Comprehensive Numerical Modeling of the Adriatic Sea

Benoit Cushman-Roisin
Thayer School of Engineering
Dartmouth College
Hanover, NH 03755-8000
Phone: 603-646-3248   Fax: 603-646-3856
Email: Benoit.R.Roisin@dartmouth.edu

Christopher E. Naimie
Thayer School of Engineering
Dartmouth College
Hanover, NH 03755-8000
Phone: 603-646-2119   Fax: 603-646-3856
Email: Christopher.E.Naimie@dartmouth.edu

Award #: N00014-93-I-0391

http://www-nml.dartmouth.edu/~naimie/files.AS/adriatic_sea.html

LONG-TERM GOALS

A better understanding of oceanic variability via modeling studies of circulation, entrainment, mixing and convection in the coastal ocean. Development and use of models for the study of generic processes and for the investigation of specific oceanic regions. Transition of these models to the US Navy.

OBJECTIVES

Development of a comprehensive, finite-element model of the Adriatic Sea, with initial focus on the seasonal circulations and later applications to mesoscale variability. Comparison of model results with those from other regional modeling efforts.

APPROACH

A high-resolution finite-element grid was constructed for the entire Adriatic Sea using the finest available topography and coastline data sets. The 3D finite-element model developed at Dartmouth (Lynch et al., 1996) is then progressively developed and applied to simulate the following dynamics: (1) Precise tidal simulations to test the model's resolution in the barotropic mode and to obtain tidal currents, (2) simulation of the circulation on seasonal time scales to test the model's performance in the baroclinic mode and to understand the baseline circulation, (3) study of events on scales of days and weeks, (4) performance comparison with other models, and (5) focus on particular regions.

WORK COMPLETED

The simulation of the tides culminated in a high-resolution run that included the four major tidal constituents, interacting with one another through nonlinear advection and nonlinear turbulence-induced bottom friction. Because of lack of data along the open boundary at Otranto Strait (the mouth of the

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**
4. TITLE AND SUBTITLE **Comprehensive Numerical Modeling of the Adriatic Sea**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Dartmouth College,Thayer School of Engineering,Hanover,NH,03755**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES **See also ADM002252.**		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Adriatic), the open-boundary conditions were interpolated from the results of an inverse, linear model on an extended domain that included the Adriatic Sea and a large portion of the Ionian Sea. This procedure effectively minimizes the difference between measured and modeled tidal elevations at observational locations. We believe that our calculations form the most accurate simulations of the Adriatic tides to date. A paper presenting the model and barotropic tidal simulations has now been submitted for publication (Cushman-Roisin and Naimie, 1998). Alongside, tidal calculations were performed with another model (2D but with higher horizontal resolution) for the northern basin of the Adriatic (Malacic, Viezzoli and Cushman-Roisin, 1998).

We then prepared for baroclinic simulations by obtaining temperature and salinity data sets of the Adriatic Sea, reviewing their contents, and assessing their suitability to our model objectives. These data sets are the Mediterranean Ocean Data Base (MODB, which contains several sets) and the Adriatic Temperature, Oxygen and Salinity (ATOS). We have objectively analyzed MODB's MED2 and MED5 data sets and utilized the results to initialize the finite-element model to obtain baroclinic circulation fields for the four climatological seasons [winter (January-April), spring (May-June), summer (July-October) and fall (November-December)]. Comparisons with published geostrophic calculations (Artegiani et al., 1997) and with drifter data (Poulain, 1998) have been performed. This work was presented in a preliminary form at the AGU Ocean Sciences Meeting (San Diego, Feb. 1998) and in a more complete form at the International Workshop on the Oceanography of the Adriatic Sea (Trieste, Sept. 1998). We are currently evaluating the suitability of the ATOS data set for monthly simulations. Alongside, we are also searching for a wind-stress data set that includes a reliable climatological component. The seasonal simulations conducted to date have used the Hellerman and Rosenstein (1983) values.

RESULTS

The seasonal circulations simulated by the model generally agree with the baroclinic structure of the basinwide circulation estimated by the dynamical (geostrophic) method employed by Artegiani et al. (1997). In addition, the 3D model results provide new information regarding the location, size and strength of sub-basin-scale gyres and current structures. We also find favorable agreement between the trajectories of numerical drifters and the recent observational drifter study of Poulain (1998). Our model results can guide the selection of sites for future drifter releases.

As a sample, Figure 1 shows the M2 tidal flood currents and the steady currents (tidal residuals + density flow + wind drift) and temperature in the northern Adriatic during the two primary seasons of the year. The top row shows the total vertically averaged currents at the time of the peak M2 flood in winter and summer, superimposed on the bottom topography; the middle row shows the near-surface currents superimposed on the surface temperature; and, the bottom row shows the near-bottom currents superimposed on the bottom temperature. In winter, we discern a baroclinic cyclonic circulation with a stronger southern branch and a weaker northern branch; this elucidates some contradictory reports of the winter circulation as inferred from hydrographic data, which pointed either to a cyclonic-anticyclonic-cyclonic gyre reversal or to a single cyclonic gyre extending throughout the northern Adriatic (Franco, 1972; Buljan and Zore-Armanda, 1976; Artegiani et al. 1997). Also noteworthy in winter is a barotropic component, which had sofar eluded previous calculations based on the so-called dynamical method (Artegiani et al., 1997). The summer circulation contains an equally strong and mixed baroclinic-barotropic circulation. Near-surface Ekman drift is more evident in summer due to the isolating effect of the pycnocline during the stratified summer months. Figure 2 displays similar information to Figure 1 but for the southern Adriatic basin, in which we recognize the well documented coast-to-coast cyclonic circulation that persists through the year.

At this stage, the model is ready for studies of seasonal transitions and of episodic events, such as bora winds and sudden variations in the Po River discharge.

IMPACT/APPLICATIONS

Fruitful collaborations have been established with research teams in Italy, Slovenia and Croatia. Our participation at the international workshop in Trieste further strengthened those relations. The ONR-supported Dartmouth initiative is now considered by the research community to be a substantial contributing effort to the study of the Adriatic Sea.

TRANSITIONS

The Dartmouth Circulation Model as applied to the Adriatic Sea will shortly be implemented at the Osservatorio Geofisico Sperimentale (Trieste, Italy) under the guidance of Dr. M. Gacic. There, the model will be used by both Italians and Slovenes for various basinwide and regional studies. We shall be providing technical assistance during this transition.

RELATED PROJECTS

1. Dr. P.-M. Poulain (Naval Postgraduate School) has recently been funded by ONR to conduct additional drifter experiments and synoptic surveys of some of the Croatian waters. Our model will be used to compare actual and numerical drifter trajectories and to help improve drifter-launch strategies, while the synoptic experiments will be used to assess the model’s predictive skills over a time interval of several days.

2. There are other, currently running models of the entire Adriatic Sea (at the Naval Oceanographic Office, at Mississippi State University, in Bologna, and in Athens). We have developed and maintain contacts with the respective teams.

REFERENCES

Artegiani, A., D. Bregant, E. Paschini, N. Pinardi, F. Raichich and A. Russo, 1997: The Adriatic Sea general circulation. Part 2: Baroclinic circulation structure. J. Phys. Oceanogr., 27, 1515-1532.

Buljan, M., and M. Zore-Armanda, 1976: Oceanographical properties of the Adriatic Sea. Oceanogr. Mar. Biol. Ann. Rev., 14, 11-98.

Franco, P., 1972: Oceanography of northern Adriatic Sea. Hydrologic features: cruises January-February and April-May 1966. Archo Oceanogr. Limnol., 17 suppl., 1-97.

Hellerman and Rosenstein, 1983: Normal monthly wind stress over the world ocean with error estimates, J. Phys. Oceanogr., 13, 1093-1104.

Lynch, D. R., J. T. C. Ip, C. E. Naimie, and F. E. Werner, 1996: Comprehensive coastal circulation model with application to the Gulf of Maine. Cont. Shelf. Res., 16, 875-906.

Poulain, P.-M., 1998: Drifter observations of the surface circulation in the Adriatic Sea. J. Mar. Syst., in press.

PUBLICATIONS

Cushman-Roisin, B., and C. E. Naimie, 1998: A 3D finite-element model of the Adriatic Sea. Part 1: Tides, J. Phys. Oceanogr., submitted.

Malacic, V., D. Viezzoli, and B. Cushman-Roisin, 1998: Tidal dynamics in the northern Adriatic Sea, Oceanologica Acta, submitted.

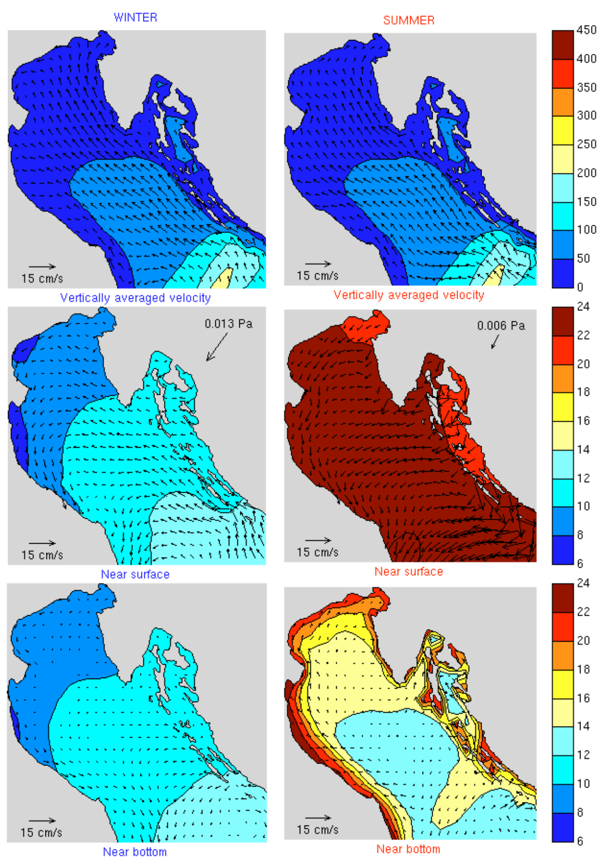

Figure 1: M2 tidal flood currents and the steady currents (tidal residuals + density flow + wind drift) and temperature in the northern Adriatic during the two primary seasons of the year. The top row shows the total vertically averaged currents at the time of the peak M2 flood in winter and summer, superimposed on the bottom topography; the middle row shows the near-surface currents superimposed on the surface temperature; and, the bottom row shows the near-bottom currents superimposed on the bottom temperature.

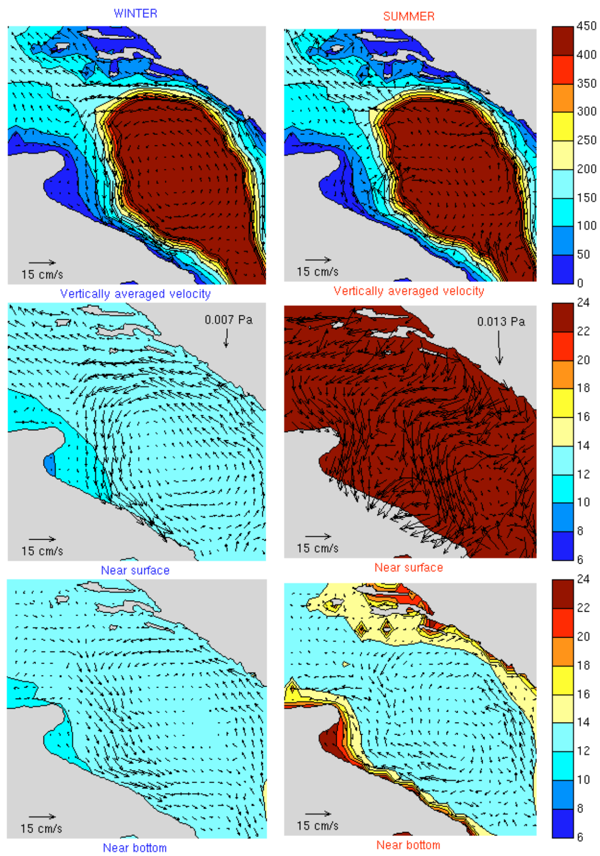

Figure 1: M2 tidal flood currents and the steady currents (tidal residuals + density flow + wind drift) and temperature in the northern Adriatic during the two primary seasons of the year. The top row shows the total vertically averaged currents at the time of the peak M2 flood in winter and summer, superimposed on the bottom topography; the middle row shows the near-surface currents superimposed on the surface temperature; and, the bottom row shows the near-bottom currents superimposed on the bottom temperature.