MASS TRANSPORT GENERATED BY FLUCTUATING WINDS

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Abstract

With regard to the transport of pollutants the possibility of generation of a mean flow by the variable winds over the northeastern Mediterranean is examined. The first order barotropic motions generated by a periodic wind stress acting on a water mass of constant depth on an f-plane are utilized to compute the second order mean flow.

Formulation

Current observations off the southern Turkish coast reveal the presence of fluctuating currents with significant energy levels. The temporal variability oberved reflects the variability of wind stress. With regard to the transport of pollutants, an assessment for capability of such oscillatory currents to induce a mean transport requires an examination of the influence of nonlinear accelerations.

The scale analysis appropriate for the dimensions of the Cilican Basin indicates that the Rossby number and the horizontal and vertical Ekman numbers have same order of magnitude but both are much smaller than unity. This then allows the use of perturbation expansion of the governing dynamical equations with first order oscillatory motion being linear. The boundary layer theory can then be applied to the flow domain. The first-order oscillatory motion is governed by the solution of depth-averaged equations for a sufficiently deep water and in the absence of bottom stress and surface divergence. The set of equations representing the mean flow generated by nonlinearities associated with the convective accelerations is, moreover, obtained by time averaging of first order equations. The nonlinear forcing function related to the first-order oscillatory flow is primarily dominant in the surface Ekman Layer.

Rapp. Comm. int. Mer Médit., **28**, 2 (1983).

Final form of the expressions for the steady interior horizontal and vertical flow, induced by first order oscillatory motion, and the assosciated Ekman transports are given as follows;

$$\hat{k} \times \vec{u}^{(I)} = - \nabla\zeta$$

$$w^{(I)} = - \frac{1}{2} E^{1/2} \nabla\cdot\{\hat{k} \times \vec{u}^{(I)}\} \qquad (1.a,b)$$

$$\vec{M}^{(S)} = \hat{k} \times \vec{R}$$

$$\vec{M}^{(B)} = \frac{1}{2} \{\hat{k} \times \vec{u}^{(I)} - \vec{u}^{(I)} \qquad (2.a,b)$$

where $\hat{k}$ be the unit normal vector in the vertical direction, E the vertical Ekman number and the superscripts (I), (S), (B) denotes the interior, region, surface and bottom Ekman layers, respectively. The surface elevation, ζ, in eq.(1.a) is obtained by the relation

$$\nabla^2\zeta = 2\{ \frac{\partial R_1}{\partial x} - \frac{\partial R_2}{\partial x} \} \qquad (3)$$

R_1 and R_2 represents the components of $\vec{R}$ and may be expressed in terms of ellipse parameters.

As a case study we consider an applied wind stress having only an offshore component definedin the form

$$\mathcal{T}(x) = T_0 \mathrm{Cos}\ (\pi x) \qquad (4)$$

with an amplitude T_0. We then simulate the steady circulation in a channel-like geometry resembling a region between southern Turkish coast and Cyprus, a region known as the Cilician Basin. The resulting circulation pattern produces onshore (offshore) transport in upper (lower) Ekman layer with a westerly horizontal flow in the interior near the southern Turkish coast. The resulting horizontal circulation pattern near the northern Cyprus coast is exactly in the opposite sense. The compensatory vertical motion produces downwelling near the coast and upwelling at the middle of the basin.