Intergovernmental Oceanographic Commission
Workshop Report No. 74

IOC-UNEP Review Meeting on Oceanographic Processes of Transport and Distribution of Pollutants in the Sea

Zagreb, Yugoslavia, 15-18 May 1991

SC-9 1 /WS-50

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SUMMARY REPORT

1. Opening of the Meeting

The IOC-UNEP Review Meeting on Oceanographic Processes of Transfer and Distribution of Pollutants in the Sea was opened at the Ruder Boskovic Institute, Zagreb, Yugoslavia on Monday, 15 May 1989, at 09.30 am. Mr. M. Kuzmic opened the meeting and extended to the participants a most cordial welcome to the city of Zagreb and to the Ruder Boskovic Institute and its Centre for Marine Research, the host institution for the meeting. Dr. L. Jeftic, Senior Marine Scientist, then welcomed the meeting on behalf of the Executive Director of UNEP, Dr. Mustafa Tolba, and on behalf of the Secretary IOC, Dr. Gunnar Kullenberg. He stressed the importance both organizations attach to the subject of transfer and distribution of pollutants in the sea. Subsequently, Dr. D. Hrsak, Director of the Centre for Marine Research, extended a warm welcome to the participants and wished the meeting success. She also expressed her pleasure at seeing representatives from eight Mediterranean countries (the list of participants appears in Annex IV) working together towards solutions of common environmental problems.

2. Adm strative arrangements

Mr. M. Kuzmic was proposed as Chairman of the meeting and the proposal was unanimously seconded by the participants. The Chairman submitted the Draft Agenda of the meeting for consideration and adoption. It was adopted without amendments. However, several participants were unable to attend the meeting, owing to last minute developments, which necessitated later revision of the programme (the revised programme is given in Annex I). The programme reflects two major objectives of the meeting: to present and discuss current research in a part of the MEDPOL programme, and to suggest future subjects of research.

Following the Chairman's elaboration of the programme and objectives of the meeting, the participants were informed of local arrangements.

3. Presentation of papers

Reflecting the first objective of the meeting, twenty-one papers were presented during the first part of the meeting. These presentations are briefly surveyed here in order of presentation; the abstracts are reproduced in Annex III.

First day presentations were started by B. Cosovic. She discussed different electrochemical methods of determining surface actions substances. By applying the methods to the water samples taken in the southern Adriatic and in the Krka Estuary, both seasonal and spatial variations of concentrations were recorded.

M. Larid described the distribution of pollutants off Bou Ismail situated on the Algerian coast. The measurements of DBOs and bacteriological analyses enabled the risk zone to be delimited. Also, an investigation of heavy metals (Cu. Cr. Pb ...) in the sediments sampled off the Algerian coast was discussed

In her presentation, V. Zutic discussed in some detail an electrochemical method for determining organic matter in sea water. Analyses carried out for the Krka Estuary showed high concentrations at the halocline level. It was pointed out that this may influence transport of pollutants across the halocline.

Following the presentation of Dr. Zutic, S. Pugnaghi presented a model simulating diurnal cycle of temperature in sea water and in the underlying sediment. Theoretical results were compared with the data collected in the Comacchio Valley, a closed lagoon in the Adriatic area. Theoretical and empirical temperature oscillations were found to agree both in amplitude and in phases.

G. Ghermandi described the results of Hydrographic and hydrochemical measurements in the Venice Lagoon. Furthermore, she described the PIXE technique of trace metal analysis. The method was calibrated with single-element and multi-element targets from standard solution in the mg/1-ng/1 concentration range; percentage errors were generally below 10%.

A. Hecht made a presentation discussing the results of Aanderaa current measurements on the continental shelf off Israel; oscillations of periods of a few months were detected. He then described Hydrographic measurements in the open Eastern Mediterranean, carried out within national projects and the POEM programme. These measurements revealed the existence of mesoscale eddies and gyres. Lows and highs were found to be correlated to the distributions of oxygen, nutrients and plankton, and may have a bearing on the dispersion of pollutants.

The second day started with two papers presented by U. Unluata. In the first of these, mesoscale variability of the Eastern Mediterranean was studies on the basis of recently collected Hydrographic data. The objective analysis of geopotential anomaly derived from the data set showed that some of the eddies were persistent during the period of observation. Eddies circumnavigating the island of Cyprus transport Atlantic water entrapped within them. The distribution of petroleum hydrocarbons, nutrients and total suspended matter is correlated with the eddy field.

In his other presentation, U. Unluata described an estimation of long-term exchanges of water and selected substances (phosphate, nitrate, total organic carbon, petroleum hydrocarbons, nutrients and total suspended solids) between the Black Sea and the Mediterranean. The evaluation of the water budget of the Turkish straits was compared with a number of earlier estimates. Moreover, the results of a numerical model were described and compared with measurements.

A. Lascaratos presented some satellite data indicating wind-induced upwelling phenomena in the Bay of Corinth. The same phenomena are also visible in thermistor chain measurements in the area. It was found that during upwelling relaxation periods, solitary waves are usually generated at high-tide time. A nonlinear model, simulating strong tidal currents in the Bay, was exposed. Its results were compared with tidegauge data at two stations.

A. Lascaratos also presented a paper submitted by C. Koutitas. A reduced-gravity model was applied to the Aegean Sea in order to reproduce upwelling events that may be observed in the eastern part of the Sea. The model showed that persistent etesian winds are responsible for the occurrence of upwelling events.

M A. Said described an investigation of the current regime off the Egyptian coast. Vertical variability of currents was discussed for a number of stations. Vertical velocity was estimated using continuity equipment. Discussion of the paper helped to clarify the measurement technology.

A series of papers on Kastela Bay followed. M. Gacic showed measurements documenting the response of the Bay to wind forcing. For the majority of stations, the relationship is obvious; however, a station in the central part of the basin apparently does not respond to wind influence.

V. Kovacevic described the results of EOF analysis of temperature and salinity in Kastela Bay. She correlated the T/S variability with global radiation, evaporation and precipitation, freshwater inflow and wind. Among other things, it was found that the north-wind component enables freshwater to spread all over the Bay surface and causes cooling of the entire water body.

M. Bone briefly explained his approach to the modelling of baroclinic motions in Kastela Bay. He showed some preliminary simulations of bore-driven flow. In the discussion, an attempt was made to clarify several points of model formulation.

T. Legovic presented a modelling study of transport of vinyl-chloride monomer in a coastal area, following leakage from a sunken ship. Parameters of steady and unsteady leakage were estimated. These were then used to simulate the dispersions of the pollutant in the current field obtained by interpolating the measured currents.

N. Limic presented measurements of currents and salinity that had been used to reconstruct the current field and to estimate the washout rate of the Punat Bay. Measurements of concentrations of Zn, Cu and Pb in both water and sediment were used for estimation of sedimentation rate and input.

M. Kuzmic presented a modelling study of currents driven by two dominant winds (bore and scirocco) in the Adriatic Sea. Both winds induce closed circulation cells in the Sea. Trajectories have been computed in order to demonstrate the importance of wind-driven currents for the dispersion of pollutants.

The second day was closed by an ad hoc presentation made by V. Dadic. He described an automatic meteo-oceanographic station in the Kastela Bay, and stressed its importance for investigating the atmosphere-sea interaction in the area.

The final series of presentations was started by J.L. Humbert. He explained the objectives of the MED-MODEL project. Data were collected on different processes influencing the general circulation of the Western Mediterranean and the Ligurian and Algerian currents. Moreover, physical and mathematical models were prepared for the area.

J.M. Martin explained the aims of the EROS 2000 project. The project is devoted to the investigation of the coastal zone and global cycles. Several organizational aspects of the project were described.

In the final presentation of the meeting, J.M. Martin compared riverine and atmospheric inputs of water, particles, trace metals, nutrients and radionuclides to the Western Mediterranean. Different data sets were critically assessed, and an estimate was put forward.

Stimulating discussions followed the presentations. Although background differences among participants were noticeable, the meeting enabled an exchange of ideas between investigators of physical and chemical aspects of pollution problems.

After the presentation of individual papers a general discussion took place. During the final day of the meeting the discusion focused on the conclusions and recommendations of the meeting; the conclusions follow in this section and the recommendations will be found in Annex Il.

4. Conclusions

Papers presented at the meeting dealt with physical and geochemical processes in sea-water and sediment in transport, mixing and dispersal of pollutants. The importance of mesoscale eddies and gyres in the open sea, wind-driven currents and upwelling events in the coastal zone, and thermohaline processes in semienclosed bays and estuaries was recognized. There is strong evidence that non-local forcing can drive circulation in the coastal area. Concentrations, horizontal and vertical distributions and transport of pollutants were investigated and presented for a number of coastal areas. Riverine and atmospheric inputs of different pollutants to the western Mediterranean were discussed. Reports on two on-going nationally/internationally coordinated projects (MEDMODEL, EROS 2000) were presented. Discussions during the meeting enabled an exchange of ideas between specialists in different disciplines to be made. It is expected that this will promote the future interdisciplinary approach in this field.

The meeting also reviewed recommendations of the Consultation Meeting on Oceanographic Processes Related to the Transfer of Pollutants, Nicosia, Cyprus, 14-18 November 1986, and noted with satisfaction that conclusions concerning tar sampling during POEM and granting of assistance for consultation meetings of collaborating scientists had been implemented. This approach should be continued since collecting samples for additional parameters can be organized with little additional cost. Consultation meetings of participating scientists have been implemented. This approach should be continued since collecting samples for additional parameters can be organized with little additional cost. Consultation meetings of participating scientists have been found to be extremely beneficial and such practice should be continued.

The meeting recognized the importance of physical oceanographic studies in investigating the transfer and distribution of pollutants in the sea and in view of the importance of the interdisciplinary approach and bilateral and/or multilateral co-operation a number of recommendations were adopted. (See Annex 11).

5. Adoption of the Report

Following a long discussion, the conclusions and recommendations of the meeting were adopted by the participants. The draft proceedings were also presented and adopted in principle.

It was agreed that particpants wishing to revise their abstracts, submitted in advance of the meeting, could do so as soon as possible; these should reach the Chairman not later than 10 June 1989. The participants gave editorial licence to the Chairman and Rapporteur to finalize the report.

6. Closure

The Chairman thanked the participants for their valuable contributions and for their collaboration throughout the meeting. He also expressed satisfaction with the successful outcome of the meeting. Dr. Jeftic stressed the importance of the topics discussed and thanked the participants for their deliberations. The Chairman closed the meeting at 18.30 on 18 May 1989.

ANNEX I
PROGRAMME OF THE MEETING

Monday, May 15

09:30-10:30 Opening of the Meeting, Welcome addresses,
Administrative arrangements

10:30-11:00 Coffee break

11:00-12:30 Morning Session

B. Cosovic:
Determination and characterization of surface active substances in natural waters by electrochemical methods

M. Larid:
La dynamique des pollutants associes aux rejets directs en mer et aux apports fluviatiles

12:30-14:20 Lunch break

14:20-16:00 Afternoon Session I

V. Zutic T. Legovic:
Processes at the halocline and pollutant transport in stratified estuaries

S. Pugnaghi, S. Vincenzi R. Zonta:
Water-sediment thermal interaction in a lagoon

16:00-16:20 Coffee break

16:20-18:00 Afternoon Session II

R Cecchi G. Ghermandi. R Zonta:
PIXE analysis of waters in checking pollutant transfer in shallow waters

A. Hecht:
Physical processes in the Eastern Mediterranean (Report to the MEDPOL Phase II Meeting, Zagreb, Yugoslavia, 15-18 May 1989)

Tuesday, May 16

10:00-11:00 Morning Session I

U. Unluata, E. Ozsoy:
Transport processes by mesoscale eddies in the northern Levantine

U. Unluata A. Yilmaz, O. Basturk
Transport of water and selected substances through the Turkish straits

11:00-11:20 Coffee break

11:20-12:40 Morning Session 11

A. Lascaratos:
Wind and tide induced baroclinic motions in the Gulf of Korinthos

C. Koutitas.:
Observations and modelling of upwellings in the Aegean Sea
(*presented by A. Lascaratos)

M.A. Said:
Analysis of currents measured in the southeastern Mediterranean off the Egyptian coast

12:40-14:20 Lunch break

14:20-16:00 Afternoon Session I

M. Gacic
Characteristics of the current field in the Kastela Bay

V. Kovacevic M. Gacic
Low-frequency variability of temperature and salinity fields in the Kastela Bay

M. Bone:
Influence des baroclines sur le regime des courants induits par le vent dans la baie de Kastela (Split)

16:00-16:20 Coffee break

16:20-18:10 Afternoon Session II

L. Legovic M Limic
Estimation of parameters for transport of a pollutant in a coastal sea

T. Legovic N. Limic V. Valkovic J. Injuk M. Nagi:
Estimation of Zn Cu and Pb input into the Punat Bay (Eastern Adriatic)

M. Kuzmic. M. Orlic Z. Pasaric Lj. Jeftic
Modelling wind-driven currents in the Adriatic Sea and its relevance for investigating dispersal of pollutants

Ad hoc presentation:

V Dadic M. Ferencak A. Puskaric, M. Glavanic
Automatic meteorological-oceanographic station (AMOS)

Wednesday, May 17

10:00-11:10 Morning Session

J.L. Humbert:
Modélisation hydrodynamique de la Méditerranée occidentale

J.M. Martin:
The EROS 2000 programme

J.M. Martin:
River versus atmospheric inputs to the Western Mediterranean

11:10-11:30	Coffee break
11:30 12:40	General exchange of views
12:40-14:30	Lunch break
15:00-	Excursion and dinner (Trakoscan Castle)

Thursday, May 18

10:00-11:10	General exchange of views
11:10-11:30	Coffee break
11:30 12:40	Preparation of conclusions and recommendations
12:40 14:20	Lunch break
14:20-16:00	Preparation of conclusions and recommendations
16:00 16:20	Coffee break
16:20-18:30	Conclusions and recommendations, Adoption of the Report and closing of the meeting

ANNEX II

RECOMMENDATIONS

Recommendation 1

Physical oceanography of the coastal seas, extending from the coastline to the margins of the shelf, is important for an understanding of transport and dispersal of pollutants. In the Mediterranean there is a strong coupling of the dynamics of deep waters with the dynamics of shelf seas. Consequently, there is a strong need for integration of large scale physical oceanographic Programmes with specific Programmes concentrating on shelf seas, detailed investigations of specific areas, including bays and gulfs and the studies involving the interaction of shelf seas with the sources located on the coast. Action to this end is strongly recommended.

Recommendation 2

Due to the dynamics of general circulation, certain substances were found in high concentration in offshore areas when compared with nearshore regions. This fact significantly changes the earlier ideas about open-sea reference stations, and requires an interdisciplinary approach in continuous monitoring of pollutant concentrations within the sub-basin gyres, mesoscale eddies and the frontal regions Action to this end is recommended

Recommendation 3

It is recommended that the data obtained in ongoing and/or recently completed oceanographic Programmes be utilized for assessment of fluxes of water and selected substances through the Mediterranean straits.

Recommendation 4

It is recommended that assistance be provided by IOC and UNEP for the information flow concerning oceanographic cruises in the Mediterranean so that co-ordinated experiments can be carried out.

Recommendation 5

Interdisciplinary approach with interactions between physical and chemical oceanographers and biologists in the research projects on the transfer and distribution of pollutants in the Mediterranean is strongly recommended, especially in selected areas such as enclosed bays and estuaries (North Adriatic basin, Kastela Bay, Krka River Estuary, Izmir Bay, Nile Estuary, Aboukir Bay, and similar specific sites).

Reco mmendation 6

Bilateral or multilateral co-operation among physical oceanographers in the Mediterranean area has proved to be very successful from the scientific point of view. Such co-operation should be further encouraged. It is, therefore, recommended that granting of appropriate assistance should be continued and intensified. Assistance could be provided by MAP in the form of travel expenses for working meetings of collaborating scientists, software development, computer time and maintenance.

ANNEX III

ABSTRACTS OF SCIENTIFIC PRESENTATIONS

Determination and characterization of surface active substances in natural waters by electrochemical methods

B. Cosovic

Organic matter in the sea, comprising a complex mixture of different compounds, originates from several internal and external sources, including excretion by plants and animals, bacterial decomposition, autolysis of dead organisms, inputs by rivers and effluents and from the atmosphere. In coastal waters the concentrations are significantly increased in comparison with the open ocean, because of the growing primary production and influence of pollution.

Organic compounds with surface active properties, both natural and artificial, are concentrated by adsorption processes at the phase boundaries of water with the atmosphere, and with solid particles such as sediment and biota. Organic matter plays an important role in the distribution of physico-chemical forms and speciation of micro and macro components in natural waters, thus influencing biogeochemical cycles and fate of naturally occurring substances and pollutants in the sea.

Surface active substances have prevalent influence on biogeochemical processes that occur at natural phase boundaries, i.e. they influence, accelerate or inhibit, exchange processes between different compartments (atmosphere/seawater, solid phase/seawater, biota/seawater).

The long term efforts in the development of electroanalytical methods for determination and characterization of surface active substances have so far enabled a wide application of these techniques for research and control of organic matter in the Adriatic Sea. Field observations of surface active substances in the sea were carried out with the aim to determine levels of naturally occurring surface active substances in the open waters of the Mediterranean and the Adriatic Sea and to estimate pollution levels in some coastal areas in the Adriatic Sea. Laboratory experiments and tests were carried out with the aim of finding out and developing suitable procedures for characterization of predominant groups of surface active compounds in the complex mixture. Special attention was paid to the investigation of the adsorption behaviour of the colloid fraction of organic matter in the sea.

Phytoplankton exudates represent the main source of organic matter naturally occurring in the sea. A large fraction of this organic matter is surface active and represents the main part of surfactant activity in the sea. Due to the large abundance of phytoplankton species and their role as the first link of the marine food chain studies of the products of their metabolisms, as well as of their interaction with other constituents in natural aquatic systems, are of particular interest in complex investigations of biogeochemical processes in the natural environment. In addition measurements of surfactant activity values in coastal areas exposed to frequent phytoplankton blooms seems to be a promising tool for the monitoring program and the basis for early warning systems.

La dynamique des pollutants associes aux rejets directs en mer et aux apports fluviatiles

M. Larid

Pour contribuer á la connaissance de la propagation des pollutants en mer, deux zones différentes ont été étudiées sur la côte algerienne. Les données recueillies nous permettent de présenter quelques résultats préliminaires.

Le premier cas d'étude concerne l'agglomération côtière de Bou-lsmail située à une cinquantaine de kilomètres à l' guest d'Alger. Les rejets d'eau usée, d'origine principalement domestique steffectuent directement en men Les mesures de DBOs permettent d'affirmer que le pouvoir auto-épurateur du miliue est encore possible, du moins pour la pcriode étudiée. En revanche les analyses bacteriologiques démontrent la présence de bactéries (SF, CT, CF) et de germes pathogènes. Le nombre d'échantillons traités (58 au total) et les techniques de positionnement utilisées (positionnement à vue à partir de la côte avec des procédés topographiques) nous indiquent une nappe de pollution importante. Pour la pcriode de l'année ou le phonomètre de la pollution est ralenti, la zone à risques qui a été delimitée est représentée sur une carte au 1/5000.

Le deuxième cas d'étude consiste en l'analyse de métaux lourds (Cu. Cr. Pb...) dans les sediments préléves dans l'embouchure de l'oued macta dans le golfe d'Arzew (guest Algerien). Il s'agissait de déterminer la teneur de chaque pollutant en rapport avec la granulométrie. Après la détermination granulométrique dc chague échantillony et le dosage des mctaux lourds obtenus par spectrophotométrie à absorption atomique, il apparaîtque la corrélation entre les deux paramètres n'est pas de type lineaire. Ceci est une première interprétation des résultats parce que le nombre d'échantillons qui ont pu être traitcs (6 au total) n'est pas suffisant pour en firer une conclusion définitive. Processes at the halocline and pollutant transport in stratified estuaries V. Zutic and T. Legovic

The organic matter pool in seawater is chemically complex, physically heterogeneous, variable in time and space (Azam and Cho, 1987). In mixing zones of estuaries there are additional transformations of chemical and biological species under extreme salinity gradients (Mantoura, 1987). While the techniques to study rates of biological transformation of organic matter have become a routine, processes of abiotic, hcterogcneous transformation of dissolved organic matter in estuaries have been mostly ignored. Asthe first step in studying physico-chemical transformation of estuarine organic matter, we have developed an electrochemical methodology to count surface active particles (Tomaic et al., 1989) typically found at haloclines of stratified estuaries Zutic and Legovic 1987).

Here we present the experimental results on coalescence, its mechanism and rate, of estuarine surface active particles at a model interface.

Coalescence of estuarine surface adive particles is compared to chemically defined adive particles and phytoplankton cells. The most important phenomenon observed in the coalescence of non-living estuarine particles are phase transitions leading to formation of 2-D organized structures at the interface, which might indicate a supramolecular structure and collective properties in organic films at natural aquatic interfaces. The consequences for transport of organic matter and pollutants across the halocline are discussed.

References:

Azam, F., Cho B. C, Bacterial utilization of organic matter in the sea. In SGM 41, Ecology of Microbial Communities, Cambridge University Press, 1987, pp. 262-281.

Mantoura, R.F.C, Organic films at halocline, Nature, 328 (1987) 932-950.

Tomaic J., Legovic, T., Zutic V., A method to determine the concentration of surface active particles in aqueous solutions, J. Electroanal. Chem., 259 (1989) 49-57.

Zutic V., Legovic, T., A film of organic matter at the fresh-water/seawater interface of an estuary, Nature, 328 (1987) 612-614.

Water-sediment thermal interaction in a lagoon

S. Pugnaghi S. Vincenzi and R. Zonta

Thermal behaviour of the water and of the bottom of a lagoon has been studied. A theoretical model has been derived. In this model a well mixed layer of water, with constant height, density and specific heat, above a solid half-space of constant density, specific heat and thermal conductivity has been considered.

The water temperature is only a function of the time while the temperature of the solid (sediment) is a function of both time and depth.

As for the thermal budget, the following scheme for the fluxes at the water interfaces has been assumed:

- Φ_i = incoming flux at the air-water interface. It is due to solar radiation and long-wave radiation emitted downward by the atmosphere.
- Φ_h = outgoing flux at the air-water interface ($z = h$). It is due to the infrared radiation emitted by the water surface, evaporation processes and so on.
- Φ_0 = incoming flux at the water-solid interface ($z = 0$). It is the conductive flux between water and sediment.

Most of the incoming flux Φ_i will be absorbed by the water and only a small part will reach the bottom. In the model it has been assumed that the fraction ε of the net flux Φ at the air-water interface [$\varepsilon\Phi = \varepsilon(\Phi_i - \Phi_h)$] reaches the solid.

From the previous scheme the following equations can be written:

– thermal budget of a column of water of unitary area for a closed basin

$$\rho c h \left[dT(t)/dt\right] = (1-\varepsilon)\,\Phi(t) + \Phi_0(t)$$

– Fourier equation for heat propagation in the solid

$$\left[\partial T_s(z,t) / \partial t\right] = D\left[\partial^2 T_s(z,t) / \partial z^2\right]$$

where D is thermal diffusivity;

– thermal budget of a column of sediment of unitary area

$$\frac{d}{dt}\int_{-\infty}^{0} \rho_s c_s T_s(z,t)\,dz = \varepsilon\Phi(t) - \Phi_0(t)$$

The vertical z axis is directed upwards and its origin is at the water-solid interface.

Assuming periodic boundary conditions, it is possible to obtain the following solutions for the temperature of water and solid:

$$T(t) = \langle T \rangle + \sum_n W_n \exp(i \cdot n \cdot w \cdot t) \qquad \textit{Water}$$

$$T_s(z,t) = \langle T_s \rangle + \sum_n S_n \exp[(1+i)\, z / \delta_n] \cdot \exp(i \cdot n \cdot w \cdot t) \qquad \textit{Sediment}$$

where $\delta_n = (2D/n \cdot w)^{1/2}$ and $w = 2\pi/24$. W_n and S_n are the complex amplitudes for the water and solid sinusoidal components.

The unknowns: $\langle T \rangle$, W_n, $\langle T_s \rangle$, and S_n can be computed by means of the previous assuming:

$$\Phi(t) = \langle \Phi \rangle + \sum_n \Phi_n \exp(i \cdot n \cdot w \cdot t)$$

$$\Phi_o(t) = \beta\,[T_s(o,t) - T(t)]$$

where constant Beta depends on the thermal conductivity.

In July 1988, a test was conducted in the Comacchio Vaüey, a closed lagoon near the Adriatic Sea. The measurements of the water temperature, of the sediment temperature and of the net flux at the air-water interface show that the fi rst two harmonics (24 and 12 hours periods) of the Fourier analysis can be used to fit the experimental data.

The mean vertical temperature of the water has its maximum at 5 p.m. that is 5 hours after the solar maximum (midday). The temperature of the sediment was measured at three different depths and the maxima of the experimental data have the following delays:

8.5 h at z = - 5.0 cm

13.7 h at z = - 12.5 cm

19.0 h at z = - 20.0 cm

Assuming a linear behaviour in the first centimeters of sediment and extrapolating to z = 0, a delay of about S hours was estimated for the solid at the water-solid interface.

The theoretical model for a lagoon like Comacchio gave the same result: about 5 hours for both water and solid. The values of density, thermal diffusivity and so on were taken from literature.

According to this test the model seems fit to explain the delay of the temperatures of the water and of the sediment in relation to the thermal perturbation (Sun). The number of harmonics considered seems very important. Using only the fundamental component (24 hours), the delay for both water and solid is about 6 hours instead of 5 hours.

PIXE analysis of waters in checking pollutant transfer in shallow waters

R. Cecchi G. Ghermandi and R. Zonta

Water pollution in the Venice Lagoon and the Northern Adriatic Sea is a very serious problem. The quality of the water and, consequently, the life environment in the Lagoon have progressively deteriorated, with a decline in fish population and an increase in eutrophication, because the Lagoon receives municipal, industrial and agricultural wastes. This matter remains in the Lagoon sometime before being transferred to the Adriatic Sea and possibly it can be trapped on the bottom and successively released from it.

About ten years ago we began our collaboration with the CNR Institute of Venice in investigating pollution progress in the Lagoon, and up til now we have been working together with the aim of cooperating in "saving Venice" Our role in this research is the trace metal analysis of water samples and other diluted matrices.

The heavy metal measurements in this work are not only a pollution check, but support, as an "artifi- tracer", the transfer modelling.

The first step of this work was a general overview of the Lagoon condition. The Lagoon of Venice (max. length 52 km, width between 8 and 14 km, crescent shaped, total area 586 km2, mean depth 05 m) is linked to the sea through three inlets, Lido, Malamocco and Chioggia; each inlet feeds one of the three natural basins into which the Lagoon is divided. The northern basin (Lido) has the largest surface expansion and includes the city of Venice. Twenty four points have been identified where water flows out from the inland drainage basin and reaches the Lagoon. Eight (natural and agricultural) channels flowing into the Lagoon were selected: 3 in North, 2 in Central and 3 in South Lagoon. At each of the eight outlets, field measurements and sample collections have been carried out monthly (and also more frequently) for some years. Salinity, air-water temperature and longitudinal velocity profiles in the river sections, pH and dissolved oxygen measurements were carried out, together with ammonia, nitrate and nitrite, ortophosphate and some heavy metal (Fe, Ni, Cu. Hg, Pa, Cd) analysis. This work (1) estimates the quantity of pollutants that are discharged in the lagoon from the drainage basin during a year.

It is more difficult to estimate the exchange between the Lagoon and the Adriatic Sea due to difficulties in evaluating the net flux towards the sea and understanding the complex phenomena of pollutant exchange in Lagoon environmental phases. The dynamics of the Lagoon normally establishes an adequate capacity for water exchange with the Adriatic Sea, but there are marginal areas in which tidal exchange is retarded and decreased that become places of pollutant accumulation. Installation of fixed and mobile protective works at lagoon inlets is neccessary to prevent the consequential habitat changes, especially accentuated in these marginal areas where lagoon dynamics is reduced.

We have selected a test area in Northern Lagoon which well represents the main-land - Lagoon interface: two of the already monitored polluted channels flow in this tidal marsh area, named Palude di Cona. Its hydraulic, morphological and physical-chemical characters are known from previous works and from recent Geld measurements and helicopter sourveillance

In order to determine the effect of fresh water forcing to distribute heavy metals on surface sediments in this shallow water area, we first mapped heavy metal distribution in the waters and surface sediments (non-residual fraction) of the whole marsh. After that we studied in more detail the principal discharging channel mouth, in which heavy metal accumulation was found to be decidedly abundant. The data on metal distribution between water and sediment phases have allowed so far:

- to estimate the average heavy metal amount in the surface and bottom material;
- to show dependence on the distance from sources of heavy metal input (2);
- to point out the preferable heavy metal accumulation in finest grain size (3).

These results also give preliminary information since the structure of the estuary, the fresh water inflow and the incoming tidal salt water influence the spatial distribution of bottom sediment sizes (4).

Any temptative description of the complex exchange mechanisms at water-bottom sediment interface requests further investigation: in order to understand these phenomena, we are carrying on heavy metal analyses of the waters (suspended and diluted matter), surface sediments and interstitial water (extracted by centrifugation) from the surface and deeper sediments. Statistic behaviour of metal concentrations and their correlations will enable us to study the element budgets in different phases as boxes of a model, in order to evaluate the residence times and the diffusion fluxes mechanisms. The other physical-chemical and hydrological parameters of the environment will be checked at the same time. In addition, the sediment growth rate will be measured from 137Cs y activity of bottom sediment cores.

Trace metal concentrations are measured by the PIXE technique (Particle Induced X ray Emission), at the 2 MeV Van de Graaff accelerator of INFN Legnaro (Padova-ltaly) Laboratories, with a 1.8 MeV proton beam in a specially prepared irradiation chamber. We have improved a chemical procedure (5) to prepare aqueous samples for PIXE analysis: it consists of preconcentrating and extracting solute metals by precipitation as carbamates, and collecting them by filtration on Nuclepore filters (0.4 u pore size). Every sample handling requires great care and checked environment in order to avoid sample contamination. This not selective procedure has been tested at different pH and with different carbamate chelants (6) to detect the maximum efficiency of metal recovery. We have experimentally calibrated this method with single-element and multi-element targets from standard solutions of Ti V, Cr. Mn, Fe, Co, Ni, Cu. Zn, Se, Cd, Ag,

Hg, Pb, Bi, Y. Mo in the mg/l - ng/l concentration range, treating up to half a litre water samples, with satisfactory results (percentage errors generally < 10%).

All the water samples and several (diluted) sediment samples analyzed in this work followed this chemical procedure and were measured by PIXE.

The PIXE spectrum reduction system is a fully automatic (or interactive mode, if necessary) program that we performed on 750 VAX computer (7). The main steps of this program are: background subtraction (average experimental blank and exponential additive function), peak linear square fit as gaussian shape, interference resolution taking into account the whole spectrum emissions and measure parameters. Element concentrations and experimental errors are calculated. References:

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Physical processes in the Eastern Mediterranean

(Report to the MEDPOL Phase II Meeting, Zagreb, Yugoslavia, 15-18 May 1989)

A. Hecht

The report contains a general description of the IOLR Physical Oceanography Department's past involment in MEDPOL Vl and the present work which could be relevant to the objectives of the MEDPOL PHASE II.

Within the frame of MEDPOL Vl, we deployed Aanderaa current meters on the continental shelf of Israel and, for a period of about two and a half years (1976-1978), maintained an almost continuous series of measurements of currents, temperatures and salinities, at two points (in 16 m and 30 m of water, with two current meters at a depth of 15 m below the surface). Shorter series of measurements, at other points and other depths, preceded the long one. Only a small section of the results were translated, and as they are, they show some interesting features such as month long persistence and perhaps a strong correlation to the local winds. Lack of funds prevented us from continuing this work.

During the years 1979 to 1984 we carried out an extensive series of cruises in the Eastern Levantine Basin. These 20 cruises - which we called the Marine Climate or MC series - revealed the spatial and temporal variability of the main water masses in the Levantine Basin and pointed to the complexity of the currents and the general circulation in the Eastern Levantine Basin (Hecht, Pinardi and Robinson, 1989). In particular, the analysis of the MC series showed that typical local water masses - Atlantic waters and Levantine intermediate waters - are trapped within the anticyclonic eddies and described the role of these eddies in the formation and transport of local water masses (Hecht, Pinardi and Robinson, 1989). Honoway et al. (1986), who studied the stirring of a passive tracer field initially concentrated inside an eddy, showed that

the eddy can carry the tracer within it for a very long time but that eventually there will be a leaking of the tracer due to diffusion or interaction with the background flow. This mechanism was shown to be active in the Eastern Levantine Basin (Hecht, Pinardi and Robinson, 1989), and it has a direct bearing and most important effects on the dispersion and distribution of pollutants throughout the entire Mediterranean Sea.

Since 1982 the IOLR is involved in POEM and, until the present report, carried out 5 extensive cruises coordinated with other POEM participants. Part of the IOLR POEM01 and POEM02 overlapped with the region of the MC cruises. In this particular region the POEM01 and POEM02 CTD casts were supplemented by a dense grid of XBT's. The analysis of these particularly dense samples revealed the structure of mesoscale eddies and jets in the Eastern Levantine Basin and established the parameteres required for the objective analysis of the entire MC data set as well as for the future POEM cruises (Robinson et al., 1987).

The analysis of the first two POEM coordinated cruises was carried out in close cooperation with the Turkish IMS-METU and revealed previously unknown Levantine Basin circulation patterns and LIW formation pro_sses (Ozsoy, Hecht and Unluata, 1989). Later, POEM coordinated cruises were analyzed by the joint effort of the whole POEM group and produced new information on the entire Eastern Mediterranean Sea. The POEM group is scheduled to continue some of these coordinated cruises, but in the future will mainly focus on the modelling and perhaps on particular processes and events.

The POEM coordinated cruises and the POEM cooperation procedures are also utilized for the collection and joint investigation of marine data which are not diredly relevant to the investigation of the circulation, but which could benefit from its being collected at the same time as physical data. For example, a number of ships participated in data collection and investigation of tar ball distribution in the Eastern Mediterranean Sea (Golik et al., 1988). Although the data is not absolutely simultaneous, it is spaced in time close enough to provide a quasi synoptic picture of the situation. Other parameters, such as oxygen, nutrients and plankton, are also collected and investigated on the physical oceanography background. These have revealed very interesting patterns which may have a bearing on the distribution and dispersion of pollutants.

Our last POEM coordinated cruise, POEM07, was again a multidisciplinary effort with some additional emphasis on the exchanges of water through the Cretan passage. Since the cruise ended in the middle of April, we have only some very preliminary results, which, nevertheless, already indicate that we may have stumbled upon some interesting processes.

Finally, the IOLR is involved in the monitoring of pollutants in a number of places along the Israeli coast and in particular in the Haifa Bay, at the periphery of one of the major industrial zones of Israel. This work was reported at some other MEDPOL meetings. Unfortunately, the pollution monitoring is not accompanied by the measurement of physical and meteorological parameters. In my opinion, this can lead to a limited understanding of the processes involved in the transport and dispersion of pollutants and the absorbing capacity of any particular region. Besides, the additional work carried out during the POEM cruises is funded on an ad hoc basis and sometimes it is cancelled for lack of budgets (e.g. no tar was collected during POEM07). If one feels that the acquisition of long range, detailed and accurate data base is critical to understand the transport and dispersion processes of pollutants, one must find ways and means to establish the regularity of such coordinated long range cruises. References:

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Transport processes by mesoscale eddies in the northern Levantine

U. Unluata and E. Ozsoy

Hydrographic data obtained in a total of nine research cruises, carried out by the R/V BILIM in the northern Levantine Basin during 1985-1988, were utilized to study the circulation and water mass characteristics. These surveys, repeated on a seasonal basis, for the first time enabled a detailed evaluation of the northern Levantine in terms of its oceanographic features. Objective analysis of geopotential anomaly, derived from the data set, shows that some of the northern Levantine eddies persisted during the period of observation, although with occasional shifts in position. There is coincidence of these eddies, which appear to be persistent, and the bottom topographic features. Long term inter annual] changes in the patterns of circulation are also significant. The central Basin jet flow which bifurcated and joined in the Rhodes gyre circulation in the early part of the observations was found reformed as a coherent flow along the Anatolian coast in the following years. Eddies circumnavigating the island of Cyprus in the latter part of the development appeared to transport Atlantic water entrapped within them, which in the earlier period appeared only in filaments west of Cyprus.

The distribution of water masses and a series of variables (petroleum hydrocarbons, nutrients, total suspended matter) coherently correlates with the eddy fields and the fronts.

Transport of water and selected substances through the Turkish straits

U. Unluata A. Yilmaz and 0. Basturk

Long term exchanges of water and the selected substances between the Black Sea and the Mediterranean are estimated. The water budgets of the Turkish straits formed by the Bosphorus, the Sea of Marmara and the Dardanelles are evaluated using the recent reliable salinity data obtained with sufficient frequency and are compared with previous estimates, as well as with the results of numerical models. The fluxes of phosphate, nitrate, total organic carbon petroleum hydrocarbons, mercury and total suspended solids are estimated by using the elements of the water budget and the concentrations of these variables.

Wind and tide induced baroclinic motions in the Gulf of Korinthos

A. Lascaratos

By the use of 152 NOAA-6 and NOAA-7 satellite infra-red images, a detailed description of sea surface temperature features and their evolution in time was obtained. More specifically, the strong wind-induced upwellings occurring in the NW coasts of the gulf near the Rio-Antirio strait were studied.

A discussion of the satellite data in the light of recent theories on wind-induced marine upwellings near the capes (Crepon and Richez 1982; Crepon et al., 1984) confirmed the existence of a number of predicted features, more specifically, the theoretical prediction of a more intensive upwelling signal in the downwind side of triangular capes compared to the upwind side.

In situ thermistor chain measurements in the area rendered a detailed image of the time evolution of upwelling events and of their relation to atmospheric synoptic variability.

Solitary waves were found to be generated during upwelling relaxation periods at high tide time.

Finally, a tidal model to simulate the very important tidal currents in the strait (up to 100 cm/s) is presented. In the model we solved the vertically integrated primitive equations. The results were compared with the existing data from one tide gauge station in Patras and one in Korinthos city. The fully non-linear version of the model gave the closest convergence with data. Residual tidal currents were found to be insignificant.

Observations and modelling of upwellings in the Aegean Sea

C Koutitas

The present study initiates an effort towards the optimal synthetic use of field data collected during the Open Sea Research Program of the Greek National Centre of Marine Research realized in conjunction with the POEM program and the mathematical modelling approach offered to modern oceanography. The study was triggered off by the persistent surface water patterns indicated in a series of satellite thermophotographs during the summer along the Eastern Aegean Sea. It keeps an introductory character but presents a logical explanation for the remotely sensed surface patterns. It is anticipated that further development of the model and more in situ observations will help to understand and predict accurately the upwelling events in the complex geometry and physical conditions of the Aegean Sea, so important for the rational exploitation of its fishery resources.

Analysis of currents measured in the southeastern Mediterranean off the Egyptian coast

M.A. Said

Studies of the current regime and water circulation of the southeastern Mediterranean off the Egyptian coast are obviously of great importance to the problem of coastal transport of pollutants, where different sources of pollution exist. Most of the known patterns of water circulation have been obtained only through indirect methods: by constructing T-S diagrams, and sections of horizontal and vertical distributions of some physical and chemical properties of sea water, such as salinity, temperature and oxygen (Halim et al., 1967; Morcos and Hassan, 1976; Abdel-Moati and Said, 1988).

Direct current measurements over the continental shelf off the Nile Delta are very scarce. An Ekman current meter was used at five stations between October 1959 and October 1961. During the summer of 1966, surface and subsurface current measurements using the Ekman current meter were made between Port-Said and Aboukir Bay by the Russian R/V Ichthyolog (Hassan, 1969). Trajectories and speeds of surface currents near the Egyptian Mediterranean coast were studied using Woodhead plastic surface drifters during the period from May 1976 to November 1977 (Gerges, 1978). None of these current measurements were properly used to draw the current pattern of the Mediterranean water off the Egyptian coast.

The paper deals with the preliminary results of an investigation of the water circulation over the Egyptian Mediterranean shelf which extends between Alexandria in the west (29°45' E) and Port-Said in the east (32°30' E). This area receives an amount of about $16.1 \cdot 10^9$ m^3/year of fresh and brackish waters, as well as industrial and sewage waters from various land based sources.

Three separate data sets were collected from 31 Hydrographic stations during the joint Soviet-Egyptian expedition on the R/V Akademik Levrentyev which took place from 20 to 26 Deccmber 1988. These were: standard meteorological measurements, CTD data and current meter data. Preliminary analysis of the surface current in the investigated area indicated that the current velocities fluctuate in the range 10.0-86.7 cm sec-1 and revealed great variabilities in direction over the area of investigation. Currents at the nearshore stations on the Nile Delta are in the southeasterly direction towards the coast, while at the offshore stations they generally vary from north-easterly to south-easterly directions. At the oceanic stations, the current is in the western direction with a velocity range 66.6-86.7 cm sec-1 The vertical distribution of absolute current velocity (V), direction (O), zonal (Vx) and meriodional (Vy) current components of the nearshore waters give an easterly flow at the surface and to the bottom, with maximum velocity values at the 10-15 m depth. An easterly flow from the surface to the bottom is observed at station 12 and to a depth of 60 m at station 43 while a westerly flow is observed in the remaining layers. A westerly flow at the surface and to a depth of 150 m is observed at the other deep stations.

On the basis of calculations of the horizontal current components, the vertical velocity was estimated using the equation of continuity. The results of the vertical current velocity are of the order of 104 cm sec-1

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Characteristics of the current field in the Kastela Bay

M Gacic

Previous studies in the Kastela Bay showed that low-frequency current oscillations in the bay inlet could be related (up to 70%) to the local wind forcing. Surface currents are in the windward direction while the deeper layer currents are in the opposite direction. The wind regime shows strong variability at the synoptic time scale related to the passage of mid-latitude cyclones and fronts over the area. The majority of these disturbances pass over the area during the fall and winter. Prevalent winds are of NE and SE directions. The NE wind generates surface outflow in the bay inlet while SE wind induces surface inflow. It was shown that the kinetic energy of current fluctuations was at a maximum in the intermediate layer. During homogeneous conditions, the kinetic energy was mainly trapped in the bottom layer. Maxima of the kinetic energy coincide with the strong wind events related to cyclone passages. The two-layer current fluctuations are entirely explained in terms of the wind forcing while the barotropic-like current variations are independent of the local wind. In order to study the response of current field to the local wind forcing in the bay interior, in 1988, current measurements were undertaken at a single station in two periods (May 1 through July 6 and August 11 through October 14). Time series of wind data for the same intervals were obtained from the neighbouring meteorological station. In contrast to the previous results for the bay inlet, it was found that the correlation between the local wind and lowfrequency current variability was very poor. This could be related to the

fact that, within the bay, the wind induces complicated circulation pattern and that the position of the station was close to the center of a closed circulation cell. The other explanation is that the bay circulation is to a large extent generated by the remote forcing through the bay inlet. A better understanding of the forcing mechanism could be obtained by numerical modelling and current measurements in the bay inlet and, simultaneously, in its interior.

Low-frequency variability of temperature and salinity fields in the Kastela Bay

V. Kovacevic and M. Gacic

An EOF analysis was applied to the temperature and salinity data sets collected on a bi-weekly basis from a station network in a small-semienclosed bay, the Kastela Bay (Adriatic Sea, Yugoslavia), in the period from February 1953 to March 1954. Temperature and salinity EOFs were determined on the horizontal plane at the surface and depths of 10 and 20 m, and along the vertical axis at four stations (two of them are situated in the Bay inlet, the third in the middle of the Bay and the fourth in the shallow part near the mouth of the River Jadro flowing into the Bay). Results of the analysis show that most of the temperature and salinity variations, related both to horizontal and vertical EOFs, are connected to large scale processes (seasonal cycle), resulting in simultaneous variations over the entire water body of the Bay. These processes are almost entirely represented by the first mode that accounts for 76 to 95% of the variance. However, there is a certain amount of salinity variance (= 10%) that can be related to the processes occurring on the length scales smaller than the basin scale. Horizontally, the eastern shallow part close to the mouth of the river Jadro can be distinguished from the central area and the inlet. Vertically, there is an out-of-phase variation of temperature and salinity in the surface layer, by comparison to deeper layers (10 and 20 m). Time-varying amplitudes of the two most energetic temperatwe and salinity modes were correlated with time-series of the river water level data and the wind stress. The seasonal cycle was removed from both the river water level and wind stress time series. The freshwater inflow seems to affect the surface salinity distribution over the entire Bay within a week. The two layer salinity variations in the inlet are independent of the local wind. On the other hand, they are highly correlated with variations in the river water discharge. The north wind component enables freshwater spreading all over the Bay surface and causes cooling of the entire water body. The east wind component has no important influence on either salinity or temperature distribution in the Bay.

Influence des baroclines sur le regime des courants induits par le vent dans la baie de Kastela (Split)

M. Bone

Partant d'un principe des Equations de champs d'Eckart (1960) est établi le modèle hydrodinamique dont les résultats numériques devraient décrire l'influence des baroclines sur le regime des courants induits par le vent. La difference essentielle entre ce modèle et les autres modèles semblambles de courants induits par le vent, comme, par example, le modèle de Heaps (1974) consiste dans le fait qu'il n'a pas été suppose que le mouvement est. en premier lieu, réglementé par un mécanisme turbulent d'échanges de la quantite de mouvement mais, qu'en principe il satisfait à l'image d'un mouvement dans un fluide idéal.

Pour la stratification, les résultats sont en accord avec le modèle phénoménologique de mouvement de Zore-Armanda (1980) alors que les courants, pour le cas d'une mer homogène, sont plus uniformes dans

leur direction, mais avec deviation vers la droite par rapport à la direction du vent. Cette situation est le résultat de la nature des Equations du module hydrodinamique. On peut observer que, dans le cas d'une mer homogène, avec l'élévation et l'abaisscment du niveau de l'eau, n'apparaissent pas des gradients de pression qui modifieraient les courants dans les modes superieurs.

Estimation of parameters for transport of a pollutant in a coastal sea

T. Legovic and N. Limic

A modelling study of the transport of vinyl-chloride monomer in coastal sea, following leakage from sunken ship, is presented in order to evaluate the impact of several strategies to rescue the pollution load.

Initially, parameters of a stationary and a nonstationary leakage were estimated. The parameters included the intensity of the source, the mean sea current vector, an extinction parameter and a horizontal dispersion coefficient. The estimation was necessary since the behaviour of the substance in real conditions was not known.

First, the results concerning the transient concentration field in an unbounded environment, following possible release, are presented. Second, the results of the stationary leakage are compared for different current regimes in a small bay.

Estimation of Zn, Cu and Pb input into the Punat Bay (Eastern Adriatic)

T. Legovic, N. Limic, V. Valkovic J. Injuk and M Nagj

An important contribution to the input of heavy metals in coastal waters comes through diffuse inflows. A method of estimation is presented that allows determination of the total inflow rate and relative contribution of several inflows.

As an example, measurements of currents and salinity in the Punat Bay (Adriatic Sea) are used to reconstruct the total current field and to estimate the washout rate from the bay. Measurements of concentrations of Zn, Cu and Pb in both water and sediment are used for estimation of the sedimentation rate and input. The total input is partitioned into five contributions corresponding to locations of five sources. Reliability of the results is discussed.

Modelling wind-driven currents in the Adriatic Sea and its relevance for investigating dispersal of pollutants

M. Kuzmic, M. Orlic, Z. Pasaric and Lj. Jeftic

A research on oceanographic processes of transfer and distribution of pollutants often necessitates development of hydrodynamical numerical models. Considering the multitude and complexity of oceanographic processes, it is prudent, when developing such models, to simplify and examine each particular problem separately.

The principal objective of the present work is development of a mathematical modelling tool to study the wind-induced dynamics of the Adriatic Sea, and of the Northern Adriatric in particular. To that end, a simple three-dimensional numerical model of the Northern Adriatic was first devcloped, based on the integral transformation method by N.S. Heaps. The modelling domain was later extended to cover the whole Adriatic. Initially restricted by the assumption of vertically constant eddy viscosity, the Northern Adriatic model was later modified to allow a rather general formulation of eddy viscosity.

The models have been used to study the wind-induced motions on the Adriatic shelf during winter, barotropic conditions. The influence of two characteristic Adriatic winds (bore and scirocco) has been studied in more detail. In particular, the spatially heterogeneous bore (NE) wind field over the Northern Adriatic has been identified as a major factor in determining the wind-induced motions. The modelling study has been supplemented by an analysis (in the time and frequency domains) of the available wind and current data collected in the area. The empirical analysis has clearly shown the pronounced Northern Adriatic response to wind forcing - with bore inducing the strongest, albeit transient, signal in the current field. Empirical data have been also used to validate the model predictions. The model to data comparisons have shown that consideration of vertically variable eddy viscosity and spatially heterogeneous wind field improves the model predictions.

A series of numerical experiments have been also performed to simulate the influence of the scirocco (SE) wind over the Adriatic Sea. An interesting result of these experiments is the persistent double-gyre response obtained in most of the experiments with the broad cyclonic gyre covering most of the Adriatic shelf and the narrow anticyclonic one extending along the Italian coast. Judging by the numerical experiments, the double-gyre response seems probable (topography of the basin supports its reality). However, computer experiments performed to date, although suggestive, have not been exhaustive. Furthermore, although some empirical data seem to favour the double-gyre hypothesis, we have not been able so far to obtain conclusive empirical evidence.

To assess the usefulness of the wind-induced current modelling for investigating dispersal of pollutants, a release of particles has been simulated and trajectories have been computed for selected release points in the Northern Adriatic. This tentative consideration of the advective part of the dispersion problem has clearly shown that spatial variability of the bore wind is an important factor determining the movement of particles and, consequently, the fate of pollutants released into the Adriatic Sea. It is hoped that continuation of this work with hydrodynamical model improvements and inclusion of the pollutant diffusion aspect of the problem will improve our understanding of pollutant transfer in the Northern Adriatic. It should also shed some light on more practical problems, like the dispersion of the River Po waters.

Automatic meteorological-oceanographic station (A M O S)

V.Dadic Dadic M. Ferencak, A. Puskaric and M Glavurtic.

An automatic meteorological-oceanographic station (AMOS) is under development at the Institute of Oceanography and fisheries jointly with the Hydrographic Institute of the Yugoslav Navy in Split. At this phase, one station has been installed in the Kastela Bay, Central Adriatic. The first testing data have given satisfactory results.

AMOS serves for the measurement of various meteorological and oceanographic parameters on the open sea under all meteorological conditions. The main parts of AMOS are: the measuring station with an anchored buoy and measuring instruments, the relais-station with a micro processor unit, and the shore station with a computer system.

The measuring offshore station is of flexible construction retaining permanently its basic configuration, irrespective of how many sensors are installed. This measuring station conception is very important also for

the cases of failure of one or more sensors, so that other sensors may undisturbedly measure and transmit the data to the computer via the relais station.

The main parts of the measuring station are instruments (most of them are of Aanderaa Instruments production), and the buoy with electronics for receiving data from all measuring instruments, their control and sending to the transmitting antenna.

The relais-station with the receiving antenna, microprocessor unit, RS232C interface, and modem is located on the land nearest to the measuring station. It receives data from the measuring station, stores them temporarily, and sends them to the shore computer station using VHF-radio or PTT link. In the shore station, with its computer system and appropriate software, data are received from the relaisstation in real time or under remote control and upon checking and processing they arc stored in the data base for future usage.

The primary advantages of meteorological-oceanographicdata collection by AMOS in relation to classical measurements from the ship are: manyfold cheaper measurements, measurements carried out for a long time without human intervention, measurements carried out under all meteorological conditions, and obtaining of data in real time.

Results of real time data processing using this type of automatic meteorological-oceanographic station represent an important improvement for the monitoring and modelling of different physical processes in the sea as well as for weather forecasts.

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Modélisation hydrodynamique de la Méditerranée occidentale

J.L. Humbert

Le projet MEDMODEL, dirigé par le CETE-Méditerranée, fait ['objet d'un programme de recherche scientifique associant trots laboratoires: le LODYC à Paris, le COM à Marseille/Toulon et 1' IMG à Grenoble. L'objectif final de ce programme est l'élaboration d'un modèle tri-dimensionnel, capable de décrire quantitativement les grands courants marine qui régissent la circulation générale en Méditerranée occidentale. Les i nformat ions seront fournies suivant un maillage de 10 x 10 km et , vertical eme nt , sur 15 nivcaux; elles concernent principalement la direction et h vitesse des courants, la pression et la température. Le programme doit curer quatre ens, les trots premiere années étant consacrées à des études préliminaires (ou études de processes) et la dernière à une synthèse générale permettant d' aboutir au modèle général; nous venons de terminer la première année d'études.

Au cours de cette première année d'études, les taches suivantes ont été réalisées:

A) Connaissance du milieu marin
- Inventaire des différents processus qui régissent la circulation générale.
- Analyse des données existantes concernant le courant Ligurien.
- Conduite et analyse d'une campagne de mesures dans le courant Algérien.

B) Modélisation mathématique

- Adaptation du modèle quasi géostrophique par l'introduclion dcs côtes et des îles et par la prise en compte des échanges et conversions entre couches.
- Etude, à l'aide du modèle Q. des processus concernant le courant Ligurien: forcing par convection d'eau profonde.

- Adaption du modèle tri-dimensionnel: rcstructuralion du code de calcul, introduction de la topographie, paramétrisation de la convection verticals.
- Réalisation d'un solveur rapide 3D dans un domaine parallépipédique puis dans un domaine réaliste (côtes, iles, topographic).

C) Modélisation physique

- Etude de la convection d'eau profonde et du courant Ligurien.

L'avancement des études est conforme au programme prévu et l'équipe MEDMODEL engage tuellement une cooperation avec d'autres équipes européennes (GHER Université de Liège, ENEA-CREA la Spezia, IMGA-CNR, ICM Barcelona), en vue d'une réponse commune à l'appel d'offres de la Commission des Communautés Européennes (MAST-DO XII). Cette coopération permettra de comparer les résultats obtenus avec différents moyens d'étude et de modclisation.

The EROS 2000 programme

J.M. Martin

EROS 2000 (European River Ocean System) is an interdisciplinary long term research programme on biogeochemical processes in the European coastal environment.

Its major aim is to provide basic information in order to find a realistic compromise between the economic development and the protection of the marine environment and its biological resources.

This project profits from the close co-operation of 25 institutions from 11 counlries of the European Community. It is financially supported by the European Commission and relevant agencies from participating countries.

The main objectives of the EROS 2000 programme are:

- to specify the sources and pathways of natural and anthropogenic nutrients and other organic compounds in the European coastal environment;
- to investigate the mechanisms and rates of the processes controlling both the land-sea-air exchanges and internal cycling and fluxes of these compounds in coastal waters;
- to develop process-specifc (e.g. eutrophication) and regional biogeochemical models to predict the long term consequences of man-induced changes.

During the first phase of the programme, which started in 1988, it was decided to focus attention on the North Western Mediterranean Basin.

The activities of the research groups participating in the EROS 2000 project are co-ordinated by a Steering Committee and an Executive Secretariat; they are organized around the following topics:

- Riverine and atmospheric input to marine waters;

- Inorganic processes in coastal waters:

- Bio-organic processes in coastal waters;
- Particles and sediment/water interactions;
- Regional integration, remote sensing and modelling of coastal processes.

In addition to investigations in coastal areas, training activities will be regularly organized with the participation of EROS 2000 scientists, in order to introduce post-graduate students from various industrialized and developing countries to sophisticated technologies and developments of ongoing European environmental research.

One of the expected benefits is to provide a lot of basic data on coastal environmental problems to policy makers in various fields (management of natural resources, industry, agriculture, coastal equipment, tourism, etc.).

These data, through an improved and continuing dialogue with the scientific community, could help the policy makers to be more sensitive to environmental risks and to plan appropriate decisions for a balance between socio-economic development and protection of our future quality of life.

River versus atmospheric inputs to the Western Mediterranean

J.M. Martin

Comparison of atmospheric and river inputs shows that trace metals, such as Cd, Cu. Pb, and artificial radionuclides (^{137}Cs $^{239 + 240}$ Pu) are essentially supplied to the North Western Mediterranean by the atmosphere. Total inorganic N would be equally supplied by both rivers and atmosphere, while 238Pu, 241Am and total P are mainly riverine. It is shown that, despite increasing anthropogenic influence accumulation of several toxic elements remains relatively low in the water column.

Detailed information will be found in:

Martin, 1.M., F. Elbaz-Poulichet, C Guieu, M.D. Loye-Pilot G. Han: River versus atmospheric input of material to the Mediterranean sea: An overview, in press Marine Chem.

Loye-Pilot, M D., J.M. Martin, J. Morelli: Atmospheric input of inorganic nitrogen to the Western Mediterranean, m press Biogeochemistry.

Loye-Pilot, M.D., J.M. Martin, J. Morelli: Influence of Saharan dust on the rain acidity and atmospheric input to the Mediterranean, Nature 321, 1986, 427-428.

ANNEX IV

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