VENICE ADRIATIC WORKSHOP

June 14-16, 2004

CNR–Istituto di Scienze Marine (ISMAR)
Palazzo Papadopoli
San Polo 1364, Venice, Italy

FINAL REPORT

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Organizing Institution:

Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS)

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P.-M. POULAIN, C. LEE, M. ORLIC,
R. SIGNELL & S. CARNIEL

Approved by: ……

Dr. Renzo Mosetti
Director, Oceanography Department

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1. Introduction

Over the past few years, various international research programs have focused on the Adriatic Sea. The ACE, EACE, DOLCEVITA and ADRIA0203 projects concentrated mainly on the dynamics of the northern part of the basin, under the forcing of strong and intermittent wind and river runoff events. The EuroSTRATAFORM project studied the sediment dispersal mechanisms along the Italian coast in the so-called Western Adriatic Current and tried to relate sediment delivery and water column transport to seabed morphology. The ADRICOSM project had the goal to demonstrate the feasibility of Near Real Time (NRT) coastal current forecasts, and to develop the integration of river systems with the coastal current forecasting.

Most of the above-mentioned projects have reached the data analysis/interpretation phase. Some of their results have already been shared and discussed at a workshop organized in Rovinj, Croatia, on 7-9 October 2003 and during a special session of the AGU Ocean Sciences Meeting in Portland, Oregon, on 30 January 2004.

The Rovinj workshop provided the first opportunity for the participants to meet after the field campaign. Its timing in the fall of 2003 allowed investigators an opportunity for initial processing and evaluation of their data. To keep the workshop to a manageable size, it was sharply focused on physical oceanography and the meteorological processes that largely control it.

A more broadly based scientific workshop, the Venice Adriatic Workshop, was organized at CNR-ISMAR in Venice, Italy on 14-16 June 2003 in which the full range of Adriatic phenomena was encompassed. By June 2004, most new Adriatic data sets became ready and available for collaborative research initiatives. Individual investigators presented their salient results and their plans for publishing them. The main goal of the workshop were two-fold:

1) Allow the scientists of the ACE, EACE, DOLCEVITA, ADRIATIC0203, EuroSTRATAFROM and ADRICOSM projects to share and discuss their results and to set the milestones of collaborative research papers in which various data sets are integrated;

2) Enlarge the discussions to non-physical aspects and to research efforts not covered under the research programs named above.

The workshop participants are listed in Section 2. The final program of the workshop and the comments written by the rapporteurs are included as Sections 3 and 4, respectively. Conclusions are in Section 5. The abstracts of all the presentations can be found in an appendix (Section 6).

Funding for this workshop was mainly provided through a grant to OGS (P.-M. Poulain) by the ONR Global Office in London (J. Miller), for which the Organizing Committee is most grateful. Additional funding was provided by OGS.

2. List of Participants

The following list includes the names, affiliations and addresses of all the scientists who participated at the workshop. More than 50 persons were present, coming from Croatia, Italy, the USA, Austria and Belgium. Eleven participants (see names in bold letters in list) were invited using ONRG funding.

First name	Last name	Institution	Address
Riccardo	Barbanti	OGS	Trieste, Italy
Alfredo	Boldrin	CNR-ISMAR	Venice, Italy
Jeff	Book	NRL	Stennis Space Center, MS USA
Stephen	Brandt	NOAA	Ann Arbor, MI USA
Fabio	Brunetti	OGS	Trieste, Italy
Alessandra	Campanelli	CNR-ISMAR	Ancona, Italy
Sandro	Carniel	CNR-ISMAR	Venice, Italy
Massimo	Celio	Marine Biology Laboratory	Trieste, Italy
Ivona	**Cetinic**	University of Zagreb	Zagreb, Croatia
Jacopo	Chiggiato	ARPA-EMR	Bologna, Italy
Gianpiero	Cosarinni	OGS	Trieste, Italy
Marco	Costantini	ICTP	Trieste, Italy
Alessandro	Crise	OGS	Trieste, Italy
Vlado	**Dadic**	Institute of Oceanography and Fisheries	Split, Croatia
Clive	Dorman	SIO	San Diego, CA USA
Pierre	Flament	University of Hawaii	Honolulu, HI USA
Serena	**Fonda Umani**	Marine Biology Laboratory	Trieste, Italy
Miro	**Gacic**	OGS	Trieste, Italy
Michele	Giani	ICRAM	Chioggia, Italy
Federica	Grilli	CNR-ISMAR	Ancona, Italy
Courtney	Harris	Virginia Institute of Marine Science	Gloucester Point, VA USA
Burt	Jones	University of Southern California	Los Angeles, CA USA
Vedrana	Kovacevic	OGS	Trieste, Italy
Milivoj	**Kuzmic**	Rudjer Boskovic Institute	Zagreb, Croatia
Nenad	**Leder**	Hydrographic Institute	Split, Croatia
Craig	Lee	University of Washington	Seattle, WA USA
Mauro	**Marini**	CNR-ISMAR	Ancona, Italy

Elena	Mauri	OGS	Trieste, Italy
Renzo	Mosetti	OGS	Trieste, Italy
Giulio	Notarstefano	OGS	Trieste, Italy
Paolo	Oddo	Università di Bologna	Bologna, Italy
Mirko	Orlic	Andrija Mohorovicic Geophysical Institute	Zagreb, Croatia
Jeffrey	Paduan	NPS	Monterey, CA USA
Mira	Pasaric	Andrija Mohorovicic Geophysical Institute	Zagreb, Croatia
Zoran	Pasaric	Andrija Mohorovicic Geophysical Institute	Zagreb, Croatia
George	Peeters		Belgium
Pierre-Marie	Poulain	OGS	Trieste, Italy
Julie	Pullen	NRL	Monterey, CA USA
Benoit	C.-Roisin	Dartmouth College	Hanover, NH USA
Nello	**Russo**	Università Politecnica delle Marche	Ancona, Italy
Mauro	Sclavo	CNR-ISMAR	Venice, Italy
Rich	**Signell**	NATO SACLANT Undersea Research Centre	La Spezia, Italy
Cosimo	Solidoro	OGS	Trieste, Italy
Nenad	Smodlaka	Center for Marine Research	Rovinj, Croatia
Federico	Spagnoli	CNR-ISMAR	Lesina, Italy
Nastjenjka	Supic	Center for Marine Research	Rovinj, Croatia
Dietmar	**Thaler**	Meteorological Office Austrian Airforce	Aigen, Austria
Laura	Ursella	OGS	Trieste, Italy
Ivica	**Vilibic**	Institute of Oceanography and Fisheries	Split, Croatia
David	Walsh	NRL	Stennis Space Center, MS USA
Anna	Zuccolo	OGS	Trieste, Italy

3. Final Agenda

Monday, 14 June
Rapporteur: Lee

Morning, 9:30 - 13:00 Presider: Poulain

9:30 – 9:45 People meet
9:45 - 10:00 Opening remarks by OGS-OGA Director and CNR-ISMAR Venice Section Head and by Organizing Committee Members
10:00 – 10:05 Discussion/updating of Agenda (Poulain)
10:05 - 10:10 Introduction to physical observations (Poulain)
10:10- 10:20 **Leder, N., H. Mihanovic and I. Vilibic**
Thermohaline fluctuations during East Adriatic Coastal Experiment (November 2002 – June 2003)
10:20 - 10:25 Orlic, M. , M. Pasaric, Z. Pasaric and V. Dadic
Currents recorded during the East Adriatic Coastal Experiment
10:25 - 10:35 **Grbec, B., Dadic,V., Beg Paklar, G., Morovic, M. and Matic, F.**
Results of recent investigations in the Middle Adriatic coastal waters
10:35 - 10:40 Book, J., H. Perkins and R. Signell
ACE/JRP Mooring Data: Data Processing, Results, and Collaboration Possibilities
10:40 - 10:45 Walsh, D.
Response characteristics of sensors in a trawl-resistant "Barny"

10:45 – 11:05 Coffee break

11:05 – 11:15 **Russo, A.**
Adriatic Sea variability: results of recent research activities
11:15 – 11:20 Lee, C., B. J. Jones, R. Arnone, J. Gobat, M. Jeffries, M. Maurini, M. Orlic, Z. Pasaric, H. Peters, P.-M. Poulain, D. Thaler and D. Vilicic.
Shallow water fronts, river plumes and strong forcing- preliminary results from intensive surveys of the northern adriatic
11:20 - 11:25 Ursella, L., P.-M. Poulain, R. Barbanti, R. Signell and R. Barbanti
Circulation dynamics in the Northern Adriatic as measured by surface drifters in relation to wind forcing
11:25 - 11:30 Flament, P., P.-M. Poulain, D. Young, C. Chavanne, F. Brunetti and J. Paduan
Monitoring surface currents in the Northern Adriatic with high frequency coastal radars
11:30 – 11:40 **Gacic, M, V. Kovacevic, I. Macero Mosquera, S. Cosoli and A. Mazzoldi**
Sub-inertial variations of the coast circulatioin and water exchange between the Venetian Lagoon and open sea
11:40 - 11:45 Mauri, E., P.-M. Poulain, S. Hatridge and B. Cushman-Roisin
Variability of the Adriatic Western Coastal Layer as seen in MODIS chlorophyll images
11:45 – 11:50 Notarstefano, G., L. Ursella, E. Mauri and P.-M Poulain
On the thermal diurnal cycle in the Adriatic Sea
11:50 – 11:55 Signell, R. P., J. C. Warner, P.-M. Poulain, J. Chiggiato and S. Carniel
Influence of different vertical mixing schemes and wave breaking parameterisation on forecasting surface velocities
11:55 – 12:00 Askari, F., Signell, R.P, Chiggiato, J., Doyle, J.
RADARSAT Wind Mapping during Bora Events
12:00 – 13:00 Poster Session

13:00 – 14:00 Lunch

Monday, 14 June
Rapporteur: Lee

Afternoon, 14:00 - 18:00 Presider: Orlic

14:00 – 14:05 Introduction to multidisciplinary observations (Orlic)
14:05 – 14:15 **Fonda Umani, S.**
New insights in the "mucilage" mystery
14:15 – 14:20 Celio, M., B. Cermelj, A. Bussani, C. Comici
Gulf of Trieste: comparison between thermohaline features observed during summer periods characterized by different meteomarine conditions
14:20 – 14:25 Costantini, M., E. Arneri, S. Fonda-Umani, A. Russo and S. Brandt
Does the Po River run off affect the distribution of the young-of-the-year anchovy YOY) in the Northern Adriatic Sea
14:25 – 14:35 **Marini, M.**
From the temporal dataset of the Senigallia transect to the features of the water masses of north Adriatic: physical and chemical aspects
14:35 – 14:40 Russo, A., D. Bigazzi, R. P. Signell, J. Chiggiato, M. Marini, F. Grilli, A. Campanelli, A. Artegiani, S. Carniel and M. Sclavo
Influence of physical factors on the autumn 2002 hypoxic event in the North Adriatic Sea bottom layer
14:40 – 14:45 Russo, A., J. Book, H. Perkins, R. Signell, M. Marini, E. Paschini, A. Boldrin, S. Carniel and M. Sclavo
The impact of different water transport determinations on the estimation of North Adriatic horizontal geo-chemical fluxes
14:45 – 14:50 Boldrin, A., M. Giani, M. Marini, F. Bernardi Aubry, A. Campanelli, L. Craboledda, F. Grilli, V. Zangrando
The effects of bora wind in water column distribution of nutrients and suspended matter in the northern adriatic

14:50 – 15:10 Coffee break

15:10 – 15:20 **Cetinic, I. D. Vilicic and Z. Buric**
Phytopalnkton assemblages across the Istiran frontal zone in the Northern Adriatic (RV Knorr and RV Vila Velebita cruises, February 2003
15:20 - 15:25 Jones, B.
Optical Processes and Physical Forcing in the Northern Adriatic Sea
15:25 – 15:30 Harris, C.
Sediment Dispersal Mechanisms within the Adriatic Sea: Recent advances from the EuroStrataform Program.
15:30 – 15:35 Spagnoli, F., F. Fiesoletti, A. Specchiulli, G. Bartholini, A. Conversi
Coastal monitoring network of the Manfredonia Gulf (Southern Adriatic Sea): new observational techniques and instrumentations as part of a monitoring system
15:35 – 18:00 Poster Session

20:00 Social dinner (offered by OGS)

Tuesday, 15 June
Rapporteur: Orlic

Morning, 9:00 - 10:30 Presider: Signell

9:00 – 9:05 Introduction to atmospheric forcing observations (Signell)
9:05 – 9:15 **Thaler, D.**
Weather forecasting and general synopsis during Dolcevita 1 and 2
9:15 – 9:20 Dorman, C.
Northern Adriatic synoptic weather events
9:20 – 9:30 **Grbec, B., Matic, F., Marki, A. and Vilibic, I**
Air-sea fluxes (winter-spring 2003) over the EACE polygon
9:30 – 9:40 **Signell,R., J. Book, S. Carniel, J. Chiggiato, J. Doyle, H. Perkins, J. Pullen, A. Russo**
Indirect determination of surface heat fluxes in the Northern Adriatic Sea via the heat budget
9:40 – 9:45 Signell, R.P., Sherwood, C.R., Book, J.
Modeling the bottom energy environment in the Adriatic Sea
09:45 – 10:30 Poster Session

10:45 – 11:05 Coffee break

Morning, 10:50 - 13:00 Presider: Carniel

10:50 – 10:55 Introduction to modeling/theoretical works (Carniel)
10:55 - 11:05 **Grezio, A. N. Pinardi, P. Oddo, A. Coluccelli, M. Zavatarelli**
Data Assimilation and Ocean Forecasting in the Adriatic Sea.
11:05 – 11:10 Oddo, P., N. Pinardi, M. Zavatarelli and A. Coluccelli
Simulating and forecasting the Adriatic Sea (2000-2003).
11:10 – 11:15 Cushman-Roisin, B. & K. Korotenko
Modeling of the mesoscale circulation in the Adriatic Sea
11:15 – 11:20 Martin, P., J.Book, Z.. Hallock,and H. Perkins
Numerical simulations of the Adriatic Sea during ACE
11:20 – 11:25 Pullen, J., J. Doyle and R. Signell
Adriatic Air-Sea Coupling
11:25 – 11:35 **Janekovic, I., M. Kuzmic, J. Book & H. Perkins**
A tidal model of the Adriatic Sea: ACE/WISE contribution to its current response validation
11:35 – 13:00 Poster Session

13:00-14:00 Lunch

Afternoon, 14:00 - 18:00 Presider: Lee

14:00 – 14:30 General discussion of research issues
14:30 – 15:40 Separate sessions (Moderators: Signell, Poulain and Lee; Rapporteurs: Carniel, Jones, Orlic)

15:40 – 16:00 Coffee break

16:00 - 17:00 General discussions

Wednesday, 16 June
Rapporteur: Carniel

Morning 9:00 - 13:00 Presider: Signell
9:00 – 9:30 Signell, R. Status of databases and data sharing agreements
9:30 – 10:40 Presentations by Book, Signell, Russo and Poulain

10 :40 – 11 :00 Coffee break

11:00 – 12:30 General discussions
11:30 – 12:00 Concluding remarks by Poulain

4. Comments on Oral Presentations and Discussion Sessions

Monday, 14 June
Rapporteur: Lee

Dr. R. Mosetti (Director OGA-OGS), Dr. M. Sclavo (Responsible CNR-ISMAR Venice) and Dr. P.-M. Poulain (Workshop Chair) opened the meeting with welcoming remarks. The members of Organizing Committee introduce themselves, followed by individual presentations of all the participants throughout the meeting room.

Poulain: Pierre followed with the explanation of the meeting format. To ensure that ample time remains for collaborative discussion, oral presentations will be limited to five minutes each (ten minutes for invited speakers). Presenters were encouraged to supplement talks with posters, all of which are on display in the nearby poster room and adjoining hallways. Pierre noted that there has been a surge of activity in the Adriatic over the past two years, with several intensive studies (e.g. ACE, EUROSTRATAFORM, ADRICOSM, EACE, DOLCEVITA) offering new perspectives and building on past efforts.

Leder et al.: Nenad discussed results from the hydrographic survey component of the East Adriatic Circulation Experiment (EACE). Seven surveys taken over the course of one year reveal strong surface heat loss and a vertically homogenous water column between November and February, with the most intense forcing occurring in January and February. Strong lateral (both along- and across-basin) temperature and salinity gradients were present during wintertime, with the densest water to the northwest. A strong thermocline developed in May, with salinity increasing throughout the year, possibly due to in flow of Levantine Intermediate Waters.

Orlic et al.: Velocity timeseries collected as part of EACE revealed peak alongshore currents in February and May. The barotropic flow includes significant energy associated with tides (12 and 24 h) and seiches (21 h), while baroclinic inertial oscillations (17 h) appear with the springtime onset of stratification. Seiches thus contribute significantly to velocity variability, which may complicate data analysis efforts. Previously, concerns focused on understanding tidal variability. Velocity records also show strong fluctuations with periods of approximately 10 days. These 10 day oscillations are not yet understood. Finally, Mirko notes that he and Hartmut Peters have submitted a manuscript describing turbulence measurements conducted in spring 2003.

Grbec et al. (Dadic presenting): Bi-weekly (weekly in spring/summer) measurements conducted during 2002/2003 along the Croatian coast between the Cetina and Neretva River outflows reveal significant deviations from climatological fields. Observed surface layer temperatures and salinities were higher that climatology, perhaps due to anomalous atmospheric forcing. During 2002/2003, both wintertime heat loss and spring/summertime warming were larger than average.

Book et al.: Jeff provided an overview of the Adriatic Circulation Experiment (ACE) moored array. Extensive data processing efforts include an attempt to recover near-surface measurements by carefully identifying the sea surface and extracting the shallowest bin containing uncontaminated returns. Early results include identification of wintertime near-inertial oscillations, perhaps associated with stratification introduced by offshore extensions of the Po River plume and signs of plankton migration in ADCP echo intensity data.

Walsh: Described attempts to correct for the slow response time of conductivity sensors mounted inside the NRL-SACLANTCEN Barny housings. Slow flushing rates through Barney housings

limits sensor response times, producing large lags in conductivity and temperature measurements. Timeseries from internally and externally mounted sensors are being used to develop a transfer function to improve results from internally mounted instruments.

Russo: Two studies (MAT, 1999-2003 and SYNAPSI, 2000-2004) provide measurements for investigating interannual and decadal variability. The Eastern Mediterranean Transient produced shifts in bottom water properties through the 90's, with the density of southern Adriatic Bottom Water decreasing such that the Adriatic no longer supplies Eastern Mediterranean Deep Water. Additionally, Northern Adriatic surface temperatures have increased since the late 80's.

Lee et al.: High-resolution wintertime surveys of the Northern and Central Adriatic characterize the response to strong Bora forcing. Two dense water pools form in response to a Bora event, one beneath the Trieste Bora pathway and the other beneath the jet extending from Kvaner Bay. An offshore extension of the Po plume separates the two pools with a region of stratified, less saline water. The presence of two dense water formation sites is tentatively attributed to Bora forcing through two distinct mechanisms: (1) small-scale variations in wind speed, and thus net surface heat flux, associated with the distinct Bora jets and (2) lateral advection of light, surface-trapped Po River plume waters into the area between Bora jets, which introduces stratification and damps dense water formation. A separate poster (Jeffries and Lee) details results from a new Adriatic climatology. The novel aspect of this effort is that data have been organized by dominant atmospheric forcing (Bora, Sirocco), river outflow (high and low Po discharge) and stratification, providing an improved characterization of different dynamical regimes.

Ursella et al.: Surface drifter data are organized by wind-forcing regime using COAMPS model data to define the spatial and temporal structure of the wind field. When organized according to wind-forcing, drifter data identify distinct circulation features that cannot be seen in the aggregate analysis. Especially for Bora events, this analysis extracts small-scale features that are consistent with expectations from previous investigations.

Flament et al.: Pierre summarized the High-Frequency (WERA) Coastal Radar effort associated with DOLCE VITA. Three radars were installed along the Italian coast to provide surface velocity maps over much of the Northern Adriatic. Solar fluctuations that occurred during the measurement period introduced contamination that has complicated data processing. Efforts are underway to use WERA data to estimate Western Adriatic Current transport. This will require a method for extrapolate surface currents downward to provide an estimated velocity profile that extends over the entire water column.

Gacic et al.: Tidal frequency variability (M2 and S2) dominates velocity measurements at three inlets to the Venetian lagoon, while Adriatic seiches control much of the low-frequency flow. Sub-inertial (non-tidal) inflow into the Venice lagoon correlates with cross-basin winds (especially Bora). Strong cross-basin forcing can push the boundary current against the openings to the Venice lagoon, modulating exchange.

Mauri et al.: Optical properties measured using remotely sensed ocean color (MODIS) and surface drifters instrumented with optical sensors provide a tracer for following features associated with the Western Adriatic Current. Although temperature contrasts are often small, coastal and Po river plume waters carry a distinctive signature. Remotely sensed images reveal filaments of Po plume water advected across the Northern Adriatic, extending to the Istrian coast in response to Bora forcing.

Notarstefano et al.: Sea surface temperature diurnal cycle observed by remote sensing show larger daily temperature differences (2 °C) than that measured in situ using surface drifters (0.5 °C). The in situ diurnal cycle also lags that measured by remote sensing. The thin skin measured by remote sensing responds to surface heating more rapidly and more intensely than the underlying water column (measured by the drifters), perhaps explaining the observations.

Carniel et al.: Sandro discussed tests of various turbulence closure schemes and their effects on regional numerical simulations. Namely, from the necessity of having a high-fidelity simulation of the upper oceanic layer, the effects that different parameterisations of vertical mixings may have on reproducing surface velocities and how these are influenced by including breaking waves dynamics by means of turbulent kinetic energy injection are presented. These issues are addressed by employing the Regional Ocean Model System.

Signell et al.: Radarsat images provide high-resolution (perhaps as fine as 200 m) wind maps of selected Bora events. The images show narrow Bora wind jets that retain intensity and spatial structure as they cross the Adriatic. Some discussion focused on whether Radarsat could provide reliable wind estimates in Kvarner Bay. A particularly interesting feature was apparent southeastward winds along the Italian coast.

Fonda Umani: Serena presented results from a three-year study in the Gulf of Trieste of the microbial community's role in determining dissolved organic carbon concentration.

Celio et al.: Massimo uses hydrographic measurements conducted in the summers of 2001 and 2003 to argue that interannual thermohaline variability in the Gulf of Trieste depends strongly on variations in riverine freshwater inflow and wind forcing.

Marini: Mauro uses repeated occupations of the Senegalia line from 1988 to the present to illustrate interannual variability in thermohaline structure and chemical tracers.

Russo et al (2 talks).: Measurements collected during two autumn 2002 cruises are used to characterize development of a hypoxic event. Hypoxic waters were found in areas covered by the surface-trapped Po plume. Model results suggest that hypoxic regions experience only weak currents, and that wind-forcing regulates their development. Nello also contrasted different approaches for estimating geochemical fluxes.

Boldrin et al.: Two field programs sampled the Northern Adriatic before and after an autumn 2002 Bora event. Hydrographic properties from the two surveys are contrasted, with changes attribute to Bora-forced water mass modification.

Costantini et al.: Hydrographic and fisheries surveys find young-of-the-year anchovies closely associated with Po River plume waters. Plume waters exhibit elevated chlorophyll fluorescence (suggesting large phytoplankton populations), forming a front with offshore waters containing lower chlorophyll concentrations. Young-of-the-year anchovy were found inshore of the front, within the front itself and within water masses thought to have originated as part of the Po plume.

Cetinic et al.: Intensive surveys across a wintertime front found off the tip of Istria revealed elevated micro-phytoplankton concentrations on the cold side of the front, with lower concentrations on the warm side. Maximum phytoplankton concentrations were found in the northwest corner of the survey, at the downstream end of the offshore-flowing current. Ivona also

notes that the phytoplankton evolve at timescales similar to that of the front, suggesting that phytoplankton populations might be useful as a semi-passive tracer.

Jones: Measurements collected in winter and spring 2003 suggest that physical forcing dominates evolution of wintertime optical variability, while phytoplankton dynamics govern springtime optical properties. In both seasons, Po River discharge produces a strong optical signal, partially due to suspended particulates and partly from biological response to the induced stratification and nutrient influx. Along the Croatian coast, optical signals were weaker during both seasons.

Harris: Courtney discussed results from the EUROSTRATAFORM program. Measurements of long-term deposition in the Adriatic are being compared with observable processes in an attempt to understand the mechanisms governing Adriatic sediment transport. Bora events intensify the Western Adriatic Current and generate energetic waves, accelerating sediment transport. Sirocco winds weaken the WAC and produce less energetic waves, leading to weaker sediment transport.

Spagnoli et al.: Two new platforms will provide real-time physical and biogeochemical measurements in the central Adriatic. A mooring will accommodate meteorological and oceanographic sensors, with data telemetry provided by short text messaging on a standard GSM network. An eight meter research vessel will also be equipped for multi-disciplinary sampling.

Tuesday, 15 June
Rapporteur: Orlic

Signell : Rich stressed the importance of meteorological analyzes and forecasts for the organization of cruises and for the study of oceanographic data collected.

Thaler: Dietmar described his experience of forecasting meteorologists aboard R/V Knorr. He then overviewed weather conditions prevailing during the February and May/June 2003 cruises and surface fluxes computed from shipborne data. Finally, he concentrated on various types of the bora wind and briefly commented on the possible influence of the sea on the atmosphere.

Dorman: Clive presented statistical results following from radiosonde measurements performed at Zadar during winter 2002/2003. He also discussed winds and surface fluxes resulting from data collected aboard R/V Knorr and at a number of oil-drilling platforms positioned in Italian waters. He paid particular attention to two main winds in the area – bora and sirocco – and associated weather conditions.

Grbec et al.(Vilibic presenting): Ivica showed surface heat fluxes computed from Veli Rat data and compared them with temperatures collected on the EACE polygon. He also discussed how surface water fluxes compare with the salinity data. It was shown that during winter 2003 the whole water column was intensively cooled and that in spring 2003 the surface layers got warmer than usual. Salinity in spring 2003 considerably surpassed average values, partially due to the strong evaporation and weak precipitation.

Signell et al. (Chiggiato presenting): Jacopo showed results of modeling the influence of the surface fluxes and the advective fluxes across the Senigallia-Susak line on the heat content of the Northern Adriatic in the years 2002 and 2003. It was found that the heat content of the region is under almost complete control of the surface fluxes, advective fluxes being small – both according to the modeling results and measurements. Modeled heat content was compared to estimates based on SST measurements. It was found that LAMI and COAMPS surface fluxes are too high.

Signell et al.: Rich commented on the way bottom stress is controlled by the wind waves and currents. He showed how the stress was computed by using ROMS, SWAN and two different meteorological models (LAMI, COAMPS) and how the modeling results were compared with the observations. Finally, he discussed the spatial variability of the bottom energy environment in the years 2002 and 2003.

Carniel: Sandro briefly described various modeling efforts that are presently undertaken in the Adriatic.

Grezio et al. (Oddo presenting): Paolo overviewed the project ADRICOSM, and in particular its various components: oceanographic observations, oceanographic modeling, hydrological observations, hydrological modeling. He then concentrated on the way oceanographic hindcasting and forecasting system was built, and on the assimilation of both the open sea and coastal data in the Adriatic implementation of POM in order to get initial conditions for the predictions.

Oddo et al.: Paolo showed results of simulations with the Adriatic version of POM for the 2000-2003 period as well as forecasts for the 2003-2004 interval. The former were verified against the data collected during MAT and ADRIA01 projects, the latter by using the data recently taken in the area. Simulations showed a pronounced year-to-year variability of circulation patterns, controlled by the corresponding variability of atmospheric conditions.

Cushman-Roisin and Korotenko: Benoit showed results of the Adriatic simulations performed with two models (DieCAST and POM) and for various winds (bora, sirocco, levante, maestro). He concentrated on mesoscale variability developing along the Italian coast in various years (2001, 2003). It was shown that DieCast reproduces the variability better than POM. The wavelengths of the variability were found to depend on internal Rossby radius of deformation, the amplitudes on the cross-basin bottom slope.

Martin et al. (Book presenting): Jeff presented results of the Adriatic modeling done with NCOM for Sep/2002-Apr/2003 interval. Modeling results were tested against the ADCP and CTD data. Jeff then concentrated on the simulations for a case of sirocco and a case of bora. Under the sirocco influence cyclonic flow developed in the area, signaling that the wind-curl effect was in this case more important than the bottom-slope effect. Circulation forced by bora mostly followed expected pattern, except that an anticyclonic small-scale feature occurred off Susak – in agreement with the data collected in the area.

Pullen et al.: Julie described results of the coupled COAMPS/NCOM modeling of the Adriatic during fall 2002. The modeling results were compared with the open-sea meteorological measurements and with remote and in situ measurements of sea temperature. Both the influence of the atmosphere on the sea and the feedback of the sea on the atmosphere were considered. It was shown that the two-way coupled model gave better results than the one-way coupled simulation.

Janekovic et al. (Kuzmic presenting): Mike showed how Quoddy was used to simulate tidal variability in the Adriatic. Selected tide-gauge data were inverted in order to get boundary conditions at Otranto for seven tidal constituents, whereupon tidal sea levels and currents were computed for the basin interior. Modeling results were generally found to agree with the data. Exceptions are sea levels at Zadar and currents at a station off Rovinj – they are still lacking a proper interpretation.

General discussion:

Craig Lee mentioned that the group is expected to produce report on activities in the Adriatic in the years 2002 and 2003 for a possible publication in e.g. EOS. The proposal was unanimously accepted. Craig will take the lead on this work.

Craig also said that the time seems ripe for a special issue of a journal. After some discussion it was agreed that the target journal is "Journal of Geophysical Research", and that the deadline for the submission of manuscripts should be 1 March 2005.

Finally, Craig asked participants in the workshop to randomly divide in three working groups. They were asked to discuss topics which could stimulate work on collaborative papers.

Meeting of working groups:

The three working groups were moderated by Signell, Poulain and Lee, and the notes were taken by Carniel, Jones and Orlic.

General discussion:

The three working groups reconvened and reported on the topics they had discussed. These were:

First group: Describing a bora event, Dense water formation, Estimation of biogeochemical fluxes, Near-surface currents, Anoxia, Model evaluation

Second group: Sediment transport, Ecosystem models, Adriatic-Mediterranean connections, Heat, salt and nitrogen budgets

Third group: Dense water formation, Residence times, Optical variability (satellite vs. in situ), Biogeochemical fluxes

After some discussion it was concluded that the following topics are most promising for the future collaborative work:

- Describing a bora event
- Dense water formation
- Estimation of biogeochemical fluxes and budgets, sediments
- Model evaluation and near-surface currents
- Residence times, ecosystem modeling, anoxia

Craig asked the participants to prepare for the discussion of these topics during the next morning session.

Wednesday, 16 June

Rapporteur: Carniel

Data exchange:

Signell reminds everybody about the "adria23" site hosted at the USGS, excellent way to communicate but not exactly suitable to store or exchange large amount of data. Data storage is currently hosted at http://radlab.soest.hawaii.edu/adria/ , where different subdirectories for data and products can be reached (password protected).

For example:

- Data from AGIP platforms, kriged drifter data, latest ADCP data, CTD in ODV format, etc.
- Model outputs: COAMPS (wind, air temp, rel hum, air press, short wave rad, sens, latent, topography), LAMI (wind, air temp, rel hum, air press, short wave rad, cloud), SWAN wave model output, ROMS circulation model output. ADRICOSM products could be made available soon since they are in NetCDF).

Discussion of Research Topics:

1. Dense Water Formation (DWF):

Signell presents different results from a ROMS run having 26 or 48 rivers run. DWF is highly sensitive to this, but at the moment only climatological river values are available. It would be of great benefit to have access to river data.

Gacic notices that the density is usually 29.4 in the center of the south Adriatic, but Lee measured 29.7-29.8 in the north during 23-24 February 2003.

The DWF does not seem to happen in Kvarnar bay, but rather outside of it. The model resolution there is about 3 km and then some passages were virtually opened up in the simulation.

Book presents salinity values measured at 3 barny sites, SS2 close to the Italian shelf, CP2 near the Po River, and KB1. Generally they tracked each other, while SS2 has the lowest salinity and minimum temperature is registered at VR5 in March.

Lee presents 2 different transects separated by 20 days along the Adriatic axis. Noteworthy, a stripe of 2 km, 29.4 density, dT=1 °C in 100 m, appears suddenly with a large value of beam attenuation (cabelling?). Bora was blowing, causing a strong current from the Croatian to the Italian coasts. Maybe this is due to lateral advection of dense water formed in Kvarner bay? Which is the direction of the flow along the transect? It would be interesting to check this with the ADCP measurements.

Gacic points out that during Bora the water is collecting from the southern part of Kvarner bay and drag out from the northern region, along the Istrian coast, therefore bringing the southern fresher water (which is influenced by several freshwater sources). Kuzmic high resolution tidal model could help to see if we are getting the right volume with other modeling tools.

2. Describing a Bora event:

Book describes a bora event on february 10 and february 17, 2003.

Poulain reminds that the bora event influenced the drifters trajectories and that the Kvarnar bay fronts structure remains to be investigated. He also shows a movie with drifter trajectories and present the Adriatic drifter data base available on the web.

3. Biogeochemical (BGC) fluxes and sediments:

All available measurements along the section used to compute the BGC fluxes were collected in a particular day. As a consequence, when carrying out the computation it must be remembered that there are huge fluctuations during days, which is affecting the resulting fluxes. Russo points out that we could use several different BGC variables to integrate and assess the seasonal variability of the fluxes.

4. Model evaluation and near surface currents:

Book wishes to have an inter-model comparison among different Adriatic sea numerical models. Signell suggests that it could be worth to compare realistic simulations, comparing results maybe at the mooring sites. Orlic wishes to have at least a list of models employed and available, in order to better keep track of their evolution. Signell reminds that different mixing schemes are expected to give different statistics. In this direction, the drifters data are to be fully explored to provide ground truth to the models.

5. Residence times, ecosystem modeling and anoxia:

Several speakers remind how relevant are numerical models in the computation of the residence time. While it seems that there is a lack in the competency of applying ecological models, it appears that the anoxia phenomena described in the presentation by Russo et al. is mainly triggered by physical and not biological activities.

Final remarks:

Questions of where and when the next meeting should be organized were discussed. Combining the meeting with another science event was considered. The time frame converged toward spring or summer 2005. The following locations were proposed:

1) Dubrovnik (as a dedicated workshop organized by Croatian colleagues, e.g., by M. Orlic et al.)
2) Vienna (as a special session of the European Geosciences Union General Assembly, 25-29 April 2005)
3) Paris (as a special session of the 2005 International Ocean Research Conference, 6-10 June 2005).

It was decided to gather most of the workshop presentations on a dedicated web page (password protected): http://radlab.soest.hawaii.edu/adria/meetings/venice2004/

Poulain concluded the meeting by thanking all the participants for coming and contributing exciting results and ideas on Adriatic oceanography. He also thanked the CNR-ISMAR and OGS staff for helping with the meeting logistics. Rounds of applause were given to A. Zuccolo (Workshop Secretary) and to P. Poulain (Chair) and S. Carniel (Local Host).

5. Conclusions

In general, the workshop was very successful. The format with oral introductions and posters, and general and divided discussion sessions, worked well and allowed the participants to present their results and share ideas in a very efficient way during the limited time of the meeting. The information shared on most of the recent oceanographic activities in the Adriatic was beneficial for the individual scientists in order to put their own results in a global Adriatic perspective. Discussions of non-physical research topics were particularly informative.

Several milestones were set to produce collaborative research papers. It was agree that some of them could be published in a special section of the Journal of Geophysical Research. The target deadline was set to 1 March 2005. Some members of the Organizing committee volunteered themselves to be guest-editors.

It was agreed that a new meeting (maybe the last one of this series) is necessary in 2005 in order to present final results of the Adriatic investigations and draw final conclusions and recommendations for future Adriatic Research. This meeting could be in the form of a more formal conference widely open to the oceanographic community. Spring or summer 2005 was proposed as time period to organize this meeting.

6. Appendix: Abstracts of Presentations

Most presentations (powerpoint introductions and posters) are available through the following web site:

http://radlab.soest.hawaii.edu/adria/meetings/venice2004/

RADARSAT mapping of bora winds in the Adriatic Sea

F. Askari and R. Signell
NATO Undersea Research Centre, La Spezia, Italy

J.Doyle and J. Pullen
NRL, Monterey, CA, USA

J. Chiggiato
ARPA Emilia Romagna, Bologna, Italy

We examine the spatial variability of the wind/roughness fields over the Adriatic Sea during two Bora events (Jan 26 and Feb 12, 2003) using RADARSAT synthetic aperture radar (SAR) imagery, insitu measurements, and simulations derived from high-resolution atmospheric models: Limited Area Model Italy (LAMI) and Coupled Ocean/Atmosphere Meso-scale Prediction System (COAMPS).

The effects of bora wind in water column distribution of nutrients and suspended matter in the northern adriatic

A. Boldrin, M. Giani, M. Marini, F. Bernardi Aubry, A. Campanelli, L. Craboledda, F. Grilli and V. Zangrando

CNR-ISMAR, Venice, Italy, CNR-ISMAR, Ancona, Italy, ICRAM, Chioggia , Italy

The distribution of hydrochemical and biological parameters of water column in September-October 2002 was analysed during the ANOSSIA and ADRIA02 cruises carried out in Northern Adriatic. Dissolved oxygen, dissolved inorganic nutrients (nitrate, nitrite, ammonium, silicate and phosphate), dissolved organic carbon and suspended matter characteristics and composition (total amount, organic carbon, nitrogen, phosphorous, chlorophyll a, phaeopigments, size distribution of particles, phytoplankton) were described in relation to hydrology and meteorological conditions.

During the observed period, Bora winds caused cooling and mixing in the upper layers modifying the biogeochemical features of the Northern Adriatic Waters. The effects of this event on the distribution of the considered parameters will be presented.

ACE/JRP mooring data: Data processing, results, and collaboration possibilities

J.W. Book[1], H. Perkins[1], and R. Signell[2]

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[2]NATO Undersea Research Centre, La Spezia, Italy

From September 2002 to May of 2003 as a part of a joint research program (JRP), the U.S. Naval Research Laboratory and the NATO Undersea Research Centre deployed fifteen upward looking, bottom mounted Acoustic Doppler Current Meters (ADCP) in the northern Adriatic Sea. The ADCPs, with one exception, were housed in trawl-resistant bottom mounts referred to as Barnys that protected the instruments through repeated trawl hits. Twelve of the Barnys also contained wave/tide gauges. These instruments measured time-series of pressure fluctuations averaged over 20 minute intervals for studies of barotropic pressure fluctuations including those induced by tides. They also measured the pressure at 2 Hz for short bursts of 150 seconds every 6 hours for the study of surface waves. For many of the sites, the attenuation of surface wave pressure fluctuations with depth allows the wave/tide gauges to observe only the largest amplitude waves. Both the ADCPs and the wave/tide gauges measured bottom temperature and in three Barnys, measurements were also made of bottom salinity. The temperature and salinity observations will be discussed in detail in another contributed paper to the workshop.

The ADCP setups varied from site to site, but with one exception the ADCPs all measured currents by burst sampling for 1-2 minutes every 15 minutes. These data were then processed to produce hourly estimates of the water column currents. The processing and corrections applied to the 15 minute data are: corrections for magnetic variation, corrections for compass drift at some sites, exclusion of data contaminated by sea surface echo returns, exclusion of data ensembles where most ADCP pings yielded unusable data, exclusion of data with high disagreements in estimates of vertical velocity that also show statistically different distributions of horizontal currents, and exclusion of data contaminated by echoes from pelagic fish. The processing used to produce the hourly estimates include: exclusion of depth bins with less than 50% data, least-squares harmonic fit and removal of tidal currents, interpolation of residual currents through small data gaps and to a common time base, low-pass filtering of data using a 2-hour cutoff period, re-addition of tidal currents, and decimation of data to hourly samples.

General results obtained from the ADCP data will be presented with a focus on the observations of the sea's response to large Sirocco and Bora winds. Some results will also be shown from the ADCP echo intensity data, which are impacted by sediment and/or biota present in the water column. Results from the wave bursting and the low-frequency sea-surface response measured by the wave/tide gauges will also be presented. .

Gulf of Trieste: Comparison between thermohaline features observed during summer periods characterized by different meteo-marine conditions

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The Gulf of Trieste (Northern Adriatic Sea) is a semi-enclosed basin whose hydrographic features are constrained by hydrological inputs and meteorological forcing, that cause a high inter-annual variability of the thermohaline properties in the summer period. This study shows different features that were observed in July 2001 and July 2003 and compares these two months with the averaged fields obtained from the analysis of 451 CTD profiles. These were collected by the Laboratory of Marine Biology of Trieste (Italy) and by the Marine Biology Station of Piran (Slovenia) from 1991 to 2001.

Fresh water inputs are one of the most important factors affecting the gulf's dynamics. In particular, the Isonzo River, the main river of the basin, has an annual mean flow rate of 100-150 m^3/s. During years 2001 and 2003 the annual mean flow rates were 120 m^3/s and 37 m^3/s respectively. From October 2000 to June 2001 the mean flow rate was 250 m^3/s, while during the same interval in years 2002-2003 the mean flow rate was 62 m^3/s. This hydrological difference seriously affected temperature and salinity of the basin in July 2001 and July 2003.

The T-S diagrams show two different structures of the water column: in July 2001 the water mass with a salinity of 33.5-37.5 extended from the surface to bottom; at the surface temperature was 25-26°C and the vertical thermal stratification was relatively weak (maximum gradient: 5°C/10 m). Contrary to that, a water mass of high salinity (>38) characterized almost the whole water column in July 2003, with a strong vertical thermal gradient (maximum gradient: 8°C/10 m), and the surface temperature exceeded 27°C. The thermohaline properties of the Gulf in July 2001 look more similar to the climatological (1991-2001) temperature-salinity distribution of July, with maximum and minimum temperatures that are about 1°C higher. In July 2003 the thermohaline structure differs from climatology pronouncedly due to high salinity and temperature at the surface of the Gulf.

Moreover, a different horizontal distribution of the surface salinity in July 2001 and July 2003 was observed. In July 2001 a southward horizontal gradient of salinity was present, while in July 2003 the gradient was reversed. These observations clearly show a modification in the distribution of the water masses in the Gulf that affects the water mass exchange between the Northern Adriatic and the Gulf of Trieste.

Phytoplankton assemblages across the Istrian frontal zone in the Northern Adriatic (RV Knorr and RV Vila Velebita cruises, February 2003)

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Phytoplankton distribution in the Northern Adriatic was analyzed using 109 discrete water samples, taken on 86 stations, during the RV Knorr and RV Vila Velebita cruises in February 2003. We used microphytoplankton species as biomarkers to investigate relationship between water movements and resulting biological properties. Different microphytoplankton assemblages were found across the Istrian front. Assemblages emerging from the species-abundance data were analysed by the method of Multi Dimensional Scaling (MDS), providing evidence of the complex structure of phytoplankton communities in February.

Does the Po River run off affect the distribution of the young-of-the-year anchovy (YOY) in the Northern Adriatic Sea?

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[5]NOAA Great Lakes Environmental Research Laboratory, Ann Arbor, MI USA

To answer the question sampling along line transects took place during two scientific cruises, one in October 2003 and one in May 2003, in the Northern Adriatic Sea, over a period of 1 week each time. The first one was carried out where the river run off generated a front all along the western shore, the second close to the plume.

Along the transects water column properties were determined from CTD measurements, fish distribution from echo surveys and coupling echosounder data and net sampling. Fish collected were measured and weighted. Hydrographic features were used to identify boundaries between habitats: IF (inside the front/plume - inshore); F (front/plume area); OF (outside the front/plume – offshore). In October a vertical front of salinity and fluorescence was detected. The presence of relatively high concentration of phytoplankton biomass inshore (IF - F), indicated by the higher values of fluorescence recorded, suggests that the hydrographic barrier may strongly enhances primary production in that area. In May the watermass generated by the river run off floated over seawaters with higher salinity and lower temperature.In October young of the year (YOY) anchovies were detected and collected only inshore (IF) and in the frontal area (F). Most of them were large post-larvae and early juveniles. In May they were distributed in two areas, inshore (IF - F) as in October, in the plume, and offshore over the thermocline close to a watermass originated by the river run off. Inshore they were juveniles, offshore most of them were slightly larger (> 90 mm in total length). Our results highlight the influence of the Po river run on YOY anchovies distribution. Overlays between hydrographic features and echo surveys data suggests that fish move to find suitable feeding conditions.

This research is part of the “Regional Collaboration in Environmental Monitoring and Forecasting in the Northern Adriatic Sea Project” and was carried out by N.O.AA. Great Lakes Environmental Research Laboratory (Ann Arbor, Michigan, U.S.), ISMAR-CNR Sezione Pesca Marittima di Ancona (Ancona, Italy) and Laboratory of Marine Biology (University of Trieste, Italy).

Results of recent investigation in the middle Adriatic coastal waters

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The Croatian part of the middle Adriatic coastal are is pointed as a region where fresh water input from the eastern Adriatic coast is observed, especially from the Cetina and Neretva rivers, whereas in the offshore waters influence of the northern Adriatic rivers during the stratified period might be significant. In this area thermohaline properties were measured bi-weekly in the cold season 2002/2003 and weekly in the warm season 2003 at 14 stations. The data set collected has space and time coverage suitable for comparison with general thermohaline climatology of the region. Temporal salinity changes registered during the experiment show strong departures from the typical annual cycle in which salinity follows average E-P variability. Throughout the experiment high salinity values were measured as a consequence of unusual spring-summer atmospheric conditions. Due to the heating season being anomalously long and strong, measured temperatures were also higher than the long-term averages.

Northern Adriatic synoptic weather events

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Synoptic weather events over the Northern Adriatic are examined during the winter of 2002/3. Relatively weak conditions persist for significant amount of the time. This is interrupted by are cold air outbreaks from the NE (Boras) that push out over the warmer Adriatic, forcing an unstable atmospheric boundary layer with unusually intense horizontal wind gusts and large heat losses from the Sea. Narrow wind jets linked to Croatian coastal topography extend almost completely across the Adriatic.

Correlation over the N. Adriatic is high. Most events behave as lee side, intensification episodes over the Croatian Coast, with have stronger winds in the lower 600 m and weaker winds above. The maximum occurrence of events is in January and February. Less frequent, are moderate winds from the SE, lasting for 1- 3 days, with relatively warm air, stable conditions and reduced heat looses. These events have a longer season and are most apparent early and late in the season.

Monitoring surface currents in the Northern Adriatic with high frequency coastal radars

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As part of the ONR-sponsored DOLCEVITA program high frequency coastal radars were installed in the Northern Adriatic starting in September 2002 to monitor the surface circulation in most areas of the Northern Adriatic until the end of 2003.

The high frequency radars used are WERA systems manufactured by Helzel Messtechnik in Kaltenkrichen, Germany in collaboration with the University of Hamburg. They are operated near 16 MHz in both beam-forming and direction-finding modes. Three radar sites were installed along the Italian coast south of the Po River delta. The northernmost site located on the delta (Faro di Goro, Goro) includes a linear array of 16 antennas (beam-forming), whereas the intermediate (Punta Marina, Ravenna) and the southernmost (Parco San Bartolo, Pesaro) sites consist of 4 antennas installed in a square pattern (direction-finding). A SeaSonde radar manufactured by Codar Ocean Sensors in Los Altos, California was installed in Ancona in April 2003 and was operated near 12.5 MHz for about two months.

Preliminary results obtained with the radar data are presented and discussed, including maps of mean surface currents and eddy variability, and maps of tidal characteristics in the Northern Adriatic. These products are also qualitatively compared to observations provided by other instruments (drifter data and visible/infrared satellite images).

New insights in the "mucilage" mystery

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To investigate the possible causes of Dissolved Organic Carbon (DOC) accumulation in the North Adriatic, which can favor mucilage production, a three-year study on microbial community was carried out in a coastal area in the Gulf of Trieste. It is a semi-enclosed shallow system, mostly controlled by pulsed external inputs (e.g. freshwater run off, Mid – Adriatic injections), which determine a high variability of plankton communities. Samples were collected monthly at two stations (3 - 4 depths) from January 1999 to December 2001. A broad suite of microbial and environmental parameters was regularly measured. Data illustrate remarkable inter- and intra-annual variability in parameters relevant to carbon biogeochemistry and ecosystem energy flow patterns. Integrated primary production (PP; 140 $gCm^{-2}yr^{-1}$) in 1999 tripled (420 $gCm^{-2}yr^{-1}$) in 2000, returning to a low level (152 $gCm^{-2}yr^{-1}$) in 2001. The slope of the regression between PP and chl a was also higher (0.82) in 2000 compared with 1999 (0.59) and 2001 (0.63). The increase in photosynthetic efficiency appeared related more to enhanced light availability than to nutrient increases. Bacteria production (BCP; by ^{3}H-thymidine incorporation) accounted, on average, for 35.3% of net PP in 1999, 9.5 % in 2000 and 29.4% in 2001. Flux into the microbial loop via bacterial C demand (BCD), assuming 30% growth efficiency, was the dominant C flow pathway in 1999 and 2001, accounting for almost 100% of the net PP but a lesser fraction (40%) of net PP in 2000. Our results suggest that in 1999 and 2001, when PP was low, it mostly fuelled, and was respired within, the microbial loop. During 2000 there was a major shift in C flux partitioning. The coupling between PP and bacteria was loose and larger fractions of PP were presumably channeled into other paths of C flow (grazing food chain, sedimentation and "storage" of C in the water column as dissolved and colloidal organic phases). The latter, particularly, can be seen as a possible precursor of mucilage.

Sub-inertial variations of the coastal circulation and water exchange between the Venetian Lagoon and open sea

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Long-term measurements of the water flow at three Venetian lagoon inlets carried out since July 2001 with the bottom-mounted ADCP's show that the main part of the variance (>90 %) is associated with the tidal variability. Semi-diurnal components (mainly M2 and S2) are responsible for about 80% of the flow variance. Wavelet techniques in combination with cumulative sum and cumulative sum of squares statistic tests were used to study the variability of non-tidal flow in the inlets of the Venetian lagoon: Lido, Malamocco and Chioggia. The non-tidal flow is controlled to a large extent by the Adriatic seiches due to remote atmospheric forcing. Local wind generates interior longitudinal sea-level slope that is responsible for the differential pressure gradient and the low-frequency flux variations. This then results in out-of-phase variations of fluxes in Lido and Chioggia. At longer time-scales (seasonal and year-to-year) the inlets' fluxes are due to the freshwater balance in the lagoon showing the net outflow on the order of 100 m^3/sec. Inlet of Lido shows an inflow while in Chioggia an outflow of the same magnitude takes place on these long time scales. Calculations of the flushing half-life using tidal prism method show that the lagoon exchanges water with the open sea rather quickly. Flushing half-time ranges between 6 and 12 hours during the spring and neap tide, respectively. In addition, starting from November 2001 the surface circulation in the coastal area of the Adriatic Sea in front of the Venice inlets has been monitored using two HF radars. The obtained data enabled us to study the relative contribution of astronomical tide and meteorological forcing to circulation in front of the Venice Lagoon inlets. Also, the seasonal variability was studied. This research is particularly oriented to the current field in the area in front of the Malamocco inlet and since data for two subsequent summer seasons exist, year-to-year variability in function of meteorological conditions are also addressed. In particular, both mean and eddy kinetic energy fields are more intense during 2002, than 2003. Significant difference in the climatic conditions of these two seasons appears mainly in the local precipitation, which was rather high in 2002, and low in 2003, while the local wind does not seem to differ to a large extent. It is hypothesized that the freshwater discharge influences the basin-wide circulation including the coastal circulation in front of the Venetian lagoon.

Air-sea fluxes (winter-spring 2003) over the EACE polygon

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The motive for establishing meteorological measurement program within East Adriatic Coastal Experiment (EACE) project was to document air-sea interaction important for the generation of East Adriatic Coastal Current. Bulk method of surface flux computation (downward momentum flux, sensible heat flux and latent heat flux) was chosen, by using the data measured at Automatic Met-Oceanographic Station (AMOS), deployed close to the EACE experimental polygon. After completed quality control procedure proposed by WMO and respecting the Aanderaa sensors characteristics, additional intercomparison with the data measured at regular meteorological station at Zadar was carried out. Finally, comparison with synoptic conditions and climatology of the region was established, as unusual weather conditions prevailed over the entire Adriatic during the whole EACE experiment.

Using new parameterization scheme for bulk equations, air-sea interaction physics was calculated on the daily basis using only AMOS data. No cloud measurements were available at the station, therefore cloudiness was computed as a ratio between solar radiation measured at ground station and theoretical values obtained at the top of the atmosphere. The latter values were estimated using equation previously developed for the AMOS Punta Jurana (140 km ESE), located in the same climate region. However, this is possible to compute only during daylight, so heat and water fluxes were calculated on daily basis, without downscaling to the hourly values.

Weather conditions during the experiment were quite anomalous. A Sirocco episode in November 2002, and rather persistent Bora blowing in late January-February, and occasionally in March and April, induced large heat losses over the EACE polygon. For example, mean January/February heat losses were about 170 W/m^2, doubled than average for the northern Adriatic computed for the 1966-1992 period. In contrast, extremely large heat gain was in progress during the last EACE stage (May-June), when heat gain by the sea was 60% over the average. In addition, mean water flux between February and June was -2.5 mm/day, totally opposite from the average (+1.0 mm/day). Such atmospheric conditions, being in progress over the whole northern Adriatic, surely induced the generation of dense North Adriatic Dense Water in January/February, being transported to the EACE polygon a month later. At the same time, surface layer was anomalously heated, additionally stratifying water column and allowing for baroclinic structures to growth, as observed in the May/June current data.

Data assimilation and ocean forecasting in the Adriatic Sea

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The ADRICOSM project (ADRIatic sea integrated COastal areaS and river basin Management system pilot project) is the innovative application of data assimilation to a forecasting system in the coastal areas. Both large scale and coastal data sets are utilized efficiently in a data assimilation scheme that uses sequential estimations to prepare initial fields for subsequent forecasts.

The large scale observing system is based on the Sea Surface Temperature (SST) which is available daily and it is used for the surface heat fluxes corrections. The coastal observing network is localized in 4 regions: the Emilia Romagna Coast, the Golf of Trieste, the Slovenia Coast and the Croatian Coast. In addition, XBT temperature profiles up to 900 m depths are collected along two VOS tracks (Voluntary Observation Ships track between Ploce-Malta and Split-Bari) which are complementary to the coastal monitoring network.

The Adriatic Model is POM (Princeton Ocean Model) implemented for the Adriatic Sea. The model has a horizontal resolution of 5 km and 21 layers in the vertical, high frequency forcing, daily Po river run off and monthly heat fluxes. The interface between the Mediterranean Ocean model and the Adriatic fields permits the selection of the lateral boundary (T, S, u, v) during the assimilation and the forecasting.The data assimilation is carried out using SOFA (System for Ocean Forecasting and Analysis) which is a multivariate reduced-order optimal interpolation method.

Salinity and temperature coming from CTD stations and XBT tracks are assimilated. The system is improved because of the sequential assimilation of multivariate parameters (T, S profiles from CTD) and univariate parameters (T profiles from XBT). The Adriatic model is efficiently corrected during the date assimilation using a coordinate transformation from sigma to z and vice versa.

Sediment dispersal mechanisms within the Adriatic Sea: Recent advances from the EuroStrataform program.

C. K. Harris

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EuroSTRATAFORM aims to relate sediment delivery and water column transport to seabed morphology. Towards this end, near-bottom tripods, current meter moorings, and sediment cores were obtained between November, 2002 and May, 2003. Oceanographic conditions and sediment suspension have been monitored near the dominant source of freshwater and sediment to the Adriatic, the Po River, since a major flood during the Fall of 2000. Numerical models, such as the one described here, can quantify sediment dispersal within the Adriatic, and thereby encompass spatial and temporal scales that can not be addressed by observational efforts alone.

Sediment distributions point to the Western Adriatic Coastal Current (WACC) as a dominant dispersal mechanism, because depocenters hug the coastline and appear downstream from sediment sources. Besides transport by oceanographic currents, however, sedimentation is influenced by wave-induced resuspension. It is unclear the degree to which along-coast gradients in the WACC or wave energy account for changes in sediment accumulation rates, textural properties, and the cross-shelf geometry of sediment deposits. To address this, we apply a three-dimensional hydrodynamic model of the Adriatic that includes fluvial delivery, transport, resuspension, and deposition of sediment. Calculations were driven by spatially- and temporally-varying wind fields for the Fall / Winter of 2002 / 2003 and realistic Po and Apennine river discharges. Waves were hindcast with the SWAN model. Dispersion of both resuspended and river-derived sediment was estimated for periods that contained intense Bora and Sirocco winds.

Predicted sedimentation and dispersal rates are sensitive to forcing winds, buoyancy, and wave patterns. Sirocco winds weaken the WACC, and because they tend to concentrate over the Eastern Adriatic, often fail to create especially energetic waves in the Western Adriatic. Bora wind conditions, on the other hand, intensify the WACC and can build high wave energies over the northwestern Adriatic. Higher sediment flux was therefore predicted during Bora conditions than during Sirocco conditions.

Optical processes and physical forcing in the Northern Adriatic Sea.

B. H. Jones

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The Po River is the single largest source of optical signal in the northern Adriatic, but other processes contribute to complex, but more subtle optical variability. Inherent and apparent optical properties were observed during two cruises in the northern Adriatic Sea during February and June 2003. Inherent optical properties were mapped three-dimensionally with a Wetlabs AC-9 mounted on the UW/APL Trisoarus. Remote sensing reflectance was mapped with a ship-mounted MicroSAS radiometer system. And detailed profiles of inherent and apparent optical properties were obtained with a Bio-Optical Profiler.

The two seasons differed dramatically in the physical forcing and the resultant optical distributions. The February observations indicate a system where optical variability was determined predominantly by the physical forcing. In contrast, the lack of forcing during May-June 2003, with the exception of the Po River flow, resulted in distributions that were dependent on the dynamics of the phytoplankton within the context of the stratified water column.

In addition to temporal comparisons, there was a distinct difference between the eastern and western boundaries of the northern Adriatic Sea. The western coast reflected the buoyant, optically-rich outflow of the Po River as well as a near-bottom suspended particulate layer that extended along much of the coast. The eastern boundary on the other hand had relatively low optical signals that that were strongly physically coupled during winter and were dependent on the chlorophyll maximum during the early summer.

A tidal model of the Adriatic Sea: ACE/WISE contribution to its current response validation

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A high-resolution, three-dimensional finite element tidal model of the Adriatic Sea [Janekovic et al., Estuarine, Coastal and Shelf Science 57 (2003): 873-885] has been refined to still better resolve the well-developed eastern coast, as well as to include seven major harmonics. The tidal constants for 31 Adriatic gauge station was used in the assimilation procedure aimed at deriving optimal open boundary conditions. The extensive ADCP current-meter data set collected at 14 Adriatic Circulation Experiment (ACE) stations and 4 West IStria Experiment (WISE) stations is used for a thorough validation of the Northern Adriatic tidal current field predicted by the model. The comparison is focused on the two dominant harmonics, M2 and K1, although both individual and seven-harmonics runs have been done. It has revealed excellent agreement between observed and modeled tidal ellipse parameters, except at three stations where more pronounced discrepancy in ellipse orientation in particular has been identified.

Thermohaline fluctuations during East Adriatic Coastal Experiment – EACE (november 2002 – june 2003)

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East Adriatic Coastal Experiment was carried out between November 2002 and June 2003. CTD profiling was done during seven cruises at a network of 21 stations (three transects) off Veli Rat lighthouse. Three SEABIRD CTD probes were used.

The data were preprocessed and averaged along the vertical every 1 m. The analyses of thermohaline properties will utilize vertical profiles at three transects, comparison of EACE values with the climatological averages, horizontal sections at 50 m depth as well as depth versus time presentation at one inner and one outer station.

The surface cooling driven by anomalous heat losses, being a result of persistent winds (bora and sirocco) over the area, prevailed between late November and late February. The result was mixing and homogenization of the water column in the whole area. In that period vertically averaged temperature drop down to approximately 12ºC (close to the climatological average). As surface heat losses were almost doubled during January-February, it may therefore be supposed that cold North Adriatic Dense Water (NAdDW) was generated, being advected to the EACE polygon in late February/March. On the contrary, very intensive surface heating was pronounced in May-June, and therefore surface temperature in June surpassed average values by more than 2ºC.

Along-basin (NW-SE) and cross-basin (SW-NE) gradients of thermohaline parameters were pronounced in the whole water column from November to April. Generally, colder and denser sea water was residing in the northwestern part of the EACE polygon. Thermocline rapidly developed in May, being stronger due to preceding NAdDW advection and extensive heat gain in late spring. A constant increase in salinity was in progress on the EACE polygon, in particular during May and June, probably related to the advection of saline Levantine Intermediate Water (LIW) from the southeast.

Shallow water fronts, river plumes and strong forcing- preliminary results from intensive surveys of the Northern Adriatic

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Quasi-synoptic, three-dimensional surveys of physical and optical variability characterize the mesoscale features that dominate the Northern and Central Adriatic, following their response to strong forcing events. During winter (February), sampling emphasized the response to episodic Bora wind events. Although springtime (May) measurement program was designed to sample during the Po River spring freshette, freshwater discharge rates were more than a standard deviation below the 12-year mean and winds remained weak throughout the survey period, leading to a study of weakly forced dynamics in a strongly stratified, shallow water regime. Wintertime sampling included surveys of a strong shallow-water front and a prominent extension of the Po River plume. The surveys captured the evolution of a nearly vertical, compensated front that tilts as the strong Bora winds weaken. A broad survey of the northern basin characterized the structure of a Bora-driven Po plume extension and reveals cyclonic (anticyclonic) circulation to the north (south) of the plume, consistent with the response found in previous numerical experiments. Results from a new climatology, organized around the dominant forcing mechanisms, characterize Po plume extensions and two Northern dense water formation sites similar to those seen in the observations.

From the temporal dataset of the Senigallia transect to the features of the water masses in the northern Adriatic: Physical and chemical aspects

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The transect of Senigallia represents an excellent observation site for the waters masses that transit in and out of the northern Adriatic from 1988 to present and where a sampling of the main physical and chemical parameters in the column water is profitable. Particularly from 1997 to present, the sampling was from coast to coast (Italy-Croatia) along a 120 km long transect and included hydrological 12 stations.

Besides the study of the features of the water masses that go through the transect of Senigallia, a study of various biogeochemistry processes will be presented:

• those natural like the process of mineralization of the bottom (that causes in some areas strong hypoxicity) and the mucilage phenomenon;

• those of human origin like the impact of the platforms for methane extraction in the northern Adriatic.

Water mass properties in the pits of the middle Adriatic will be also shown as well as the temporal dataset initiated in 1980 to present, and of their dynamics related to the processed taking place in the northern Adriatic.

Numerical simulations of the Adriatic Sea during ACE

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Numerical ocean simulations have been conducted of the circulation in the Adriatic Sea between Sep 2002 and Apr 2003 using two different grid setups: a 2-km resolution grid covering the Adriatic with an open boundary near Otranto and a 3-km grid covering the Adriatic and extending just past Otranto into the northern Ionian Sea with a 1-km nested grid in the northern Adriatic. The ocean model being used is the Navy Coastal Ocean Model (NCOM). Initial and boundary conditions are from a global version of NCOM being run at NRL. Atmospheric forcing is from the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS), which was run on a triply-nested grid with a resolution on the innermost nest of 4 km. Freshwater inflows were taken the from the monthly climatology of Raicich (1994), except that daily real-time discharge data was used for the Po. Simulations were run both with and without tides.

Model results are being compared with ADCP data from a number of moorings and with CTD data taken from ship surveys. Comparison of the model velocities (with tides) with the ADCP velocities observed along the line between Senigallia and Susak showed average mean and rms errors and correlations of 0.01 m/s, 0.06 m/s, and 0.03, respectively, for the cross-shore flow, and 0.03 m/s, 0.09 m/s, and 0.7, respectively, for the alongshore flow. The response of the ocean circulation to strong wind events was found to be fairly robust in that both of the grids that were used developed similar circulation patterns.

The cooling of the northern Adriatic from Sep 2002 to Feb 2003 in the model simulations was mainly due to the surface heat flux, with the contribution from advection across the southern boundary of the northern Adriatic being relatively small. Comparison of the model simulated temperature and salinity profiles with the observed CTDs showed that the observed profiles frequently indicated more stratification and sharper thermoclines/haloclines than the model profiles.

Variability of mesoscale structures of the Adriatic as seen in MODIS images

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The strong contrast between oligotrophic and mesotrophic waters present in the Adriatic Sea gives the opportunity to study the variability of specific mesoscale features. The large amount of nutrients, detritus and dissolved discharged by rivers in the Adriatic basin (in particular the Po river) creates regions of high turbidity/chlorophyll concentration. Because of its low salinity, the WAC (Western Adriatic Current) density is lower than the open sea values, resulting in a higher sea level and corresponding geostrophic currents down the coast in the SE direction. Optical properties and chlorophyll concentration are excellent tracers to study not only the morphology and the variability of the WAC, including instability features, but also the Po plume and mesoscale structures in the South Adriatic Pit. The above properties are useful tracers throughout the year (as opposed to sea surface temperature for which gradients tend to disappear in summer).

Images of optical properties (K490) measured by MODIS on the NASA Aqua polar-orbiting satellite are used to study the variability between September 2002 and July 2003 of the WAC, the Po plume and the mesoscale structure of the South Adriatic Pit. During this period intense observations were carried out in the ACE, DOLCEVITA and other programs. selected image snap-shots and monthly image composites are used.

On the thermal diurnal cycle in the Adriatic Sea

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As part of the DOLCEVITA program, a study was conducted to describe the spatial and temporal variations of the thermal diurnal cycle in the near-surface waters of the Adriatic Sea. In particular, this work focuses on the comparison between statistics of the bulk sea water temperature, as measured by drifters released in the Adriatic Sea, and statistics of the (skin) sea surface temperature, as measured by infrared radiometers (Advanced Very High Resolution Radiometer-AVHRR), onboard NOAA polar orbiting satellites. All statistical analyses were done for all the months between September 2002 and December 2003 in geographical areas of 0.5 x 0.5 degrees.

Using both the drifter and the satellite data, the maximum sea water daily temperature difference (?T) was computed and the times of minimum and maximum daily temperatures were recorded. Once this first analysis step was done, we computed the monthly means and monthly maxima of the daily ?T and the monthly means of the times of the maximum and minimum temperatures.

We found that the monthly means ?T computed with the satellite data can be as large as 2°C whereas those computed with the drifter data are smaller (~0.5°C). This difference is related to the overheating of the sea surface skin layer during the day. We also analyzed the trend of the mean of times of maximum and minimum temperatures. They are quite different between drifter and satellite data. The times of the maximum satellite temperatures occur 1-2 hours prior to those inferred from the drifter data. This can be due to the faster heating of the sea surface with respect to the water column below.

Simulating and forecasting the Adriatic Sea (2000-2003)

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A free surface, three dimensional finite difference numerical model based on the Princeton Ocean Model (POM) has been implemented, within the ADRICOSM project, in order to simulate and forecast the Adriatic Sea circulation. The implementation makes use of an interactive surface momentum and heat flux computation that utilizes the ECMWF 6 hours fields and the model predicted sea surface temperatures. The model is also nested, using an off-line technique, at its open boundary with a coarse resolution Mediterranean general circulation model, utilizing the same surface forcing functions. The study period spans 4 years (2000 January 1st to 2003 December 31st). The simulation and forecast experiments differs for the atmospheric forcing, the boundary values and the Po river run-off. The forecast numerical simulation is reinizialized every week from the simulation results. The model simulation results are validated by mean of a comparison with the observed data collected during MAT and ADRIA01 projects. Model results for the simulated years show a strong interannual variability of the circulation patterns, linked to the atmospheric forcing variability.

Currents recorded during the East Adriatic Coastal Experiment

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In the framework of the East Adriatic Coastal Experiment currents were recorded by two ADCPs mounted on the bottom off the Croatian coast, between 30 November 2002 and 14 June 2003. The measurements documented variability over a wide frequency range. Monthly mean currents revealed an inflow being maximal in February 2003 (onshore station) and May 2003 (both stations). The first maximum could probably be related to strong cooling and dense water formation in the North Adriatic, the second to pronounced evaporation and inverted estuarine circulation in the basin. Also observed were fluctuations at periods exceeding 10 days. They are still lacking a proper interpretation. At several-day time scales currents directly responded to the wind forcing. The response to both the bora and sirocco winds was similar. Finally, variability was recorded at smallest periods: 24 and 12 hours (tides), 21 hours (fundamental Adriatic seiche) and 17 hours (inertial oscillations). According to the results of harmonic, spectral and cross-spectral analysis, tides and seiches were barotropic, inertial oscillations baroclinic and thus dominating during the spring season. Particularly interesting are seiches, as they were previously recorded mostly by tide gauges, and now it becomes obvious that they contribute considerably to the Adriatic current variance.

Adriatic Air-Sea Coupling

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Our COAMPS^{TM}/NCOM high-resolution modeling studies focus on evaluating Adriatic air/sea temperatures and fluxes in one-way and two-way coupled simulations during fall 2002. We document the evolution of the atmospheric and oceanic boundary layers over the course of a bora episode, as well as the mean boundary layer structure for a month-long simulation. In addition, validation of model results using over-water oil platform observations of meteorological variables (including air temperature and wind velocity) and remotely sensed and in situ measurements of oceanic temperature demonstrates the skill afforded by a fully coupled high-resolution model. In particular, MCSST data is used to evaluate model-derived SST during a bora event. The two-way coupled simulation had lower mean bias and RMS error compared to the one-way coupled simulation. Additionally, at a station located in a bora finger the two-way coupled model produced lower mean wind speeds that accorded better with measurements than did the values from the one-way coupled model. Reasons for this enhanced agreement are investigated, including atmospheric stability effects induced by the SST gradient in the two-way coupled simulation.

Modeling of the mesoscale circulation in the Adriatic Sea

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The DieCAST Ocean Model is being run to study the mesoscale variability in the Adriatic Sea. After spin-up with climatic Hellerman-Rosenstein winds, COAMPS winds with a 4-km resolution and faithful temporal and spatial variability are used for studying the effects of bora, sirocco and other realistic wind events. For comparison purposes, a recent version of the Princeton Ocean Model (POM2k) is also implemented for the Adriatic Sea with same horizontal and vertical resolution as well as initial and boundary conditions. Unlike DieCAST, POM2k generates excessive damping and too few meanders, jets and eddies. Finally, the effect of bottom topography is studied at selected locations.

Influence of physical factors on the autumn 2002 hypoxic event in the North Adriatic Sea bottom layer

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The northern Adriatic sub-basin is very shallow, with an average bottom depth of about 35 m. River runoff is particularly strong in this area and affects the circulation through buoyancy input and the ecosystem by introducing large amounts of organic matter. Po river, with an average annual discharge of 1500 m^3s^{-1} , accounts for about 50% of the total northern Adriatic river runoff. This area is often exposed during summer-autumn period to anoxic events, which can be divided into coastal (almost every year along the Emilia-Romagna region) and offshore ones (less frequent but affecting wider areas). In this study we focus on the latter ones.

It is known that the bottom water layer most frequently exposed to hypoxic events is often influenced by a cyclonic circulation gyre governed by the Po plume, trapping its fresh waters at surface. Low current velocities at the gyre centre, enhanced stratification (reducing vertical mixing) and high turbidity (stopping sunlight in the first meters) due to the fresh water, high production and sedimentation are some of the factors that cause hypoxic events in this area (typically occurring between Sept.-Nov.).

Several oceanographic cruises were conducted in the northern Adriatic Sea (more than 600 CTD casts) from 16 September to 16 October 2002 by the R/V G. Dallaporta and R/V Alliance. Both ships utilized SBE 911plus CTD probes, equipped with redundant T-C sensors, SBE 43 dissolved oxygen (DO) and other ancillary sensors, and coupled with SBE Carousel water samplers. Water samples were collected to analyze nutrient salts and to determine DO content by potentiometric titration method (to verify the probe DO sensors).

The first cruise revealed the presence of a relatively large hypoxic area, that subsequently reduced, and finally moved offshore, covering a broader area; in some stations dissolved oxygen content reached values below 1 ml l^{-1}. In an effort of exploring the water column dynamics, the HOPS and ROMS ocean models have been implemented, initialised by the CTD data and forced by the LAMI meteorological model. Results showed that the bottom layer of the hypoxic area was influenced only by weak currents and that the wind played a major role in controlling the evolution of the examined hypoxic event.

The impact of different water transport determinations on the estimation of North Adriatic horizontal geo-chemical fluxes

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The North Adriatic Sea receives the highest river runoff of the Mediterranean Sea, most of it coming from the Po River. The shallowness of this sub-basin (average depth less than 35 m) makes its physical and ecological environment highly sensible to variations in river runoff and atmospheric conditions. River runoff affects the circulation through buoyancy input, which is one of the major driving forces of the Western Adriatic Coastal Current (WAC or WACC), and impacts the ecosystem by introducing large amounts of organic matter, nutrient salts and sediments. Some studies have attempted to quantify the exchange rates of water and transported materials between the northernmost part of the Adriatic Sea and the remainder of the basin. A first study (Degobbis and Gilmartin, 1990) used chemical data, measured roughly biweekly in the North Adriatic (roughly along the Cesenatico-Pula line) at one station located in the western area and one station located in the eastern area, combining them with a previously estimated water exchange rate of 10^5 m^3 s^{-1}. A second study (Gacic et al, 1999), conducted in the same area with different methodologies (more stations along the transect, but only 4 samplings during 1995/96), quantified the outflow fluxes in summer 1995 and winter 1995/96. Monthly and mean nutrient fluxes were derived in a third work (Paschini et al., 2003): physical and chemical data were monthly collected in the same area and along the Senigallia-Süsak Island transect (southeastward of the the previous area); geostrophic velocities were computed and combined with contemporary measured dissolved inorganic nutrients data to obtain fluxes.

For the first time, in the framework of the Adria02 cruise, high resolution CTD casts, bio-geo-chemical sampling stations, hydrodynamic model simulations, ship-tethered ADCP surveys, and 7 bottom mounted ADCP plus 3 traditional moored current-meters at 2 sites were available along the Senigallia-Süsak Island transect. Namely, as on 28th September 2002 all the data sets had an optimal coverage along the transect, geostrophic velocities, daily averaged current data and model velocities were used to assess the relevance of different simultaneous water transport estimations on geo-chemical fluxes determination.

Adriatic Sea variability: Results of recent research activities

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Decadal and interannual physical variability of the Adriatic Sea and its possible links with marine ecosystems have been studied in the wider framework of two relevant research projects: MAT (1999-2003) and SINAPSI (2000-04), funded by the Italian Ministry of Environment and the Italian Ministry of University and Research respectively. Outcomes of these projects are being published in scientific papers, and main aspects interesting the North Adriatic Sea will be exposed.

Decadal anomalies of temperature and salinity, eventually related to the Eastern Mediterranean Transient (EMT), have been evidenced in the North and the Middle Adriatic Sea. Starting from the late 1980s, the North Adriatic surface temperature significantly increased and salinity showed relevant variations. Northern Adriatic dense water characteristics also varied, as deduced by time-series measurements of bottom waters in the Middle Adriatic Depressions; the deduced trend results similar to the one detected for the southern sub-basin deep waters which originate the Adriatic Bottom Water (ABW). During the last years, aiming to investigate influence on massive mucilaginous phenomena, thermohaline properties in the North Adriatic Sea have been carefully monitored, as well as circulation: relevant year-to-year variability has been detected.

Indirect determination of surface heat fluxes in the Northern Adriatic Sea via the heat budget

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Modelling the process of dense waters formation and spreading in the northern Adriatic Sea is a challenging task. As direct measurements of fluxes in such a large area are difficult to be carried out, meteorological models have to be employed in order to make information available about dominant winds, temperature, cloud conditions, etc. Part of the difficulty consists indeed in correctly determining the magnitude and location of strong cooling events associated with bora winds, intense dry winds from the northeast with strong spatial gradients resulting from orographic effects. Clearly, this directly reflects on the quality of resulting surface heat fluxes that are forcing the ocean surface and consequently on the resulting circulation induced.

We implemented the Regional Ocean Model System (ROMS) forced by meteo fields provided by the Limited Area Model-Italy (LAMI) model, and calculated the heat budget for the Northern Adriatic, i.e. a region of approx. 20000 km^2 north of Senigallia-Susak transect. We found that the heat content of the region is nearly completely controlled by surface heat fluxes, with advective heat fluxes by ocean currents through the Senigallia-Susak section playing a minor role.

This suggested the possibility of assessing changes of heat content in the Northern Adriatic from satellte SST imagery and in situ CTD and ADCPs data, deployed in the region during fall 2002-winter 2003. Such a data-derived direct estimation of heat content, expressed as equivalent surface fluxes, is then compared to that obtained implementing ROMS using LAMI met values via bulk formulae, and that obtained forcing ROMS directly with LAMI turbulent fluxes (no modelled SST feedback).

Modeling the Bottom Energy Environment in the Adriatic Sea

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Sediment is resuspended from the bottom of the Adriatic Sea by a combination of wave and current effects. The combined wave-current bottom stress is calculated from the Regional Ocean Modeling System circulation model linked with the SWAN wave model and compared to observations at locations where both currents and waves were measured from Sep 2002- May 2003. The spatial and temporal variability in this bottom energy environment is discussed.

Influence of different vertical mixing schemes and wave breaking parameterisation on forecasting surface velocities

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The ability to successfully track the path of an object in the marine environment is a relevant issue for several potential end-users. Examples are search-and-rescue (SAR) activities and oil-spills emergencies that have been causing a growing environmental concern in the last decade.

The trajectory of drifting object is dependent on many near-surface processes, including pressure driven currents, drift currents induced by winds and wind-generated gravity waves on the ocean surface. Since observations are seldom available to provide details of the spatial and temporal distribution of these currents, when facing the necessity of tracking drifting objects it is often necessary to resort to numerical models of the oceanic, atmospheric and sea state. Additional information from in situ measurements (CTD, XBT, ADCP), coastal radars (providing surface currents) and remote sensing (SST, SSH, positions of slicks and filaments) can be integrated.

From the necessity of having a high-fidelity simulation of the upper oceanic layer, the paper discusses the effect that different parameterisations of vertical mixings may have on reproducing surface velocities and how these are influenced by including breaking waves dynamics by means of turbulent kinetic energy injection. We address these issues by presenting results obtained by employing the Regional Ocean Model System (ROMS, developed at Rutgers University, NJ) in the Adriatic sea during the period of fall 2002-winter 2003.

The numerical tests were performed using the hydrological data collected during the NATO-SACLANT ADRIA02-03 field trial and meteorological forcing from a high-resolution limited-area model (LAMI, Limited Area Model Italy). During the cruises more than twenty drifters were deployed in the basin, subject to different meteorological conditions, and most of them have been successfully satellite-tracked. Their positions are simulated by the model runs and results using different turbulence closure schemes are discussed, particularly the influence of the currents shear on the drifter dynamics.

Coastal monitoring network of the Manfredonia Gulf (Southern Adriatic Sea): new observational techniques and instrumentations as part of a monitoring system

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At present, news techniques and instrumentations need for real time marine environmental monitoring. This necessity arises from the need of knowing in real time the evolution of marine phenomena due to anthropic pressure or natural events.
The PITAGEM project (Integrated methodologies for the study of marine trophic processes and deployment and management of oceanographic platform for marine monitoring), coordinated by CNR - ISMAR of Lesina, aims to develop new oceanographic instrumentations and to set up and to manage an automatic monitoring integrated network in the Gulf of Manfredonia (Southern Adriatic Sea) and in the Gulf of Taranto (Ionian Sea).

The technology and instrumentation developed during the PITAGEM project are the following:

1. An oceanographic platform, still under testing, deployed in the Gulf of Manfredonia, equipped with (a) a meteorological station measuring air pressure, air temperature, solar radiation, wind direction and wind speed; (b) an automatic phosphorous and nitrogen compound analyser of water samples collected at five different depths; (c) a multiparametric probe for temperature, salinity, dissolved oxygen, pH, *in vivo* fluorescence measurements of water samples collected at five different depths; (d) a near real time communication system transmitting data via SMS.

The monitoring program performed by the platform has began on October 2003, but at the moment the platform is under maintenance.

2. An eight meter vessel equipped with a surface pumping system and a multiparametric probe for measuring in continuous physico – chemical parameters of surface waters of the Gulf of Manfredonia. The monitoring program performed by the vessel has began on May 2003 with bimonthly frequency, and includes: (a) horizontal continuous tracks of surface physico–chemical parameters (temperature, salinity, dissolved oxygen, pH, *in vivo* fluorescence and turbidity) along a transect parallel to the coastline; (b)vertical physico-chemical profiles (temperature, salinity, dissolved oxygen, pH, fluorescence) at 20 fixed stations along 4 transects (one parallel and 3 perpendicular to the coastline); (c) sub-surface and bottom water sampling, by rosette, for suspended solid, nutrient (NO_3, NO_2, NH_3, PO_4, $Si(OH)_4$, total P and N) and chlorophyll "a" analyses at fixed stations.

An additional component of the project is the realization of two multidisciplinary cruises aiming to study optical properties, primary production and biogeochemical processes of the Gulf of Manfredonia.

The data are stored in an integrated data bank provided with a GIS system. The platform data are validated by a data quality control check. The validation and calibration protocols will be designed and modified in according to all the developing system of the platform. The final aim of this system is to set up an ecological model to obtain forecast scenarios.

The initial data obtained with the platform and the boat monitoring in the Gulf of Manfredonia show how this area is subject to high seasonal influence, that processes between coastal and central marine areas differ, and the high influence of the general winter cyclonic circulations of the Adriatic Sea in more offshore areas.

Weather forecasting and general synopsis during Dolcevita 1 and 2

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The author was invited to participate at both Dolcevita cruises as a forecasting meteorologist. The main reason for this was to allow the oceanographic campaign in the central and northern Adriatic sea what can be called an adaptive strategy with fast reactions on changing meteorological forcing.

The talk gives an overview about the operational conditions on board of the research vessel KNORR. Because of limited data line resources it turned to be of great importance to have contact to a land based expert of the Croatian weather service.

Additionally a short abstract is delivered about the general synopsis of both the winter and summer cruise. Dolcevita 1 was essentially characterized by frequent bora events, most of them anticyclonic, some of them cyclonic with at least one case of scirocco prior to it. Sometimes very large heat flows from the sea to the atmosphere could be observed. Dolcevita 2 showed quite contrary weather patterns. There was almost no bora. Anticyclonic situations with weak gradients were prevailing. It was the onset of an exceptionally warm and dry summer over wide areas of Europe. According to it the vertical energy balance of the sea surface was mainly controlled by radiation.

Circulation dynamics in the Northern Adriatic as measured by surface drifters in relation to wind forcing

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The near-surface circulation of the Northern Adriatic is explored using Lagrangian drifting buoy measurements. More than 120 drifters were deployed in the Northern Adriatic within the DOCEVITA project between September 2002 and October 2003. The data set presents a very good coverage over the studied area and within the measurement period. The main pathways of the surface waters are defined and the major persistent surface features are described, together with their variability. In particular current features are described in relation to different wind regimes. COAMPS high resolution winds are used to get spatial and temporal evolution of wind forcing, and means over the entire region are calculated all over the considered period. Bora and Scirocco winds are the most representative ones, interesting the majority of the considered area and time. The behavior of the surface currents are related in particular to these winds. Finally, selected zones in the considered area are studied due to their current and/or wind particular features.

Response Characteristics of Sensors in a Trawl-Resistant ``Barny''

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Response characteristics of sensors installed in trawl-resistant ``Barnys" used in the ACE experiment are investigated in an attempt to understand and correct for the filtering effect of the Barny housing. The effective response time of temperature and conductivity inside Barnys is limited by the finite flushing time of the flow-through Barny housing, leading to frequency-dependent attenuation and phase-shifting of the measured signal. The body of an ADCP installed on a Barny and the syntactic foam around it can have a significant insulating effect on the ADCP temperature sensor, again causing attenuation and phase-shifting of the measured temperature. At high ping rates ADCP temperatures are found to be consistently high, suggesting that internal heating by electronics is important. Comparison of records from internal sensors with data from nearby instruments outside Barnys allows the frequency response function of the Barny sensors to be estimated. A simple mathematical model is advanced which accounts for many of the observations, and the model and data suggest a technique to optimally correct for the limited frequency response of the sensors. Corrected bottom temperature, salinity, and density data are presented for ACE Barnys, illustrating application of the technique.