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Stratification effects on the wind-induced currents in the Northern Adriatic

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ABSTRACT

Three-dimensional multilevel model has been used to examine summer stratification effects on the currents induced by scirocco and bora winds in the northern Adriatic. Persistency of motions has been observed in the stratified fluid.

L'effet de l'influence de la stratification d'été sur les courants induits par le Scirocco ét la bora, vents du Nord de la Mer Adriatique, est examiné à l'aide du modèle tridimensionnel. On a observé la persistance des mouvements du fluide stratifié.

The passage of cyclones over the Adriatic Sea is characterized by scirocco and bora winds which cause characteristic flow patterns well studied for homogeneous winter situation. A number of papers have recently appeared reporting numerical modeling studies of wind-induced currents in the northern Adriatic during the winter. Two basic approaches have been made. The first one is based on the vertically averaged equations (Stravisi, 1977) and the second one on the three-dimensional spectral Heaps model (Kuzmić and Orlić, 1987, Orlić et al, 1986). Both methods are unable to include the effect of stratification, so to do that we must use three-dimensional multilevel model with equation of continuity of density.

During the summer the Adriatic region is under the influence of subtropical high pressure and only its northern part feels the influence of the cyclonic activities. In this paper we will examine the influence of summer stratification on currents induced by scirocco and bora winds in the northern Adriatic.

The model used in this paper is based on: (1) momentum equations including local change of velocity, Coriolis force, gradient force in Boussinesq approximation, vertical stress and horizontal stress, (2) equation of continuity of density including advection and turbulent exchange, (3) hydrostatic equation and (4) equation of continuity for volume. The Bowden relation is taken to describe horizontal dependence of vertical exchange coefficients (Heaps, 1974). To describe its vertical dependence we assumed surface and bottom boundary layers with coeficients increasing going off them (Pearce and Cooper, 1981). Along the solid boundary zero normal horizontal flow and zero diffusion transport are assumed while a radiation condition is postulated at the open boundary. At the surface the wind stress is taken as a quadratic function of wind velocity and for the bottom friction linear low will be used. Initial condition is the state of rest with density lineary increasing with depth. Differential equations of motions and continuity were translated into finite difference equations using the leapfrog-time and staggered-space approximation. It should be mentioned that this model gives the same results in homogeneous fluid as model developed by Stravisi and models based on the Heaps approach (Bone, 1990).

Above described model was run in the following numerical experiment. Simulations were performed for 24 hours with scirocco wind followed by 24 hours bora and 48 hours with no wind, the situation characteristic for passage of cyclones over the Nord Adriatic in the summer. Homogeneous wind forcing was assumed for scirocco while for bora heterogeneity in the wind field was taken into account. In order to examine stratification effects the same numerical experiment was performed for stratified and for homogeneous sea. For each run four fields were analyzed : sea-level displacement, vertically averaged current, surface current and bottom current. During the wind forcing the main differences in stratified and homogeneous case are caused by gradient currents. Wind currents acting on initial density field induce characteristic topographically controled gradient currents. The most pronounced difference in the current response were observed in the free oscillating period where we could notice the greater persistency in baroclinic than barotropic mode due to gradient currents.

This is the first time that the effects of stratification were considered for wind induced currents in the northern Adriatic. Under the same forcing conditions, the differences between currents in a stratified fluid and currents in a homogeneous fluid are about 20% of the wind induced current intensities while the flow patterns are mostly the same.

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Process Studies of the Complex Mesoscale Circulation Observed in the Western Mediterranean Sea

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Satellite observations of the Mediterranean Sea reveal extremely complex circulation patterns which are highly time-dependent. This is in stark contrast to the simple idealized flow patterns presented in historical studies based on limited in-situ observations. These pre-satellite studies were based on collections of data which were not synoptic in time nor space and resulted in overly smooth idealized flow patterns.

A series of process studies using a hierarchy of numerical ocean models has been undertaken in an attempt to illucidate the dynamics controlling the observed circulation. The numerical models used are variations of a multi-layered primitive equations model. The simplest version is a one-active layer, reduced gravity model forced by winds, inflow/outflow mass flux and/or density variations. The results from this simplest version yields flow patterns which are qualitatively similar to the historical representations, but do not help to understand the highly time-dependent mesoscale variability observed in the remotely-sensed data.

Adding additional complexities, such as multiple layers and thus allowing for baroclinic instabilities; bottom topography; realistic non-climatic wind stress, etc., increasingly adds to the realism of the numerical simulations. However, with the more complex models, it becomes increasingly evident that simple explanations for the causes of the observed mesoscale variability will not be forthcoming. By a systematic series of process studies, various responses to the specified forcing can be ascertained. The results to date reveal that no single forcing mechanism by itself can explain all the variability and in most cases a combination of forcing mechanisms are required to produce a simulation of the observed circulation patterns.

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