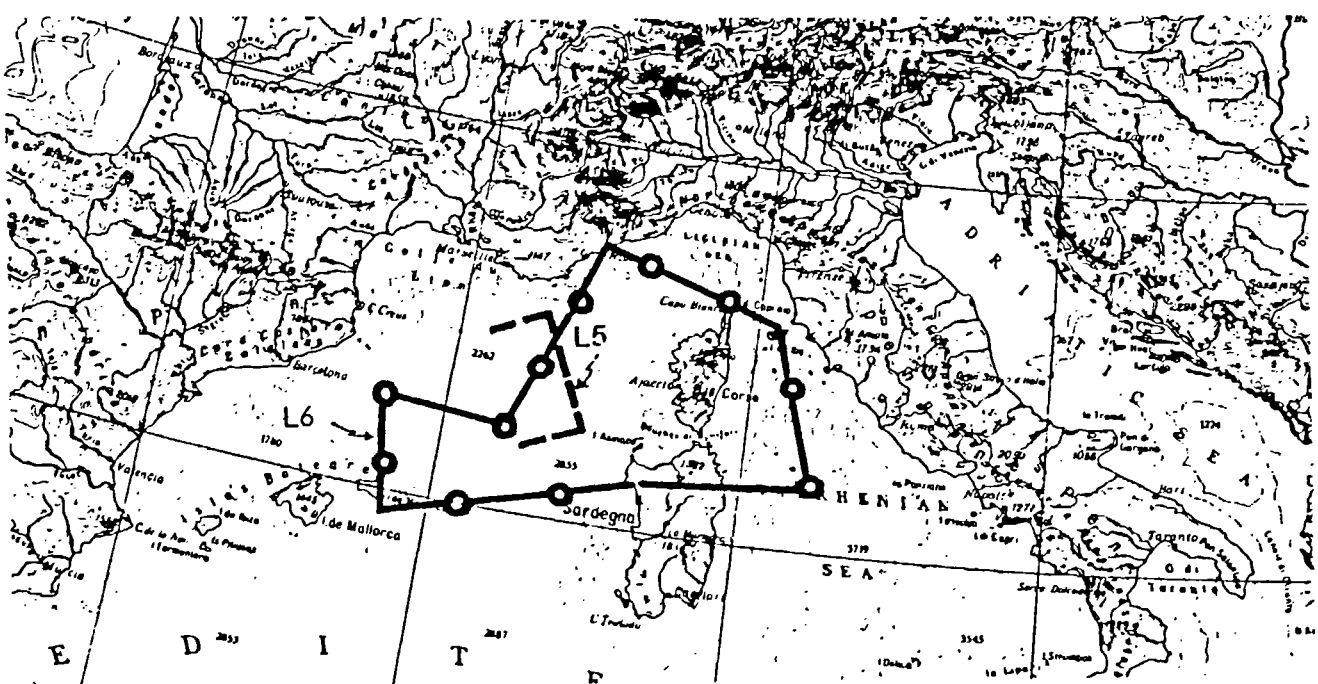


Figure 4 . - Mission Lima 5 and 6 (Day 3)
The low-level track (dashed) will measure turbulent fluxes near the sea surface. The high level track will survey the air flow over the Mediterranean Sea using dropwindsondes (circles). Turboprop aircraft.

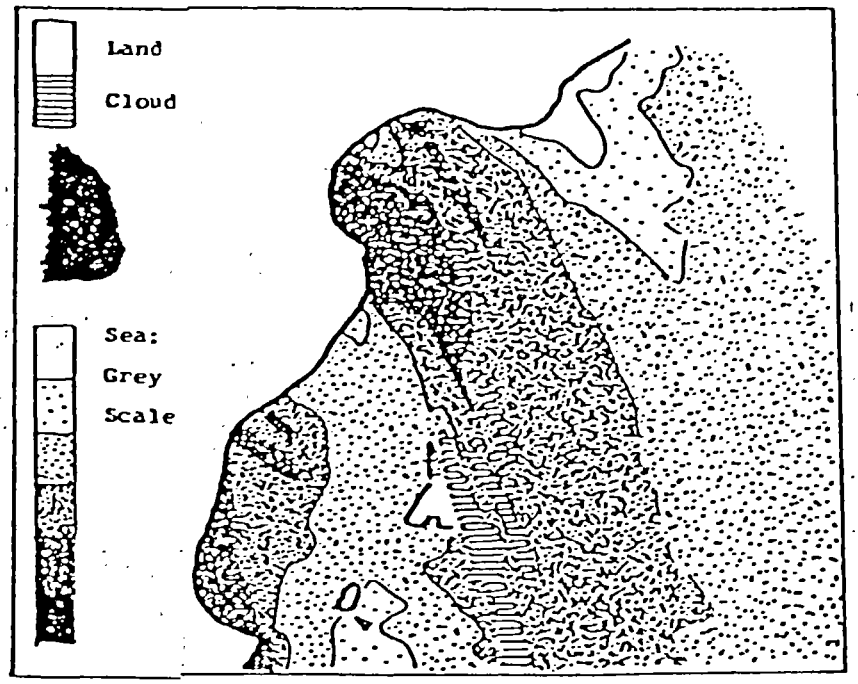


Fig. 5. The coverage of the mistral over the northwestern Mediterranean, reaching at times the coasts of Africa, is shown by the observed sun glitter visible image from NOAA satellite (A. Jansen, INM, Spain).

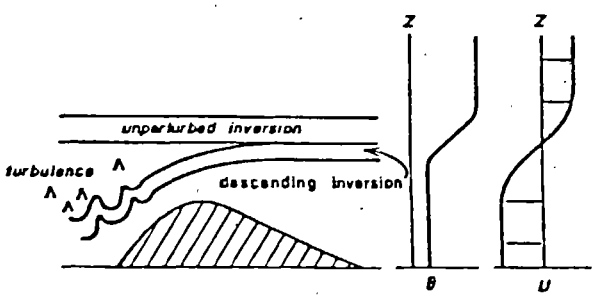


Fig. 6. A schematic illustration of bora structure with reversed winds aloft. The altitude of wind reversal determines the portion of the inversion which will descend. Strong reverse shear develops along the descending inversion and Kelvin-Helmholtz instability occurs. Mixed air fills in between the two inversions (from R.B. Smith, July 1985).

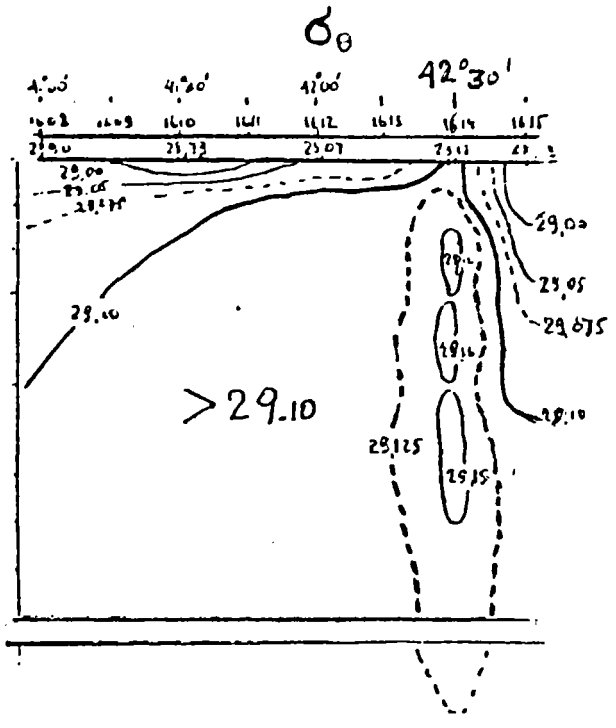


Fig. 7. Typical chimney shaped convergence with deep water formation. This 2-8 April 1982 case was recorded from the Wodjanickÿ, USSR ship south of Toulon in the mistral area.

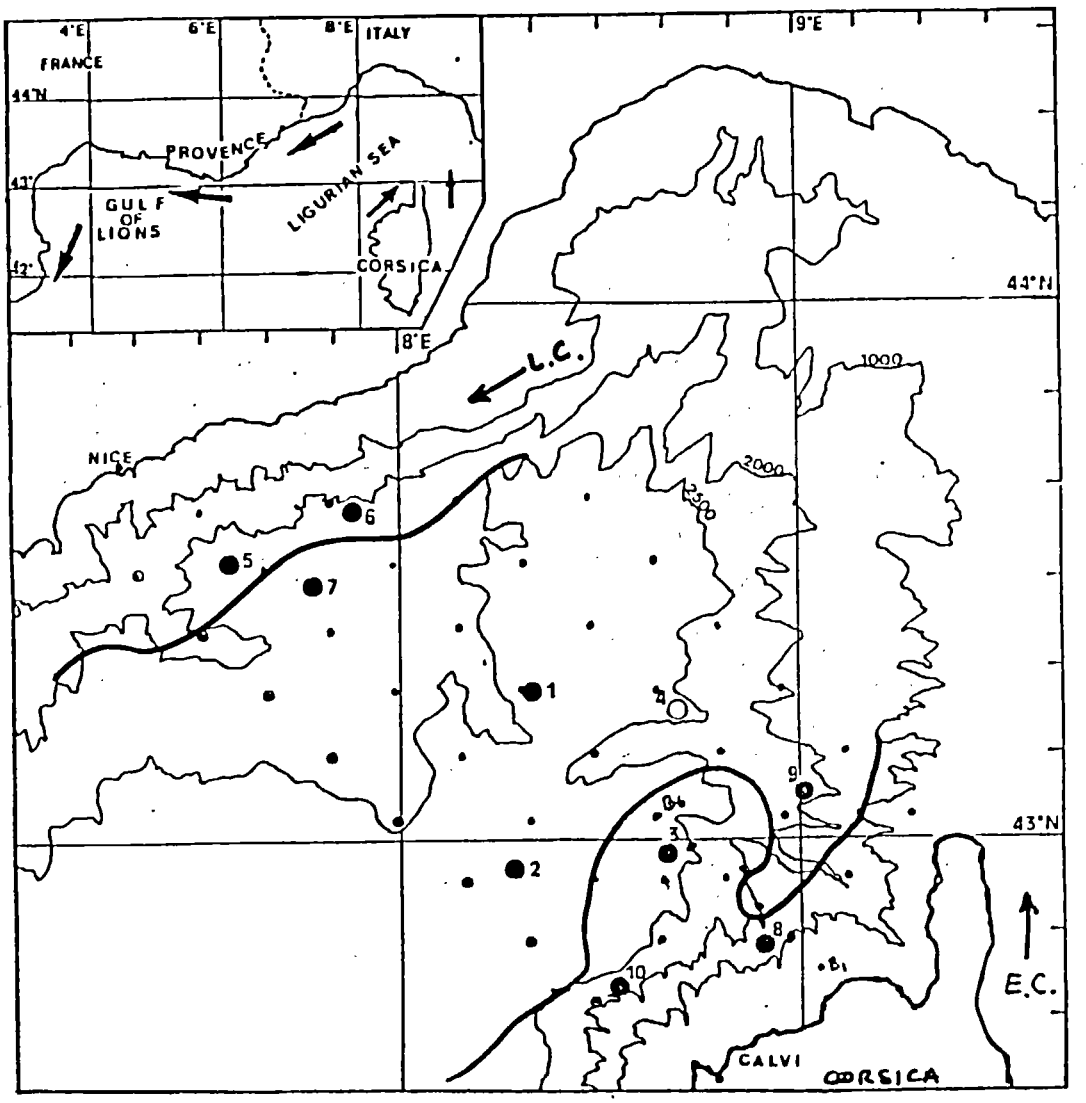


Fig. 8 The NE Corsican current, measured from the moored buoys (numbered points) is shallow and creates eddies. The Ligurian current (L.C.) in the north, is narrower deeper, has twice the velocity of the Corsican current and meanders (dark line) creating marked fronts.

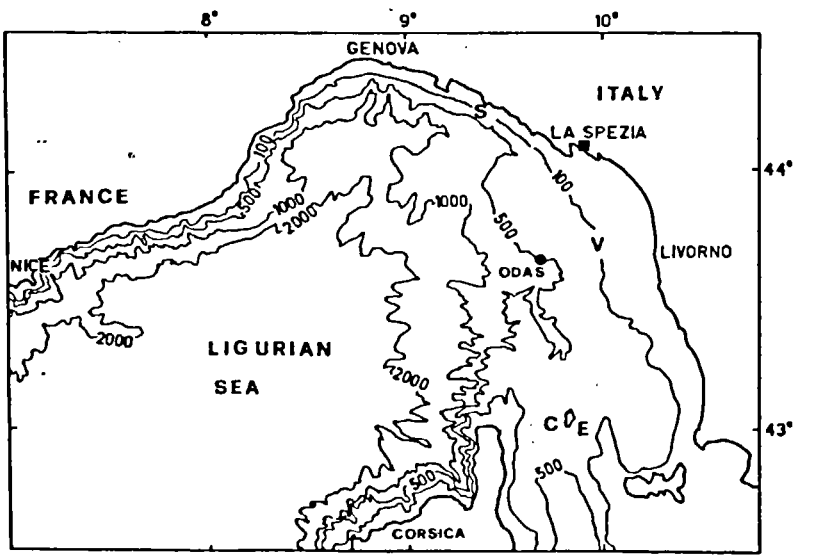


Fig. 9. The Ligurian Sea. The letters denote current moorings, the meteo-buoy Odas 1-1 and the tide gauge station are indicated. Depth in metres.

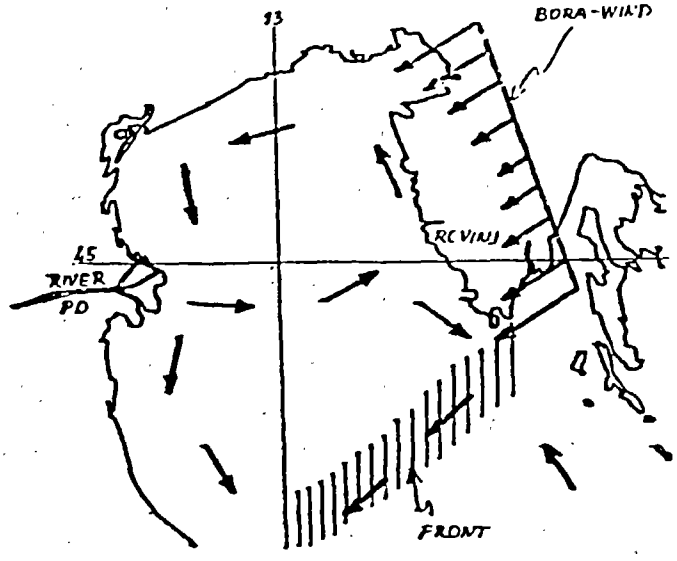


Fig. 10. Bora wind stress in combination with hydraulic forcings of the Po river runoff generates a split cyclonic and anticyclonic gyres in the northern Adriatic Sea.

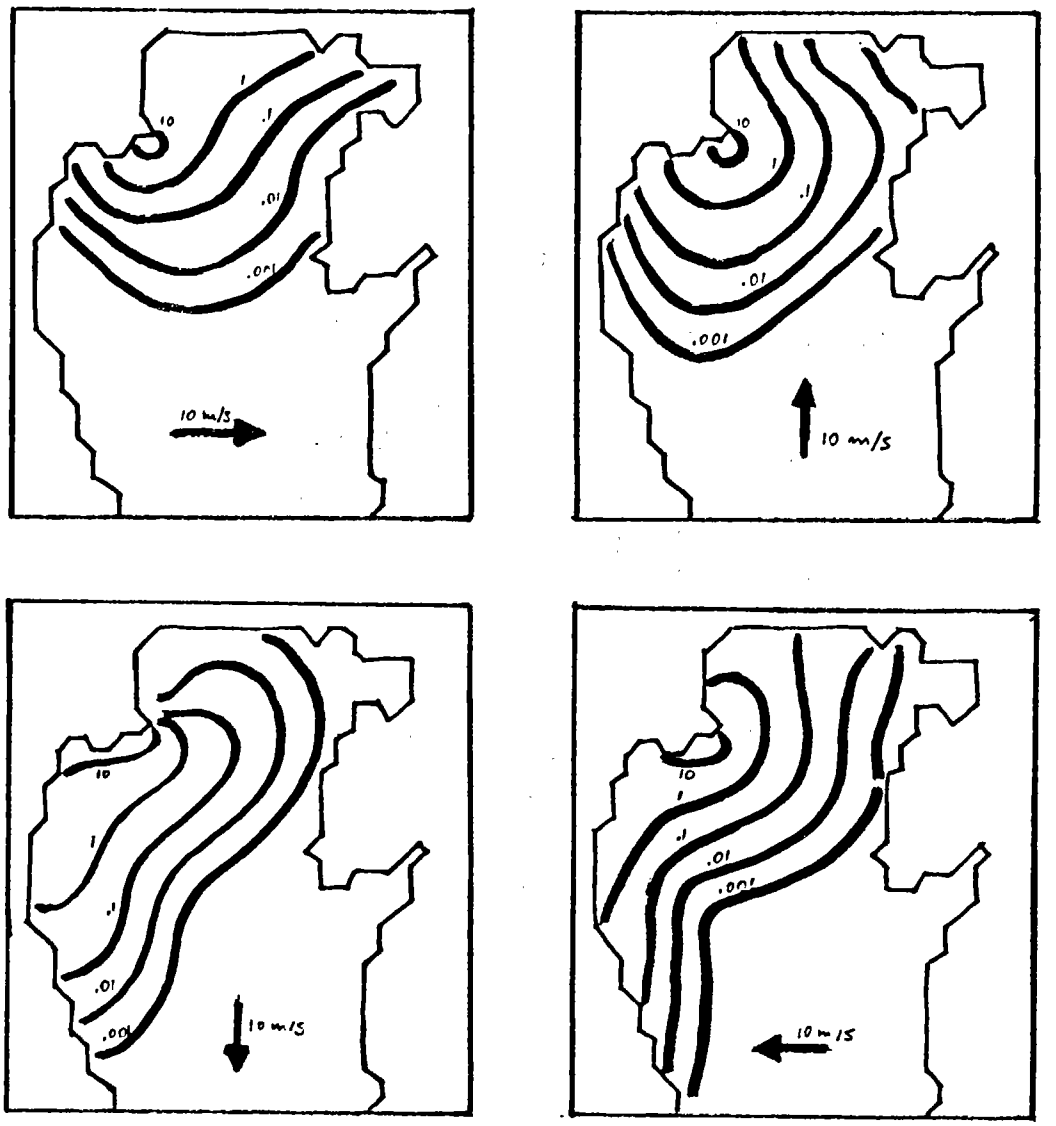


Fig. 11. Surface horizontal distribution of a dimensionless passive scalar substance in four different wind cases. Daily mean situations after 30 days of simulation with with the four principal winds. (Bergamasco and Rizzoli)

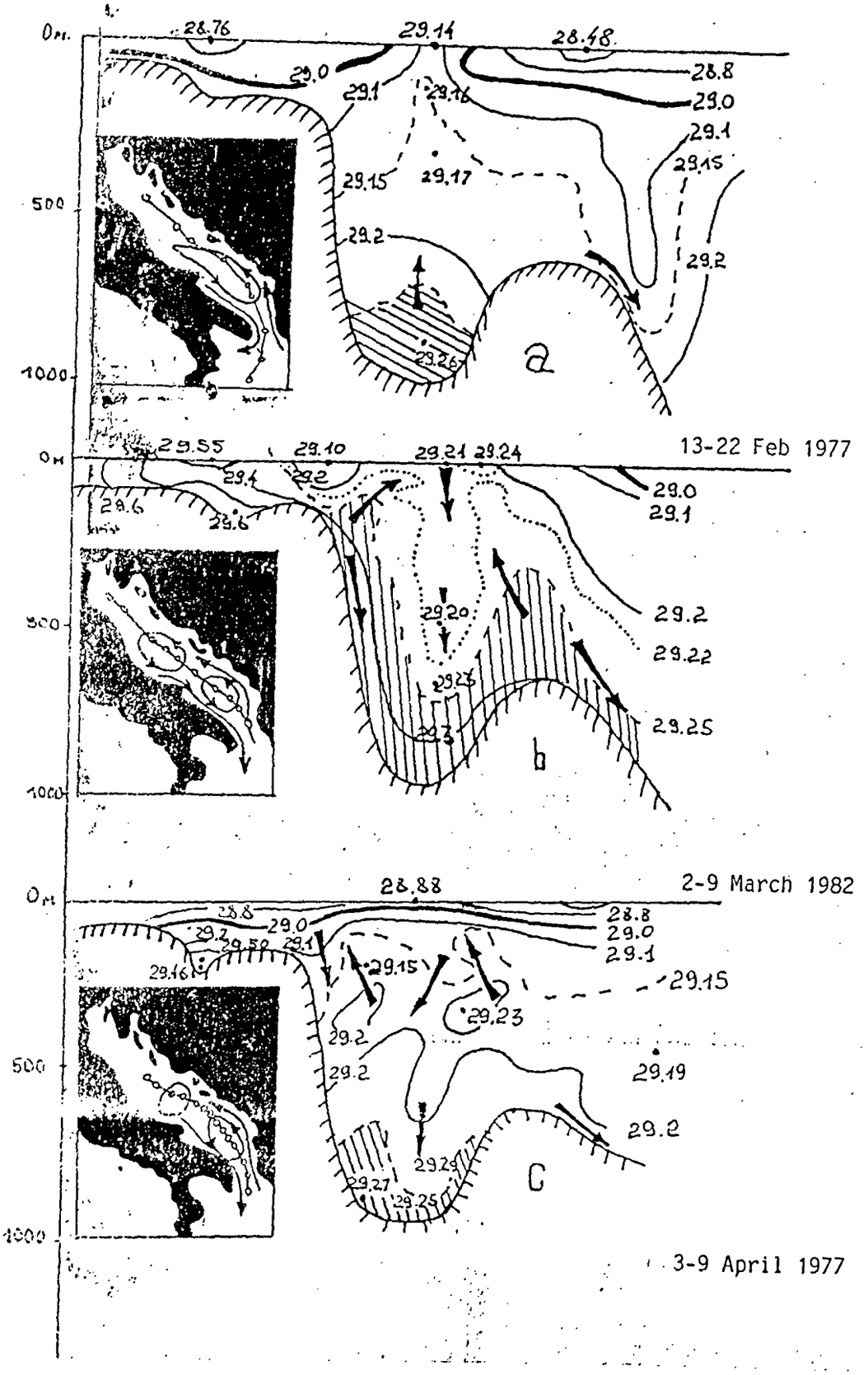


Fig. 12. The distribution of relative potential density (σ_e) on the section along the Adriatic Sea according to deep-water measurements: a - r/s "Akademik Petrovsky", February 13-22, 1977; b - r/s "Professor Vodyanitsky", March 2-9, 1982; c - r/s "Professor Bogorov, April 3-9, 1977.

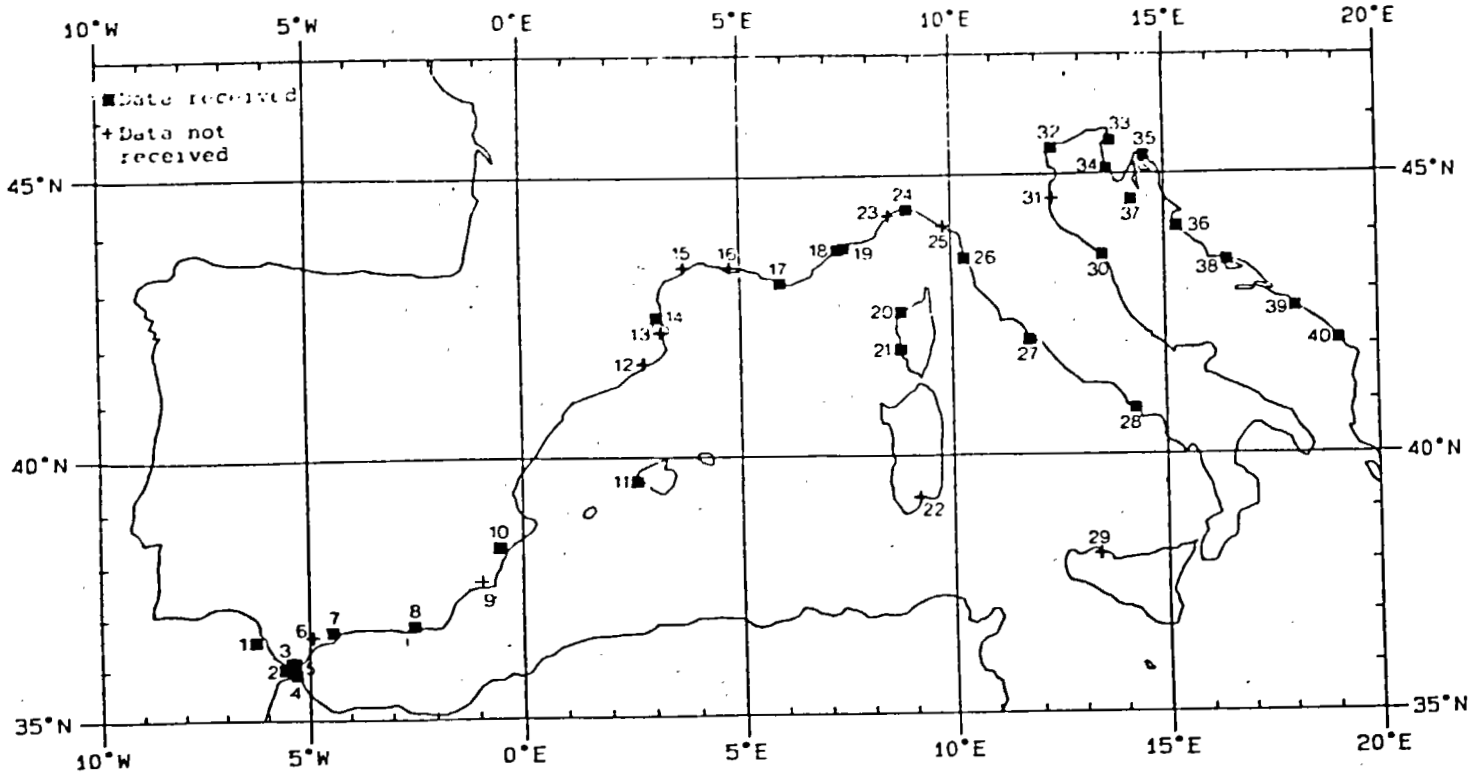


Fig. 13. MEDALPEX SEA LEVEL SITES.

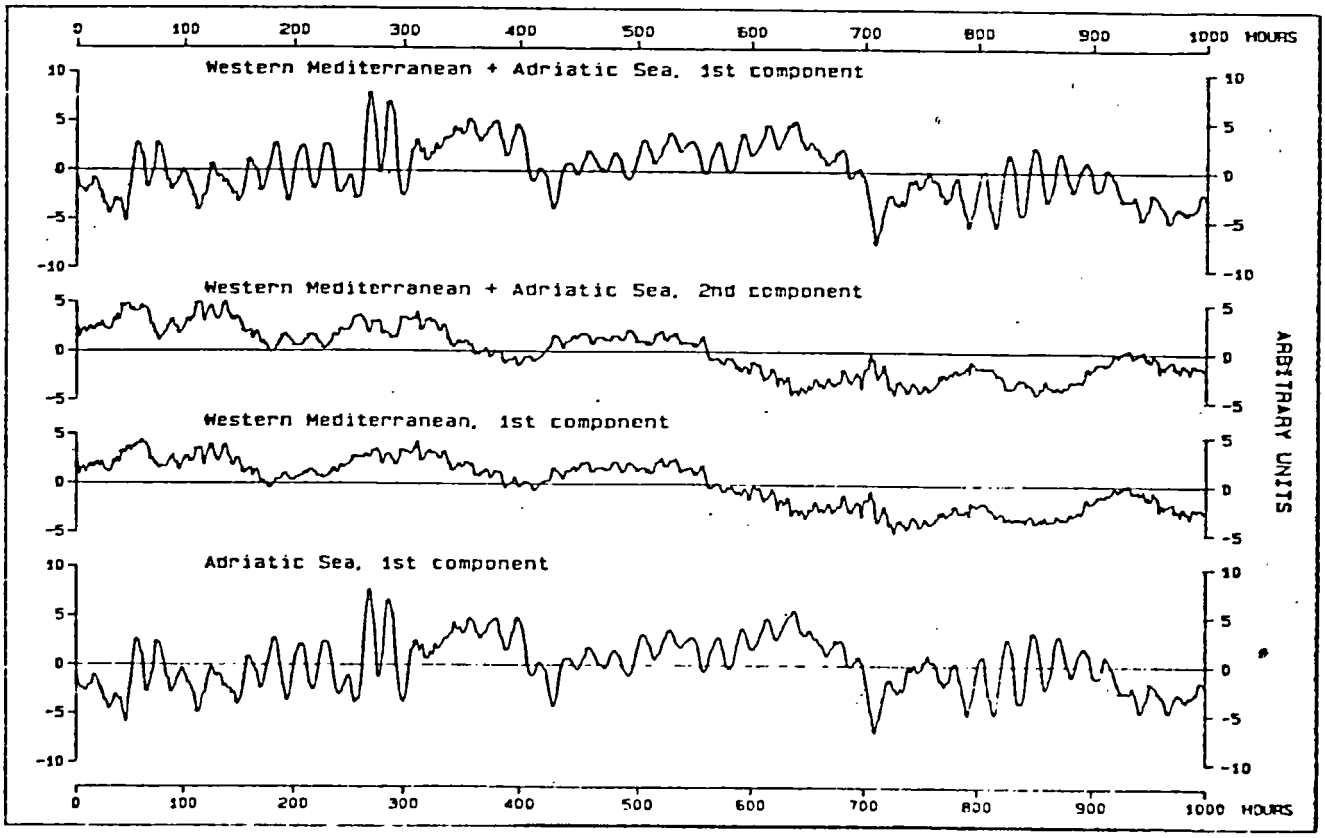


FIGURE 14. Principal Components Analysis

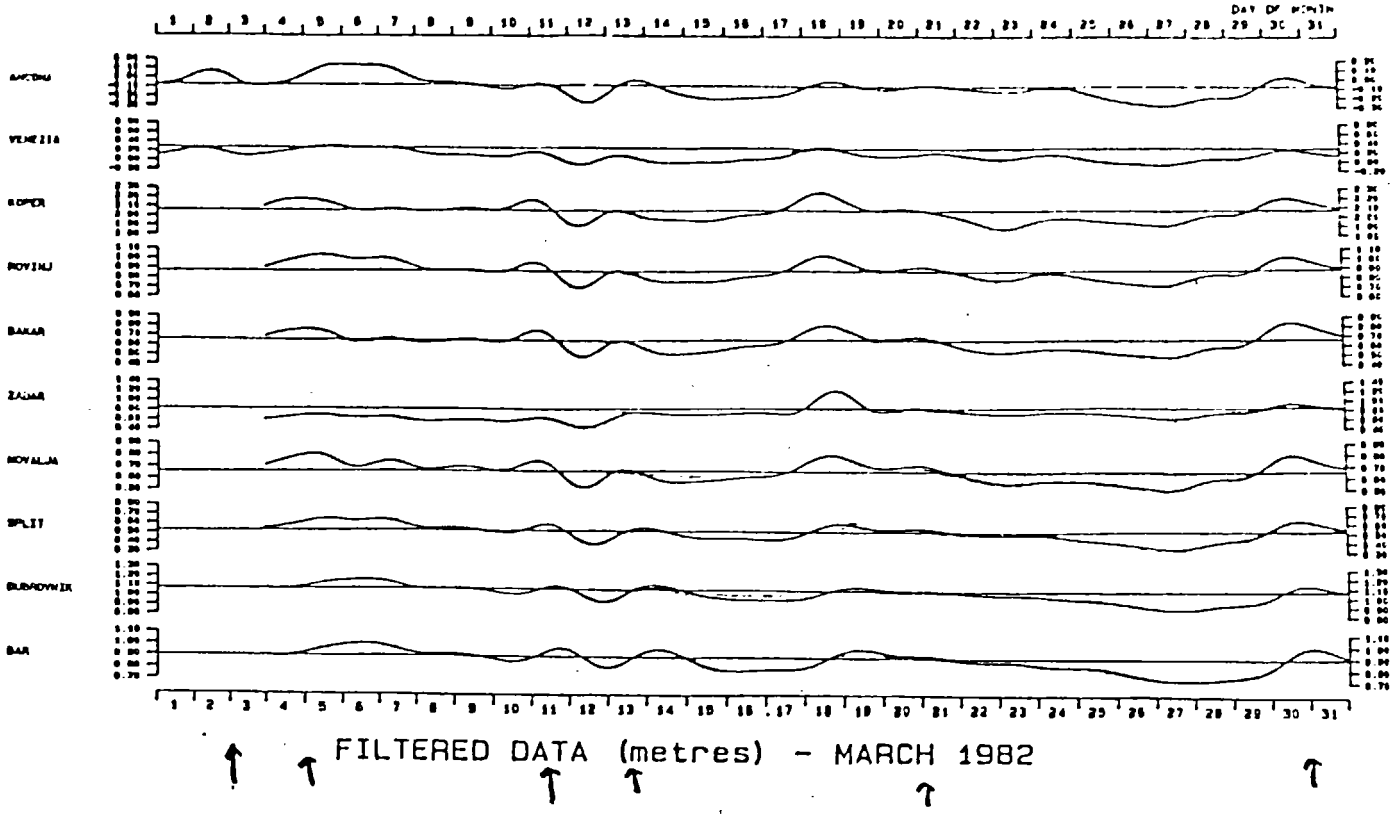


Fig. 15. The residuals from the original data of ten stations after the elimination of the astronomical tide component and after filtering represents the meteorological component. The sea level variance is shown at the passage of meteorological perturbations at all stations with some delay (arrows) (L.I. Richards, IOS, U.K.).

Appendix 1

List of Available ALPEX Data Sets

LIST OF AVAILABLE ALPEX DATA SEATS
(Identified by February 1986)

Data Sets	Contents Data types	Period	Area	Average Estimated Resolution AIEA*	 AOEA**	Format	Archived and Available at	Remarks
Level II-A data set (quick-look)	WWW Operational data	15.1.82-15.5.82	AOEA	WWW network	WWW network	FGGE Level II-A	WDCs	
Level III-A data set (quick-look)	Global Operational ECMWF analyses ;	15.1.82-15.5.82	Global	1.875°	1.875°	FGGE Level III-A	"	
	Global ECMWF topography;	-	Global	"	"	"	"	
	High resolution topography		AOEA	10 km	10 km	FGGE Level II-A	"	
Merged GTS-Type Level-II B data set	Delayed GTS-Type data							
	- Surface and upper-air data:							
	SYNOP, SHIP, TEMP, TEMP-SHIP	SOP	AOEA	50-250 km	WWW network	ALPEX Level II-b	"	
	AIREP, SATEM, SATOB	"	"	WWW network	"	"		
	- Merged Special Data							
	NAVAID upper air	"	N. Italy	150 km		"	"	Merged with TEMP data
	AIDS	"	AOEA	50 km	200 km	"	"	
	TIROS-N satellite clouds analysis and sea surface temperature	"	AIEA	"		"	"	
	Aircraft dropsonde	IOP	Local flights	100 km			"	
	Research aircraft	"	Flights	240 km		"	"	
	- Oceanographic data:							
	BATHY, TESAC	SOP	AOEA	WWW network	WWW network	"	"	very poor coverage

* AIEA - ALPEX inner experimental area
** AOEA - ALPEX outer experimental area

Data Sets	Contents Data types	Period	Area	Average Estimated Resolution AIEA*	 AOEA**	Format	Archived and Available at	Remarks
Non-GTS conventional data set	Precipitation: 3, 6, or 12 hourly, daily	SOP	AIEA	50 km	WWW network	ALPEX Level II-b	WDCs	
	Snow	"	"	"	"	"	"	
	Soil temperature	"	"	"	"	"	"	Poor coverage
Surface-based radiation data	Solar (diffuse and direct) and long-wave fluxes albedo	AOP	AIEA	150 km		FGGE Level II-c	WDCs	
Research aircraft	Electra, P3, Falcon Aircraft Data	IOPs + other days	Regional flights	High resolution (1 sec)		ALPEX Level II-b	WDCs	
Oceanographic data set	XBTs, STDs, currents data	AOP	AOEA	uneven	uneven	GF-3(IOC)	WDC-B	
	Sea level (gauge data)	AOP	West Med. Adriatic	26 stations		IOC standard	PSMSL (UK)	
High resolution AIDS data set	AIDS observations	AOP SOP	AOEA	1 sec	1 sec	ALPEX Level II-b	SADC (Switzerland) WDCs	
Microbarograph data set	Microbarograph observations	SOP	Local traverses	25 km			SADC (Switzerland)	
Small range research aircraft data sets	French aircraft	IOPs	South of French-Alps flights	1 sec		ALPEX Level II-b	SADC (France)	
	Aircraft motor gliders (Germany)	IOPs	South of Germany, Austria and Switzerland	0.1 sec		Special format	SADC (DFVLR)	
Special data sets	Acoustic sounder measurements	IOPs	One site (Martigny)			Graphical format	SADC (Switzerland)	
	Constant level balloon measurements	IOPs	Ruess Valley	5 sec		Special format	SADC (Switzerland)	
Satellite operational products	Tiros-N AVHRR (EAC), + VIS/IR measurements, SST, TEMP, radiation heat budget	AOP	AOEA	500 km		Photographs, microfilm, special format	NOAA/NESS	

Data Sets	Contents Data types	Period	Area	Average Estimated Resolution AIEA*	 AOEA**	Format	Archived and Available at	Remarks
METEOSAT DATA SETS	MIEC cloud motion vector winds	3-6.3.82	AIEA	- Low resolution -		SATOB CODE	ESOC	
	Digital MIEC products		"	"		"	"	
	SST	from 1.4.82						
	Cloud analysis	" 15.4.82						
	Upper tropospheric humidity	" 15.4.82						
	Digital HR image data	SOP	AIEA	lines 1950-2455 pixels 850-1449		Special	"	
	Photographic: 40x40 negatives IR (1.5 hrs) 4 VIS (1.5 hrs) 4 WV (3 hrs)	SOP				Photographic	ESOC	
	IR image loop	3-7.3.82	AIEA			Image Loop	ESOC	
Climatological Data Sets	Surface and upper-air observations	AOP	Austria	National Network		National	NADC (Austria)	
	"	"	Belgium	"		"	" (Belgium)	
	"	"	France	"		"	" (France)	
	"	"	F.R.G.	"		"	" (F.R.G.)	
	"	"	Italy	"		"	" (Italy)	
	"	"	Poland	"		"	" (Poland)	
	"	SOP	Spain	"		"	" (Spain)	
	"	AOP	Switzerland	"		"	" (Switzerland)	
	"	"	Yugoslavia	"		"	" (Yugoslavia)	

Appendix 2

Tables

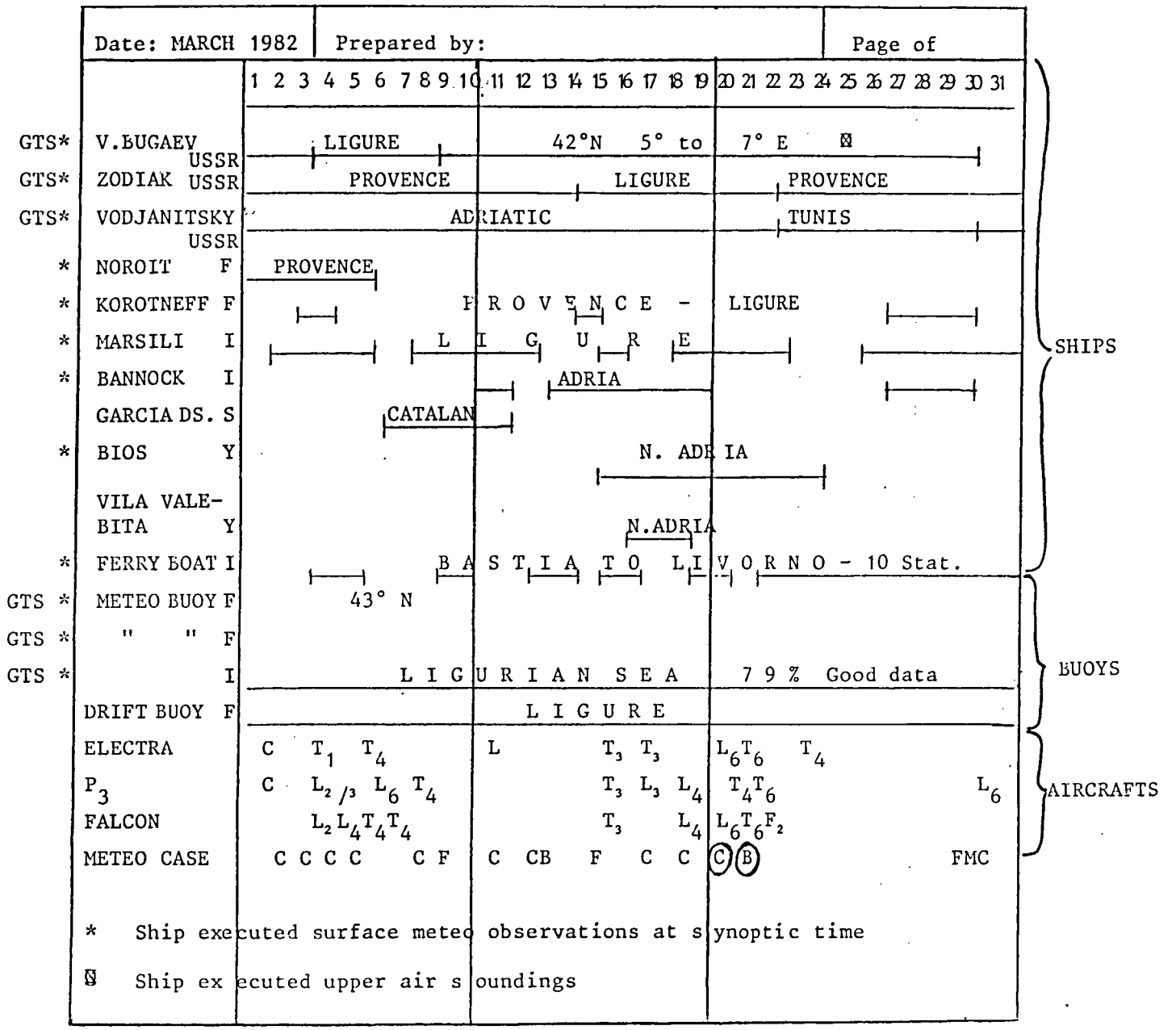


Table 1 - Calendar of operating platforms for March 1982:

- operating time is indicated by plain lines
- the area of operation is named above each plain line
- the asterisks (*) indicate the ships that made surface meteo observations at synoptic times during their cruises.

Only the Bugaev made upper air soundings (⊠) which were sent to GTS.

- the aircraft (Electra, P_3 and Falcon) operating from Geneva flew through cyclogenesis (C), Alp traverses (T), or L patterns according to the ALPEX Flight Plans
- the meteorological events are indicated on the last line. C stands for cyclogenesis, B for Bora, M for Mistral, and F for Foehn (north and south).

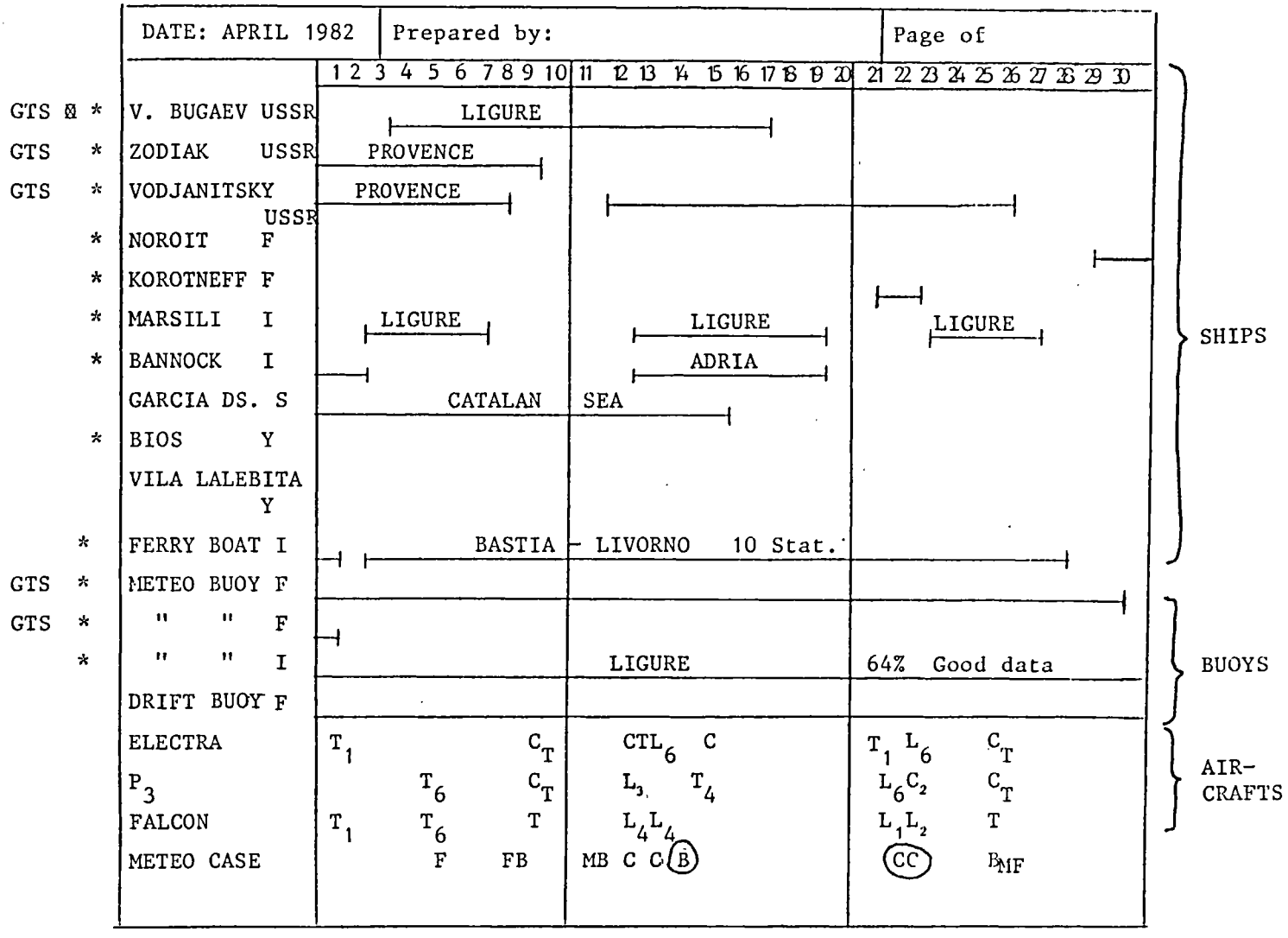


Table 2. As in Table 1. The time of activity of the various platforms are shown here for April 1982.

Appendix 3

List of acronyms

AIDS	Aircraft Data Set
AIEA	ALPEX Inner Experimental Area
AIREP	Aircraft Weather Report
ALPEX	Alpine Experiment
AOEA	ALPEX Outer Experimental Area
AOP	ALPEX Observing Period
BATHY	Bathythermographic observation
BORHA	Bouée Océanographique de Recherche Habitée
CEMMO	Centro de Estudios Meteorologicos del Mediterraneo Occidental
CNR	Consiglio Nazionale delle Ricerche
DYOME	Dynamique Océanique à Moyenne Echelle
EARSEL	European Association of Remote Sensing Laboratories
ECMRWF	European Centre for Medium Range Weather Forecasting
ERS	ESA Remote Sensing Satellite
ESA	European Space Agency
ESOC	ESA Space Operation Centre
GARP	Global Atmospheric Research Programme
GTS	Global Telecommunication System
IADC	International ALPEX Data Centre
IMGA	Istituto per lo Studio delle Metodologie Geofisiche Ambientali
IOC	Intergovernmental Oceanographic Commission
IOP	Intensive Observation Period
IOS	Institute of Oceanographic Sciences
IR	Infra-Red
ISDGM	Istituto per lo Studio della Dinamica delle Grandi Masse
MEDALPEX	Mediterranean Alpine Experiment
MEDOC	Méditerranée Occidentale (programme de recherches en)

NADC	National ALPEX Data Centre
NAVAID	Navigation Aid
NESS	National Environmental Satellite Service
NROSS	Navy's Remote Ocean Sensing System
ODAS	Ocean Data Acquisition System
POEM	Physical Oceanography of the Eastern Mediterranean
PSMSL	Permanent Service for Mean Sea Level
RNODC	Responsible National Oceanographic Data Centre
SADC	Special ALPEX Data Centre
SATEM	Report of satellite remote upper-air soundings of pressure, temperature and humidity
SATOB	Report of satellite observations of wind, surface temperature, cloud, humidity and radiation
SCOR	Scientific Committee on Oceanic Research
SOP	Special Observing Period
TESAC	Temperature, Salinity, Current
TIROS	Television and Infra-Red Observing Satellite
TOPEX	Topography Experiment
WDC	World Data Centre
WMCE	Western Mediterranean Circulation Experiment
WMO	World Meteorological Organization
WWW	World Weather Watch

ANNEX IV

PRESENTATION OF SOME ON-GOING PROGRAMMES IN THE MEDITERRANEAN SEA

ADRIATIC SCIENTIFIC CO-OPERATION PROGRAMME (ASCOP)

In recognition of the problems with pollution of the Adriatic Sea a Joint Italian-Yugoslavian Commission has been formed and met for the first time in Dubrovnik, in June 1977. Its work has been organized around three subcommissions. Mandate of the first subcommission is scientific cooperation and coordinated control of the pollution of the Adriatic Sea. Its major result has been a joint multidisciplinary monitoring and research programme. The programme has been organized around several major themes, namely monitoring, modelling, data bank, ecophysiology, bibliography and directory of institutions and projects. In order to coordinate modelling efforts Yugoslavian-Italian North Adriatic Modelling Group (YINAMG) has been formed (the acronim was changed to YIAMG when the project area was enlarged). A working plan was set up for three modelling centers (Trieste, Venice, Zagreb/Rovinj) along the lines of hydrodynamic/dispersion modelling and interaction/ecological modelling.

Joint activity in the period July 1979-October 1980 has been covered by the first Common Report, written in English and edited by Dr. E. Accerboni of OGS, Trieste. The second Yugoslavian, national report, covering period 1980-1984, has been just finished. Similar nationalreport is about to be finished in Italy, so that the second joint report will soon be published in English. Details concerning this joint programme can be obtained from chief national coordinators, Dr. Z. Konrad (Center for marine research, P.O.Box 1016, Zagreb, Yugoslavia) or Prof. Michelangelo Merlin (Facoltá di Chimica Industriale, Calle larga, Santa Maria, Venezia, Italia).

THE WESTERN MEDITERRANEAN CIRCULATION EXPERIMENT (WMC EXPERIMENT)

A brief description of an experiment whose main objective is to derive the circulation and causes of the circulation of the western Mediterranean Sea.

1. INTRODUCTION

Historically, the circulation of the western Mediterranean Sea has been described in very simplified patterns. Although intensive studies have been made of small regions in the sea, studies of the overall circulation have been limited by study techniques, available technology, and national interests. When the results of these regional studies are coupled with recent information available from satellite imagery, the circulation in the upper layer is indicated to be more complex than the previous generalized studies have shown. The coupled data indicate that the western Mediterranean circulation is organized into a series of mesoscale patterns or gyres modified by bathymetry, seasonal changes, meteorology, and tides.

State-of-the-art numerical methods have now attained the capability to realistically model a basin the size of the western Mediterranean (i.e., from the Strait of Gibraltar to the Strait of Sicily) and to resolve the mesoscale circulation. Such modeling, in conjunction with the synoptic measurements of boundary conditions (i.e., the flow through both straits and the meteorology) and field measurements to conform or suggest modification to models, provides the natural framework for a large-scale oceanographic experiment. Logically included in the plan experiment are studies of the Intermediate and Deep Waters. The details of their formation and subsequent flow paths are important both locally and as an example of similar processes that occur in the more inaccessible areas of the open oceans.

The WMC Experiment includes intensive studies in several critical regions. The most important of these are the studies of the inflows and outflows through the Straits at Gibraltar and Sicily. Knowledge of these critical inputs are required to understand the local dynamics of flow near these straits and to the fluxes of water, heat, salt, nutrients and pollutants both in the Mediterranean and in the North Atlantic. Present estimates of these fluxes through the straits are based on short-term measurements and assumptions. To help prove these assumptions, a continuous set of moorings will be maintained in the Straits of Gibraltar and Sicily for a one-year period. In addition, several shorter-term current water moorings will be installed in selected areas during the seasonal intensive phases of the experiment. These data, accompanied by satellite imagery and ship, aircraft, and drifter buoy measurements, will be used to describe the spatial and temporal variability of the circulation within the confines of the western Mediterranean.

The WMC experiment is an international, multi-platform experiment whose overall objective is to determine the circulation of the western Mediterranean Sea on scales ranging from basin-size down to 1 km. The result will be a dynamically and statistically correct representation of the circulation in terms of the forcing processes, adequate for understanding chemical and biological transport and for climatic studies. Thus, the

operational plans and follow-on analyses of the experiment are designed to answer the following questions:

1. What are the prime features of the western Mediterranean circulation and how do these spatially and temporally vary?

2. What are the basic forcing mechanisms that control the circulation?

3. How does the circulation affect the chemical, biological, and optical properties of the western Mediterranean?

4. How can this knowledge be implemented into numerical models?

2. APPROACH

An interdisciplinary approach is the mainstay of the WMC Experiment. A NORDA-led international team of modeling, physical, chemical and remote-sensing oceanographers, as well as meteorologists, has been formed. The emphasis of the effort is the development of multi-layer and statistical models that will be supported by field data. The 12-month field experiment will allow data to be collected during a complete seasonal cycle. Although some data will be collected throughout the twelve months, the intensive field phases will occur during the seasonal extremes coinciding with the recovery and reinstallation of the current moorings in the Straits of Gibraltar and Sicily.

PHYSICAL OCEANOGRAPHY OF THE EASTERN MEDITERRANEAN (POEM)

(from POEM Newsletter No.1, August 1985)

POEM is a multi-national research programme for the scientific study of the Physical Oceanography of the Eastern Mediterranean waters, which are considered to be the least scientifically understood parts of the Mediterranean Sea. POEM's ultimate goal is to establish the scientific basis, as concerns the Eastern Mediterranean, for the study of:

- Dynamics, variability and energetics of the general circulation;

- Fundamental physical processes such as deep convection and water mass formation and spreading which occur there, and which are common to different areas of the World Ocean, and

- Numerical modelling of the physical processes, occurring at different scales.

POEM Scientific Objectives

The overall scientific objectives of POEM are to: (a) describe the physical phenomena and quantify their kinematics; (b) define basic dynamical processes and (c) construct physical models suitable for general ocean scientific studies and application.

The specific objectives are:

(i) definitive phenomenology of hydrography, currents and transports,

(ii) dynamics of circulation and currents,

(iii) water mass formation, spreading and transformation, and

(iv) implications of the circulation with respect to:

  (a) transports and distribution of biological and chemical properties and

  (b) determination of critical interdisciplinary process research problems.

POEM Components

The programme's main thrust is basic research in physical oceanography of the Eastern Mediterranean, with converted observational, experimental and modelling components, which are essential to determine the circulation, its variabilities and associated transports. This will ultimately lead to a better and permanent physical-dynamical understanding of the marine environment as well as its interaction with the overlaying atmosphere, the submarine basin and the surrounding coasts.

POEM Field Experiments

These include general hydrographic surveys, localized high resolution surveys in regions of intense dynamic activity and in the identified regions of the intermediate and deep water formations, monitoring of straits, transient tracer surveys, and remotely sensed data collection.

POEM Implementation

The programme is to be carried out co-operatively in the second half of this decade by scientists from several countries, many of whom have already been working together as an Organizing Committee for the programme to build up its scientific basis and construct a definitive operational plan.

POEM Long-term Impact

The knowledge sought by the programme is needed to:

- update scientific information on the physical environment of the area;

- understand chemical and biological transport processes and distribution;

- quantify surface and coastal regional exchanges of heat and dissolved substances;

- promote the efficient utilization of marine resources;

- understand regional climatology and air/sea interaction processes;

- improve marine environmental management and pollution control.

THE JANUS EXPERIMENT

With this name we have indicated a series of oceanographic cruises to be effected in the Sicilian Channel for the investigation of the hydrological and dynamic conditions of the Strait, situated at the interface of the two basins of the Mediterranean sea. For this reason the Janus Experiment is able to give a contribution to the POEM and WMCE international programmes pertinent to the Mediterranean sea.

The Experiment foresaw (see enclosed figure):

(a) the use of three current meter chains moored crosswise in the deepest part of the Channel; every chain equipped with three Aanderaa meters placed at different depths;

(b) the use of three sea level recorders in the harbours of Mazzara del Vallo, Pantelleria isle and Lampedusa isle; a fourth instrument assembled on the central chain, at a depth of about 600m;

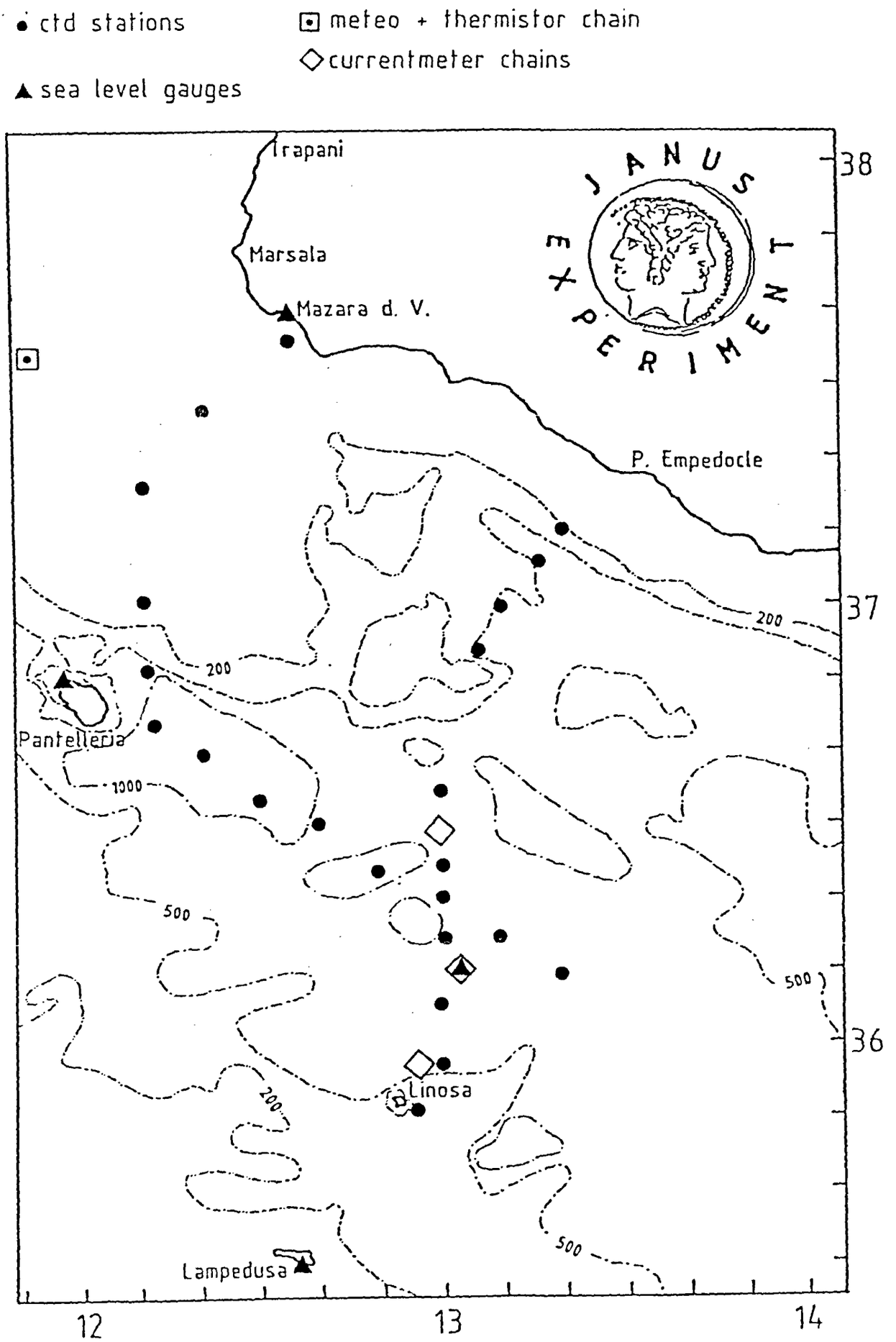
(c) a series of hydrological measurements with a Neil Brown profiler along selected sections of the channel;

(d) the use of an Aanderaa thermistor chain (one thermistor every 10m) with the support of the oil tanker AGIP MILANO moored on the Sicilian shelf at a depth of 100m, and, on the same ship, an Aanderaa meteorological station.

Measurements were begun in November 1985, when all the instruments were put in their positions and will end in June 1986, with their recovery. The hydrological stations were repeated in November 85 and March 86.

Within the Janus Experiment, in Novembe 1985 a further current meter chain was moored near the sill of the Corsica Strait, where it will remain for one year at least. This part of the programme is developed in collaboration with the Saclant Centre of La Spezia.

Up to now (March 86) the Experiment is proceeding as scheduled.


• ctd stations
⊡ meteo + thermistor chain
◇ currentmeter chains
▲ sea level gauges
Trapani
Marsala
Mazara d. V.
P. Empedocle
JANUS EXPERIMENT
Pantelleria
Linosa
Lampedusa
200
1000
500
38
37
36
12
13
14

ANNEX V

PROPOSAL FOR A PROGRAMME ON WATER MASSES CIRCULATION IN THE WESTERN MEDITERRANEAN

Goals

The primary objective of the IOC Workshop on Future Oceanographic Programmes in the western Mediterranean was to list those of the dynamical phenomena which were of major importance for the oceanographic community and still badly known. The Workshop agreed that the main goal should to better understand the circulation of the three Mediterranean water masses. This proposal, therefore, deals with circulation only. Additional proposals regarding other phenomena that may be considered as of a similar interest would of course be welcome.

The ciruclation of the water of Atlantic origin is of major importance. It involves a number of forcings and physical processes and it is thus relatively complex. The circulation of the Levantine intermediate water is mainly forced by buoyancy; the resulting current paths are probably topography-dependent; they can easily be checked and used for testing numerical models. The circulation of the deep Mediterranean water, although being weak on a yearly time scale, displays a large mesoscale variability the understanding of which is fundamental from a theoretical point of view.

Need for a reference document

When trying to develop a research programme aimed at a better understanding of the circulation, one discovers that no synthetic analysis of current knowledge is available. Now, a reference document is necessary, not only as a starting point, but mainly to assess the level of agreement of the scientific community on some specific aspects of the circulation.

A preliminary draft of such a document is being circulated amongst the members of the Steering Group of Experts for comment, amendment and correction, as necessary. When a general agreement about this document is reached, the following sections can be more easily addressed.

The scientific objectives

Besides taking stock of the well-known aspects of the circulation, a synthetic analysis of the available data sets will lead researchers to put together some assumptions in order to set up a right description of the circulation in the western Mediterranean.

Specific aspects of the circulation of the water of Atlantic origin have to be clarified in priority. In the Algerian Basin, dynamics of the eddies (several dozens km in diameter) have to be defined and variance of mesoscale currents to be estimated. Near Sardinia and in the middle of the Tyrrhenian Sea, the average circulation has to be specified. Around the Balearic Islands, the different paths have to be classified and the re-entering of the surface flow into the Algerian reservoir has to be specifically analysed. The occurrence of an actual vein of Levantine intermediate water has also to be checked everywhere along the continental slope (except off the African coasts) and around most of the Balearic Islands. It is now obvious that the deep Mediterranean water is driven by mesoscale currents too, mainly during winter in the Liguro-Provençal Basin and throughout the year in the Algerian Basin; both the vertical extent and the intensity of these phenomena have to be evaluated.

The observational strategy

Remotely sensed data (mainly infrared at the present time) can provide valuable information at relatively great depths. Moreover, analysing data collected in situ or planning future experiments at sea shall take into account the satellite imagery.

A number of devices for in situ measurements (mainly CTD, current meters, drifting buoys) can provide complementary information and most of them have to be used simultaneously in a circulation experiment. In the case of the western Mediterranean, some of them are specifically required. Estimating mesoscale currents in the homogeneous deep Mediterranean water, down to the bottom, far from shore and throughout the year is possible only with moored current meters. Searching for the occurrence of Levantine intermediate water along the continental slope can be easily and definitively made during any favourable period with 20-25 m boats equipped with a CTD and a ≃1,000 m cable. Obviously, all devices have to be used to describe the circulation of the water of Atlantic origin; in particular, drifting buoys are unique to cope with the large space and time scales of this phenomenon.

Suitability of tide gauges for circulation studies in the western Mediterranean Sea is more questionable. Attractive aspects (low cost, easy setting, security) should not mask difficulties in data analysis (digitilization, 0-levelling, atmospheric pressure correction, tides filtering, ...). Moreover, anticipated sea-level measurements have to be corrected from independent phenomena (wind, seiches, ...) and seem to be mostly related to mesoscale structures (eddies, ...) which are only indirectly related to the circulation.

Modelling

See Annex VI.

Scientific evaluation

Assumptions made can easily be tested, data collection is planned or can be carried on request, and various models have been initiated. Therefore, experimental and theoretical results will be easily compared in an interactive way. Scientific evaluation of the work undertaken in the western Mediterranean will be mainly made through self criticism.

Implementation plan

Account should be taken of individuals/laboratories/organisms' activities, be they underway or at the planning stage. Members of the Steering Group of Experts are requested to collect relevant information in their home countries. As a second step, careful consideration will be given to possible additional plans that would meet the afore-mentioned scientific objectives. An important item in this undertaking will be the setting up of a convenient international data management scheme that enables any participant in the programme to get access to any data gathered.

Actions to be undertaken

At least one action dealing with satellite data has to be initiated as soon as possible: all infrared images processed in CMS-Lannion should be geometrically corrected, analysed by a group of oceanographers, stored if necessary on a magnetic tape and made available to the interested scientific community. Obviously, this action concerns both the eastern and western basins.

ANNEX VI

MODELLING THE MEDITERRANEAN

(by Allan R. Robinson, Harvard University)

The Mediterranean Sea is a dynamically interesting ocean within which many processes occur which are relevant to global general circulation physics. The western basin is geometrically isolated from the North Atlantic and the eastern basin by the Straits of Gibraltar and Sicily. The eastern basin is even more geometrically isolated since the transports through the Aegean and Bosphorous Straits are much smaller than the Sicilian Straits transports. Straits dynamics and the localized source-sink driven aspect of the basin scale flows are dynamically interesting, important to the Mediterranean circulation, and require some special modelling considerations. However, momentum and buoyancy fluxes over the surface of the Mediterranean Sea itself are primary driving mechanisms for the Mediterranean general circulation. There results a combined wind-driven and thermohaline general circulation (of course, coupled non-linearly to the source-sink flow). Moreover, the thermohaline forcing is due to intermediate and deep water formation within the Mediterranean itself. Thus, the Mediterranean presents, in a relatively small and confined region, general circulation modelling problems with planetary characteristics. Compare, for example, the Carribean Sea or Gulf of Mexico which are from this viewpoint simply flushed by major current systems which have been energized externally.

Furthermore, the Mediterranean Sea is dynamically very interesting with respect to medium and smaller scale processes which occur there and which are implicated in the modelling of the circulation and its consequences. Included are air-sea exchange and interaction processes, convection, subbasin scale features, mesoscale eddies, straits-dynamics, mixing, and dispersion and transport processes. The treatment of these processes is necessary for the regional modeller and their study is of considerable interest to ocean dynamicists generally. The Mediterranean is an attractive location to study medium and smaller scale processes: scientifically, processes of interest have relatively large signals; technically, the logistics are convenient.

The Mediterranean modelling problem is not an idiosyncratic regional problem but is essentially a regional version of the global general circulation problem. Along with the opportunities for general research contributions from Mediterranean studies come also the full set of challenges and demands of modern ocean circulation modelling. Modelling is a rapidly evolving branch of ocean science stimulated by advances in phenomenological and theoretical knowledge of the ocean, the rapid growth and relevance of computational fluid dynamics, and the availability of new, cheaper and more powerful computational resources. The practice of modelling involves a blend of physical, mathematical and computational (numerical) research. Dynamical oceanography today is characterized by partially defined phenomena, insufficient (but growing) quantitatively accurate data sets, and partially verified and evolving models. The development of realistic and mature general circulation models for scientific studies and marine application is occuring. It is entirely feasible and timely to construct such a model for the Mediterranean. The relevant approach involves initially a number of related theoretical and process studies of both analytical and numerical characters. The numerical model itself must be developed through a succession of preliminary simplified models. Contemporary ocean modelling employs sophisticated methodoloy

analogous to techniques utilized in meteorology, engineering, etc. Noteworthy is the method of optimal field estimations, or four-dimensional data assimilation which blends model forecasts with new observational data on an on-going basis. Remotely sensed data from satellites is especially useful in this regard. These techniques are efficient and powerful and should be brought to bear on the Mediterranean problem ab initio.

What is the nature of an ocean circulation model today? Because of the variety and distribution of processes and the many time and space scales involved in the circulation, and because of data availability or special interest, an ocean circulation model is not a single monolithic entity. It is rather a collection or "hierarchy" of models including surface and bottom boundary layer models, high resolution regional models (e.g., open ocean, coastal, etc.), eddy-resolving or coarse resolution basin or larger scale general circulation models, etc. Research on embedding and coupling techniques is current. Each model is characterized by assumptions about the explicitly resolved physics (primitive equations, quasi-geostrophic, linear vs. non-linear, etc.). Subgridscale hypotheses involve eddy diffusivities, enstrophy dissipating filters or high-order viscosity, turbulence closure hypotheses, etc. The computational algorithm and methods are also varied and their choice related to questions of accuracy, efficiency, convenience and taste. Vertical structures include levels, layers and density co-ordinates. Finite difference, finite element and (pseudo) spectral techniques are all utilized. Domain size, geometry, topography, resolution requirements, computational resource and experience influence choices. The physical and computational structure of the model govern the mathematical and discrete-mathematical structure of the model. The initial-value, boundary-value problem is central, but different model types require different data sets for running tuning and verification. Boundary condition sensitivities is an important current research topic. The response of the model to parametric variations and sensitivity studies are as important as a central case study or best forecast run.

In the above, we have emphasized the commonality of Mediterranean modelling with ocean modelling generally. But there are, of course, special considerations for the Mediterranean Sea and also for each of the eastern and western basins:

(i) As mid-latitude general circulation basins, they differ from the major ocean basins because the seasonal signal is much stronger relative to the mean. The transient winds and surface fluxes must be known since, e.g., the interannual variability of a monthly mean can be as important as the annual variability. A special-purpose regional atmospheric model for surface flux estimation (and eventually for regional air-sea interaction studies) is of crucial importance.

(ii) The basins are small and the geometry and topography, including islands, is complex. The importance and manifestations of topographic-"beta" effects are not yet clear.

(iii) Mesoscale eddies are characterized by the Rossby internal-deformation radius. This is typically about 40 km in the Atlantic and Pacific but is only about 12 km in the Mediterranean (because of the different mean stratification). Smaller eddy effects and very high resolution measurements are required. Mesoscale eddy phenomenology is essentially unknown in the eastern basin and is just emerging in parts of the western basin (Algerian Current, Ligurian Sea). In addition, the non-linearity of the Mediterranean mesoscale vorticity balance appears to be more strongly non-linear than elsewhere, which could indicate unique processes.

(iv) Deep and intermediate convection occurs within sizeable areas of the basins. Thus, the usual simple parameterization of convection in general circulation models may be inadequate and/or inappropriate. Moreover, the location and extent of convection (in both basins but especially the eastern) is not certain. Preconditioning research is necessary and post-convective phenomenology is essentially unknown.

(v) The existence and formation of distinct water masses in close juxtaposition indicates relatively strong mixing and stirring processes which again may require more than existing conventional wisdom for adequate treatment.

The Mediterranean modelling problem is challenging, broadly-based and generally interesting. A well conceived effort with adequate resources should result in a useful and realistic model within a few years' time. Such a model should be developed co-operatively for each basin's general circulation, with a well co-ordinated experimental and observational programme. Those interested in regional coastal processes can develop local high resolution models for attachment to the general circulation models. Eventually, the basins should be connected and an interactive atmospheric model operated (simplified full Mediterranean and coupled air-sea models should of course be researched earlier). Scientific research, environmental management and pollution control, marine resource exploration and development, and marine operations will benefit from such models. The physical ocean circulation and transports required for studies in geochemistry, biological oceanography and regional climatology are provided by such a model.

ANNEX VII

DRAFT LAY-OUT OF AN ISSUE PAPER ON FUTURE OCEANOGRAPHIC PROGRAMMES IN THE WESTERN MEDITERRANEAN

1. CONSOLIDATED SCIENTIFIC PROGRAMME

1.1 Goal

1.2 Scientific objectives: - general
- specific

1.3 Observational strategy: - in situ
- remote sensing

1.4 Modelling

1.5 Scientific evaluation

2. IMPLEMENTATION PLAN

2.1 National plans: - firm
- tentative

2.2 Additional proposals: - mandatory
- desirable

2.3 Observational means: - existing
- to be developed

2.4 Data processing/models: - existing
- to be developed

2.5 Data management, exchange and archiving: - during the field phases
- after the field phases

2.6 Intergovernmental support: - for overall co-ordination/management
- for implementation of the field phases
- for participation of developing countries

3. ACTIONS TO BE UNDERTAKEN

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ANNEX VIII

LIST OF PARTICIPANTS

Mr. M. Astraldi
Stazione Oceanografica
ISDGM
Pozzuolo di Lerici (SP)
Italy

Tel.: (0187) 536309

Mr. L. Bertotti
Ist. Dinamica-Grandi-Masse
1364 San Polo
Venice
Italy

Tel.: (041) 705060

Tlx : 410095

Mr. L. Cavaleri
Ist. Dinamica-Grandi-Masse
1364 San Polo
Venice
Italy

Tel.: (041) 705060

Tlx : 410095

Mr. G. Chabert d'Hières
Institut de Mécanique de Grenoble (IMG)
B.P. 68
38402 Saint Martin d'Hères
France

Tel.: (76) 467966

Prof. H. Charnock
Department of Oceanography
The University
Southampton
SO9 5NH
United Kingdom

Tel.: (703) 559122

Tlx : 47661

Dr. A. Chouikhi

Institut des sciences de la mer et de l'aménagement du littoral
B.P. 90
Alger 1er Novembre - Amirauté
Algeria

Tel.: 62 73 19/62 66 59

Tlx : 53414 CROP DZ

Mr. F. Clement

GHER
University of Liège
Sart Tilman B5
Liège
Belgium

Tel.: 041 56 13 53

Prof. M. Crépon

Laboratoire d'océanographie physique
Muséum National d'Histoire Naturelle
43, rue Cuvier
75005 Paris
France

Tel.: 47 07 85 44

Mr. J. Font

Instituto de Investigaciones Pesqueras
P. National s/n
08003 Barcelona
Spain

Tel.: (34) 3 - 3106450

Tlx : 59367 inpb e

Mr. P. Franco

Istituto di Biologia del Mare
Castello 1364
Venice
Italy

Tel.: (041) 70 76 22

Prof. R. Frassetto

Istituto per lo Studio della Dinamica delle Grandi Masse - Consiglio Nazionale delle Ricerche
1364 San Polo
Venice
Italy

Tel.: (41) 70 56 49

Mr. M. Gacić

Institute of Oceanography and Fisheries
RT Marjana, Box 114
Split
Yugoslavia

Tel.: (058) 46688

Mr. G. Gasparini

Stazione Oceanografica
Ist. per lo Studio della Dinamica delle Grandi Masse
Pozzvolo di Lerici (SP)
Italy

Tel.: (0187) 53 63 09

Mr. G. Heburn

NORDA Code 323
National Space Technology Laboratory (NSTL)
MS, 39529
USA

Tel.: 601-688-5448

Mr. E. Kelky

US Office of Naval Research
223 Old Marylebone Rd,
London NW15TH
United Kingdom

Tel.: (44) 1-409-4661

Tlx : 299739

Mr. E. Khedouri

COMAREAASWFOR Sixth Fleet
P.O. Box 2
CTF 66
FPO N.Y. 09521
USA

Tel.: (39) 181-724-4107

Dr. M. Kuzmić

Center for Marine Research
Ruder Bošković Institute
P.O. Box 1016
41001 Zagreb
Yugoslavia

Tel.: (041) 435 111

Mr. P.M. Lehucher

Centre d'études techniques de l'équipement
Méditerranée
B.P. 39
13762 Les Milles Cédex
France

Tel.: 42 59 99 10

Tlx : 430579

Mr. Michelato

Osservatorio Geofisico Sperimentale (OGS)
Trieste
C.P. 2011

Tel.: (40) 21 40 221

Dr. C. Millot

Laboratoire d'océanographie physique du Muséum
Antenne de Toulon
B.P. 330
83507 La Seyne sur Mer
France

Tel.: 94 94 18 36

Tlx : 400 662 F IFREMER

Prof. C.J. Nihoul

Université de Liège
Mécanique des Fluides Géophysiques
Sart Tilman B5
B-4000 Liège
Belgium

Tel.: 32 41 56 13 50

Mr. M. Orlić

Geophysical Institute
University of Zagreb
P.O. Box 224
41001 Zagreb
Yugoslavia

Tel.: (041) 420 222

Mr. S. Piacsek

SACLANT Center
400 Via S. Bartolomeo
La Spezia
19026 Italy

Tel.: (039) 187-540-323

Dr. L. Prieur

Laboratoire de Physique et Chimie Marine - CNRS
B.P. 08
06230 Villefranche sur Mer
France

Tel.: 93 55 56 56

Dr. R. Purini

Ist. di Fisica dell'Atmosfera - CNR
Piazzale L. Sturzo 31
00144 Rome
Italy

Tel.: (06) 59 10 941/2/3

Tlx : 614344 ATMOS I

Dr. L. Rickards

Institute of Oceanographic Sciences
Bidston Observatory
Birkenhead, Merseyside, L43 9JA
United Kingdom

Tel.: 051 653 8633

Prof. A. Robinson

Harvard University
Center for Earth and Planetary Physics
Pierce Hall
Harvard University
Cambridge, Mass 02138
USA

Tel.: 617-495-2819

Tlx : 257550 HARV UR

Mr. J. Salat

Instituto de Investigaciones Pesqueres
Paseo Nacional s/n
08003 Barcelona
Spain

Tel.: 34-3-310-6450

Tlx : 59367 INPBE

Ms. R. Santoleri

Istituto di Fisica dell'Atmosfera - CNR
Piazzale L. Sturzo 31
00144 Rome
Italy

Tel.: (06) 59 10 941

Tlx : 614344 ATMOS I

Mr. F. Spanio

Istituto Idrografico della Marina
Passo Osservatorio 4
Genova
Italy

Tel.: 010-265451

Tlx : 270435 MARIDR I

Mr. Y. Tréglos

Intergovernmental Oceanographic Commission
Unesco
7, place de Fontenoy
F-75700 Paris
France

Tel.: 45 68 39 76

Tlx : 204461 Paris

Dr. M. Zore-Armanda

Institute of Oceanography and Fisheries
RT Marjana
Box 114
Split 58000
Yugoslavia

Tel.: (058) 46-688

No.	Title	Publishing Body	Languages
32 Suppl.	Papers submitted to the UNU/IOC/Unesco Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the Context of the New Ocean Regime Paris, 27 September-1 October 1982	IOC, Unesco Place de Fontenoy Paris, France	English
33	Workshop on the IREP Component of the IOC Programme on Ocean Science in Relation to Living Resources (OSLR) Halifax, 26-30 September 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
34	IOC Workshop on Regional Co-operation in Marine Science in the Central Eastern Atlantic (Western Africa) Tenerife, 12-17 December 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
35	CCOP/SOPAC-IOC-UNU Workshop on Basic Geo-scientific Marine Research Required for Assessment of Minerals and Hydrocarbons in the South Pacific Suva, Fiji, 3-7 October 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
36	IOC/FAO Workshop on the Improved Uses of Research Vessels Lisbon, 28 May - 2 June 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
36 Suppl.	Papers submitted to the IOC-FAO Workshop on Inproved Uses of Research Vessels Lisbon, 28 May-2 June 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
37	IOC/Unesco Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs Colombo, 8-13 July 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
38	IOC/ROPME/UNEP Symposium on Fate and Fluxes of Oil Pollutants in the Kuwait Action Plan Region Basrah, Iraq, 8-12 January 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
39	CCOP (SOPAC)-IOC-IFREMER-ORSTOM Workshop on the Uses of Submersibles and Remotely Operated Vehicles in the South Pacific Suva, Fiji, 24-29 September 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
40	IOC Workshop on the Technical Aspects of Tsunami Analyses, Prediction and Communications Sidney, B.C., Canada, 29-31 July 1985 (in press)	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
41	First Workshop of Participants in the Joint FAO/IOC/WHO/IAEA/UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region (WACAF/2) Dakar, Senegal. 28 October - 1 November 1985 (in press)	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
42	IOC/UNEP Intercalibration Workshop on Dissolved/Dispersed Hydrocarbons in Seawater Bermuda, USA, 3-14 December 1984 (in press)	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
43	IOC Workshop on the Results of MEDALPEX and Future Oceanographic Programmes in the Western Mediterranean Venice, Italy, 23-25 October 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English