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Weakly turbulent self-similarity relations for experimentally observed growing wind-waves

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The theory of weak turbulence developed for wind-driven waves in recent theoretical and extensive numerical study [1] concludes that non-dimensional features of self-similar wave growth (i.e. wave energy and characteristic frequency) have to be scaled by internal wave-field properties (magnitudes of total fluxes of energy, momentum or wave action) rather than by external attributes (wind speed) which have been widely adopted since the Kitaigoroskii's approach [2] was proposed. In the present paper, these conclusions are verified by means of experimentally observed power-law dependences for total energy and peak frequency in special cases of duration- and fetch-limited wave growths.

Based on the hypothesis of dominating nonlinear transfer introduced and validated in [1], the asymptotic weakly-turbulent relation for total energy ε and a characteristic wave frequency ω_* was derived

$$\frac{\varepsilon\,\omega_*^4}{g^2} = \alpha_{ss}\left(\frac{\omega_*^3\, d\varepsilon/dt}{g^2}\right)^{1/3}. \qquad (1)$$

Quasi-universal self-similarity coefficient α_{ss} was found in the numerical duration-limited experiments and was shown to be naturally varying in a relatively narrow range being dependent on the energy growth rate only.

In this work, the analytical and numerical conclusions are further verified by means of known field dependences for wave energy growth and peak frequency evolution. A comprehensive set of more than 20 such dependences, obtained over almost 40 years of field observations, is analysed. The estimates give α_{ss} very close to the numerical values. They demonstrate that the weakly turbulent self-similar relationship (1) has a general value and describes the wave evolution well, apart from the earliest and full wave development stages which are not self-similar.

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