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Stochastic Form of the Growth of Wind Waves in a Single-Parameter Representation with Physical Implications

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ABSTRACT

It is shown that a simple relation, $E^* = 5.1 \times 10^{-2}\ \sigma_m{}^{*-3}$ for describing the conditions of growing wind waves, is supported by various available data, where $E^* = g^2E/u_*{}^4$ is dimensionless energy. $\sigma_m{}^* = u_*\sigma_m/g$ the dimensionless angular frequency at the maximum of the energy spectrum, g the acceleration of gravity and u_* the friction velocity of the air. This expression is an alternative form of the relation between dimensionless wave height and period, $H^* \propto T^{*3/2}$, which was previously proposed by the author (Toba, 1972) for energy-containing waves, and is extended to individual waves in the wind-wave field in a statistical sense. It is also shown, supported by various data, that the essential part of the one-dimensional energy spectra of growing wind waves should have the form $g_*u^*\sigma^{-4}$ for the high-frequency tail of the frequency spectrum, where g_* is g expanded to include the surface tension. This is the form previously proposed by the author (Toba, 1973b) as the one-dimensional spectral form consistent with the above power law relationship, instead of the $g^2\sigma^{-5}$ form proposed by Phillips (1958). By use of the power-law relationship for E^*, it is shown that the proportion of that part of momentum which is retained as wave momentum to the total momentum transferred from the wind to the sea can be expressed by a function of $\sigma_m{}^*$, which has essentially the same physical meaning as C/U, the ratio between the phase velocity of the energy containing wave and the wind speed. The value of the proportion decreases from about 6% in the form of an error function of C/U. A prediction equation for the growth of wind waves by a single-parameter representation is proposed, in which the rate of change of E^* is expressed by a formulation including the error function or by a simple stochastic form. The integration of the equation for the case of fetch-limited conditions is in excellent agreement with data compiled by Hasselmann *et al*. (1973). Reviewing results of recent wind-wave tunnel experiments, emphasis is given on the fact that wind waves are strongly nonlinear phenomena, especially for $C/U \lll 1$. A discussion is presented from this standpoint as to the physical basis for the existence of the simple power law relationship. the spectral form of $g_*u^*\sigma^{-4}$ and the stochastic

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form of the growth equation, and a systematic derivation of these relationships and equations is attempted.

top

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