# THE DYNAMICS OF THE COASTAL ECOSYSTEM OF THE NORTHERN ADRIATIC SEA

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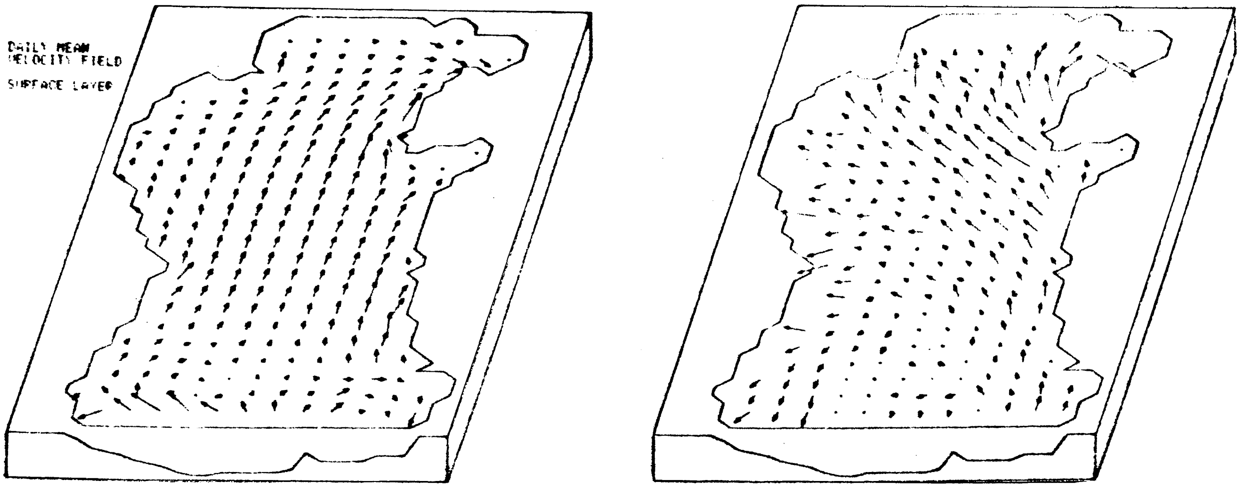
Abstract

A two-layered baroclinic numerical model is used to simulate the sea level and currents in the entire northern Adriatic and the hydrodynamics of the nearcoastal area of the Emilia-Romagna Region along the northern Adriatic during September-October 1978. They allow to study the influence of the Po River outflow on the general circulation pattern of the northern Adriatic.

The northern half of the Adriatic Sea is constituted by the continental shelf, which reaches very shallow depths ($\sim$ 20 m and less) in the northernmost extremity. In particular, the nearcoastal region adjacent to the Italian coastline forms a shallow strip, with isobaths running parallel to the coast and a topography gently increasing towards the interior of the basin. In the region immediately south of the Po River delta - the major source of fresh water input into the Adriatic - important eutrophization phenomena have recently occurred in the summer, with the first emergency of eutrophized "red sea" in the late summer of 1976. The controversial question thus arose whether these eutrophization phenomena were caused by anomalous inputs of nutrients, in particular phosphates, injected into the sea by the local industrial waste discharges; or whether instead the nutrient source was due to the Po River waters, which, outflowing from the delta mouths, are carried southward along the Italian coastline in the general cyclonic gyre characterizing the Adriatic yearly average circulation. The general question to be answered was therefore: where does the Po River water go? To answer this question the near coastal circulation had to be hydrodynamically studied as part of the general circulation of the Adriatic Sea. A multilevel hydrodynamic model was therefore constructed to study the transient Adriatic circulation, which in the nearcoastal region south of the Po delta can be approximated by a two-level system. The model numerically integrates the horizontal momentum equation in linearized form, integrated over each level; the continuity equation integrated over the whole depth; advection-diffusion equations for the temperature and salinity; an equation of state relating density to temperature and salinity closes the system. The pressure is hydrostatic and is expressed in terms of a barotropic component, depending upon the surface pressure and sea level, and a baroclinic component, depending upon the interior density field.

The model needs as inputs: i) a realistic bathymetry, ii) the wind stress field at the sea surface, computed from real data, given as surface boundary condition to the horizontal velocity shears evaluated at the sea surface; iii) the air-sea interface evaporation, latent and sensible heat fluxes as well as precipitation when available, given as surface boundary conditions to the temperature and salinity fluxes; iv) the fresh water river inputs at the coast given as horizontal boundary conditions and expressed in terms of daily averages of sea level, v) the sea level distribution at the southern open mouth of the integration basin, evaluated from the harmonic constants of the coastal stations at the same latitude. The model predicts the space-time evolution of i) the sea level; ii) the total horizontal transports integrated over the whole local depth; iii) the horizontal transports in each horizontal layer; iv) the vertical velocity at each level rigid interface; v) the horizontal distribution of temperature, salinity, density in each layer. The model was run in a basic numerical experiment, with real input data, from September 15, 1978 to October 16, 1978, taken as the typical summer test case. The numerical grid had a size of 7.5 km and the resolution was increased to 2.5 km in the nearcoastal strip south of the Po delta. Model outputs were recorded every 2 hours and subsequently averaged over 24 hours to filter the tidal signal. The model was sampled at various grid points, from the interior region towards the coastline, at various latitudes south of the Po delta, using salinity as a "tracer" of the fresh Po River water. As an example, we show the steady summer distribution of Adriatic currents, in Figure 1 (a,b) respectively for the




(a) (b)

Figure 1. Daily mean velocity field.

for the surface and bottom layers. The general conclusions which can be drawn from the basic numerical experiment are the following. The "signal" of the Po River water, represented by the salinity field, is lost when progressing towards the coastline, even during intense episodes of northeast wind, when significant advective effects are present in the surface layer of 10 m thickness. The nearcoastal strip, of about 10 km width, is almost stagnant. The total transports are essentially zero. Not only is there no significant southward transport; in the whole nearcoastal region, of 30-35 km width, the total transport in alongshore direction is most often directed northward, contrary to what occurs in the winter. This last situation--northward alongshore transport in the nearcoastal region--seems to constitute the average late summer situation, in the absence of a significant wind field and consequent wind-driven currents in the surface layer.

Dynamical considerations (Csanady, 1978; Hendershott and Rizzoli, 1976; Beardsley and Winant, 1979; P. Tung-Shaw, 1981) suggest that the nearcoastal circulation is driven by the bottom torque, which dominates the dynamical balance of forces as soon as an alongshore density gradient is present. This alongshore density gradient determines the direction of the vertically integrated flow in alongshore direction. In the winter, with a dense water pool concentrated in the interior of the northern basin, density decreases going southward in the nearcoastal strip; the consequent transport is southward flowing. In summer, the density gradient in the nearcoastal region reverses direction, density actually increasing going southward; this produces a recirculation with alongshore current flowing northward. Current records taken in time-series fashion for 2 years and preliminary experimental results seem to confirm the above dynamical considerations.

References

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