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Scales of nonlinear relaxation and balance of wind-driven seas

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We present analytical and numerical arguments that support the fact of leading role of nonlinear transfer in balance of wind-driven seas. The argumentation is based on a decomposition of the collision integral S_{nl} in the kinetic equation for deep water waves. This term describes the effect of four-wave resonant interactions and can be presented as a sum of nonlinear damping $\Gamma_k N_k$ and forcing F_k as follows

$$S_{nl} = F_k - \Gamma_k N_k \qquad (1)$$

Here Γ_k – positive nonlinear damping decrement, N_k – spectral density of wave action. Both terms $\Gamma_k N_k$ and F_k surpass conventional parameterizations of input and dissipation of wind-driven waves by, at least, one order of magnitude, as our numerical and analytical results show. For wind-wave community, this basic (and, to some extent, trivial) fact is masked by a number of stereotypes. First, conventional scaling of relaxation time τ due to nonlinear transfer claims proportionality $\tau = C_{nl}\mu^{-4}$ ($\mu = ak_p$ – characteristic steepness of water waves, k_p – wavenumber of spectral peak) implying the multiplier $C_{nl} = O(1)$. In fact, C_{nl} appears to be a huge value in our estimates for directionally narrow ($C_{nl} = 36\pi$) and isotropic spectra ($C_{nl} = 45\pi/2$). The second stereotype comes from numerical algorithms for S_{nl} where annihilation of huge terms is considered as a good luck for accelerating calculations the collision term S_{nl}. As a result, the problem of wind-wave balance is usually treated as comparison of the whole S_{nl} with terms of wave input S_{in} and dissipation S_{diss}. Such approach belittles the role of the strong inherent relaxation mechanism due to four-wave resonant interactions and overestimates dramatically the effect of wind input and wave dissipation on spectral balance of wind-driven waves.

The key message of the leading role of the nonlinear transfer is illustrated by analysis of cases of fully developed (see the milestone paper by Komen et al. 1984) and the mixed sea.

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