Effects of airflow on hydrodynamic modulation of short surface waves by long waves

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Abstract

A model is developed for the effects of airflow on hydrodynamic modulation of short surface gravity waves by a dominant long wave. The propagation of the short wave and distribution of its wavenumber and energy density with respect to phase of the long wave are specified by the kinematic conservation equation and the wind-forcing modified wave action equation, which are solved using linear ray theory and modelled by the Reynolds-averaged Navier-Stokes equations

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The hydrodynamic modulation of short surface waves by a longer wave is a result of both kinematic and dynamic effects. The kinematic effect predicts that the maximum modulations occur at the crest of the long wave while the dynamic effect is due to the modulation of the local shear stress by the long wave which stimulates the growth rate of short waves. The latter dominates the hydrodynamic modulation processes when the ratio $\mathbf{U_\lambda/C_L > 2}$ ($\mathbf{U_\lambda}$ is the wind speed at height equal to the long wave length and $\mathbf{C_L}$ is the phase speed of the long wave). For a smaller ratio (<2), the maximum modulations are located about 5° ahead the crest of the long wave while for a larger (>2) ratio, the maximum modulations are shifted to around 30° behind the crest of the long wave.

The present model has several innovations over previously published work. First, it accounts for nonlinear changes to the wavenumber and wave action, whereas most previously studies have assumed small changes to the wave action. Secondly, the wind forcing is treated in a way that incorporates recent developments, and finally the model calculates the wind field dynamically..