A STUDY OF THE INFLUENCE OF OPEN-BOUNDARY CONDITIONS ON THE PREDICTIONS OF A WIND-DRIVEN MODEL

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Abstract

A three-dimensional numerical hydrodynamical model has been used to study the wind-driven flow in the Northern Adriatic. It revealed a cyclonic gyre formed over the area. Since the radiation condition at the open boundary was suspected to influence the solution, modified radiation condition, modified continuity equation and data from the Adriatic model were further used to investigate the influence.

Résumé

Un modèle hydrodynamique tri-dimensionnel a été utilisé afin d'étudier les courants engendrés par le vent en Adriatique du Nord. Le modèle a mis en évidence un mouvement giratoire cyclonique. Ayant soupçonné que la condition de radiation à la frontière ouverte pouvait influencer les résultats, nous avons étudié l'influence d'une condition de radiation modifiée, de la loi de conservation de la masse modifiée, ainsi que des données obtenues à partir d'un modèle appliqué à la mer Adriatique dans son intégralité.

In numerical modelling of water movements in estuaries or coastal seas computational constraints usually demand setting the solution domain smaller than required by the nature of the flow, which necessitates prescribing artificial boundary conditions. We have faced this problem in our mathematical modelling study of winter dynamics of the Northern Adriatic. A three-dimensional numerical model was used in the study. In obtaining the vertical distribution of current, the model relies on vertical decomposition into eigenfunction modes (Heaps, 1972). The details of the Northern Adriatic model as well as results of the study are given by

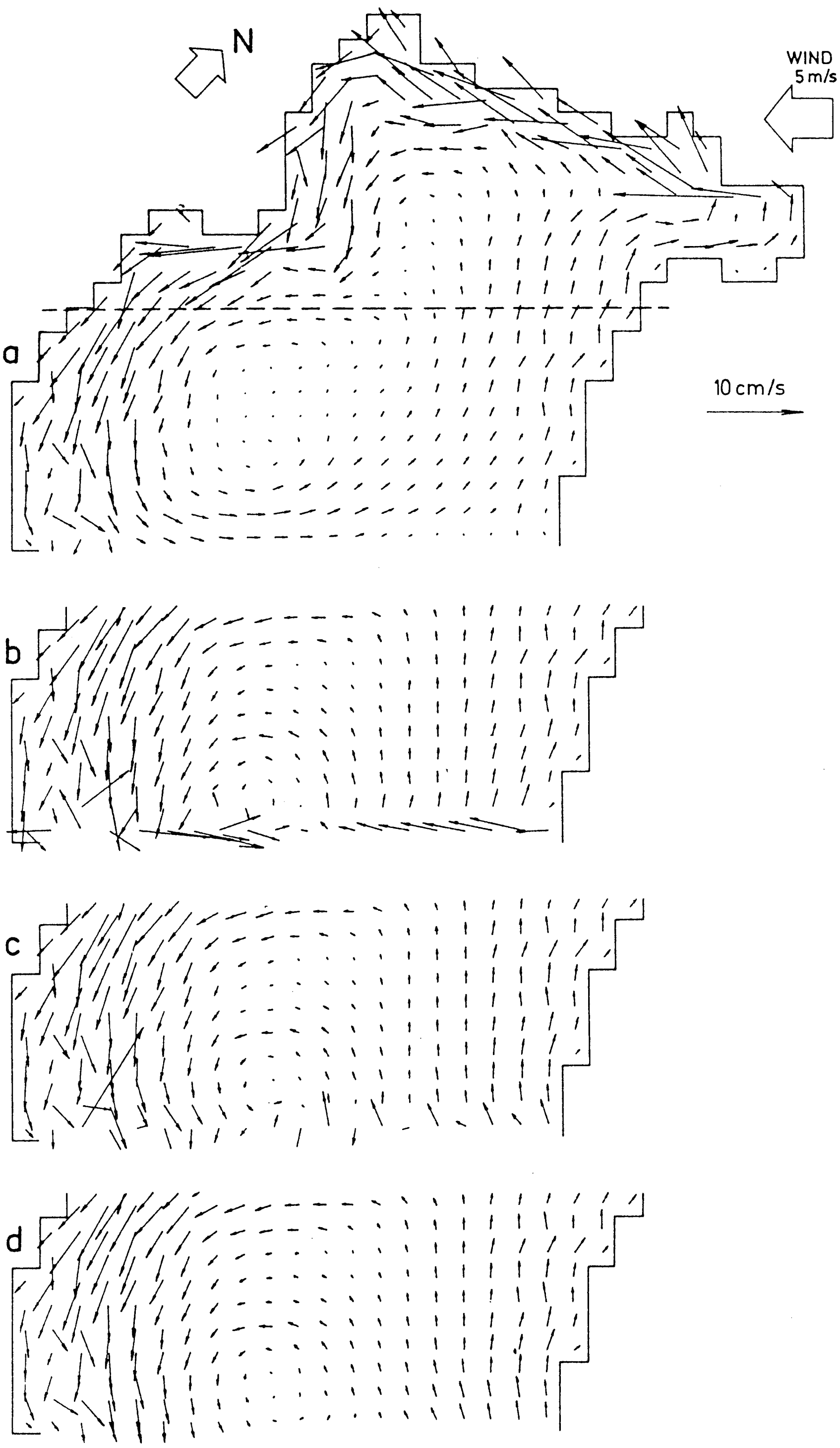

Figure 1. Bottom-slope current for different cases.

Kuzmić et al. (1984).

The model simulates the impact of suddenly imposed, uniform and constant wind on the homogeneous, motionless sea. Four output fields, the sea level, vertically averaged current, surface current and bottom current, have been analyzed in the steady state. The surface and bottom currents conformed to the expected Ekman dynamics, while the bottom-slope current was revealed in the vertically averaged current field. This current formed a cyclonic gyre over the modelled area. Although such a circulation could have been set up under the topographic influence, we have suspected that the southern part of the gyre was the consequence of an inadequate open boundary conditions and therefore further considered three other conditions. The model was also extended over the whole Adriatic Sea and the information from that model used for forcing the smaller-area model.

Altogether, four cases were considered at the open boundary:

$$v_B^r(i) = \alpha(i) \cdot \zeta_I(i) \qquad \text{(a)}$$

$$v_B^r(i) = \alpha(i) \cdot \zeta_E(i) \qquad \text{(b)}$$

$$v_B^r(i) = f_1[\zeta_E(i)] + f_2 \ [u_I, v_I] \qquad \text{(c)}$$

$$v_B^r(i) = v_E^r(i) \qquad \text{(d)}$$

where B indicates the open boundary, I the internal (N. Adriatic) and E the external (Adriatic) data, i is the nodal and r the modal index, $\alpha(i)$ is the set of constants, f_1 and f_2 are some functions, and ζ, u and v are the sea level and velocity components, respectively. The case (a) is the radiation boundary condition imposed initially, the case (b) is a modified radiation condition; the case (c) is a modified continuity equation with advanced values of ζ from the Adriatic model, and the case (d) is the case with the boundary velocity values from the Adriatic model. The case (a) has been used, and the case (c) proposed by Heaps (1972). Only the first mode was used in cases (a)-(c), and ten modes in (d).

The results of the study are summarized in Fig. 1. The whole modelled area is given for the reference case (a), and only the lower part of it for the other three. A closed, cyclonic gyre is clearly visible in Fig. 1a, and equally clearly lacking in Fig. 1d. The modified radiation condition and modified continuity equation both improved the prediction by not closing the gyre, but gave somewhat erroneous predictions at the boundary. It should be noted that cases (b)-(d), that rectify the circulation, all require running the larger-area model. Among them the case (d) is getting more data - intensive as number of transferred velocity modes is increasing. Although running the larger-area model helped resolving this particular problem, the method is highly impractical for regular use since it is computationally demanding and time consuming, so improvement is needed within the framework of the smaller-area model.

References

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