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Theory and applications of the interaction between surface waves and currents in water of varying depth

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In this thesis, the non-linear interaction which occurs when surface waves propagate on a non-uniform stream is studied. The system of partial differential equations describing the wave-induced mean flow is determined by several different approximation techniques. In particular, a formal derivation by depth-averaged conservation laws and the two-variable expansion procedure is given. The results are shown to be equivalent. The governing equations are expressed both in terms of particle velocities and functions related to mean fluid transport.

The implications of this model of the current - surface wave interaction are developed in two widely separated fields of interest, namely,

1. the existence of an exact solution and its relation to approximate solutions produced by asymptotic procedures;
2. the application of the equations governing the wave-induced flow to commonly occurring oceanographic phenomena.

In this study, a method for establishing the validity of asymptotic expansion procedures and estimating partial wave reflection coefficients is developed for a wide class of wave propagation problems. However, it has not been possible to adapt this technique or other standard techniques to justify rigorously the asymptotic methods used in studying surface waves in a channel of slowly varying depth. In this sense, the development of this

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model of the current - surface wave interaction is incomplete.

Within the nearshore region, the transport of mass and momentum by the incoming ocean waves produces and maintains a wide variety of current systems. Many of these systems may be analyzed in terms of the theory presented here.

The wave-induced current and mean water level variations in the neighbourhood of a blunt headland between shallow bays are described. As expected, wave convergence in the vicinity of the headland leads to an increased seaward flow in the model. In this situation, the interaction between the incoming waves and the seaward current is assumed negligible. On the other hand, in the vicinity of a 'rip' current, the current-surface wave interaction is shown to be the mechanism which produces the variations in the radiation stresses necessary to generate fluid vorticity.

Data from a specially-designed laboratory model have been used to test the theoretically-predicted current system. The agreement in this preliminary study is quite satisfactory, as far as the comparison has been made. As an application of this theory of wave-induced flows, the current in the neighbourhood of a symmetric submerged mound on which plane waves impinge has been computed. Standard numerical techniques were employed in solving this problem.