Abstract View

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Mass Transport in Deep-Water Waves

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ABSTRACT

The problem of mass transport induced by monochromatic waves in a viscous fluid of infinite depth and infinite lateral extent is examined. The fluid viscosity is assumed constant and the effects of Coriolis force and a nonzero surface shear stress are incorporated in the analysis. The solution shows the wave-induced surface drift to be finite, thus eliminating the apparent paradox of an infinite wave-induced surface drift predicted by Longuet-Higgins' classical solution. The nature of the present solution depends on the ratio of the Ekman depth δ to the wavelength L. The combined wind- and wave-induced drift velocity is found to be composed of a classical Ekman current and a wave-associated mass transport current. For large values of δ/L the wave-associated mass transport current is a superposition of Stokes' mass transport and the shear current arising from the unbalanced surface velocity gradient predicted by Longuet-Higgins' mass transport theory. For small values of δ/L the wave-associated mass transport velocity exhibits the features of a pure shear current corresponding to the surface velocity gradient induced by the wave motion, i.e., the mass transport becomes proportional to δ and approaches zero for an inviscid fluid in agreement with Ursell's finding. For all values of δ L the wave-induced surface drift is found to he at an angle of approximately $\pi/4$ to the direction of wave propagation. The results show that a simple superposition of the Ekman current and Stokes' mass transport to find the combined surface drift of winds and waves is invalid. The extension of the present analysis to a fully developed sea, described by its spectrum, is discussed.

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