Abstract View

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Momentum and Energy Transfer in Wind Generation of Waves

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ABSTRACT

Complete expressions for wind momentum and energy transfer to wind-generated waves are derived based on a boundary-layer integral method. The airflow and wave measurements as made by Wu *et al*. (1977, 1979) are used to provide a first-order estimate of the momentum and energy budget. The momentum and energy transfer to waves are found to be dominated by the wave-induced pressure and mainly received by the dominant wave, which agree with the wind energy input mechanism of a nonlinear wind-waves model proposed by Lake and Yuen (1978) and Yuen and Lake (1979). It is found that the waves support about 61% of the total wind momentum, but receive only about 29% of the tow wind energy across the interface. This low fraction of energy to the waves is found to be the consequence of a high ratio of mean surface current velocity to wave celerity which results in a considerable leakage of energy delivered by the wave-supported momentum to the current. The measured energy transfer to waves by the wave-induced pressure is found to be in good agreement with that observed by others in the laboratory and in the field. The comparison of wave-growth parameter based on the wave-induced pressure to the field observations of Snyder *et al*. (1981) and to the predictions of Al-Zanaidi and Hui (1981) shows a strong dependence of the wave-growth parameter on the wave slope.

Based on the side-band instability theory of Benjamin and Feir (1967) and the nonlinear wave-modulation theory of Yuen and Lake (1980), the down-shifting of dominant wave frequency f_0 along the fetch x_1 is found to be described

by $f_0 u_*/g = 0.91(x_1 g/u^2_*)^{-5/16}$, where u_* is the wind friction velocity and g the gravitational acceleration. As a result, the dominant wave slope $k_0\bar{a}$ changes with the fetch as $k_0\bar{a} = 0.58 \times (x_1 g/u^2_*)^{-1/8}$; this implies an evolution of the wind wave from a bounded, nonlinear system at short fetch to a free linear system at large fetch (a fully developed sea state). The decrease in the saturation range constant (Phillips, 1958, 1977) with increasing fetch is found to be closely related to this evolution.