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Nonlinear fast growth of surface gravity waves under the action of wind

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The generation of ocean waves by wind is a highly nonlinear problem where the physical processes at the air-water interface are difficult to measure and to model for the presence of turbulence in both fluids. Direct field measurements of the induced pressure by airflow on waves are rare and difficult to perform, thus the underlying mechanisms leading to wave amplification are still unclear. We consider here the Miles' mechanism, which is characterised by growth rates, Γ_M/f, in the range from 10^{-3}-10^{-2} for fast-moving waves and in the range 10^{-2}-1 for slow-moving waves and waves in laboratory tank experiments. This prompted us to investigate the case with Miles' growth rates of first order in the wave steepness, $\Gamma_M/f = O(\epsilon)$, instead of the usually considered one, $\Gamma_M/f = O(\epsilon^2)$, where ϵ is the wave steepness which both in ocean and tank experiments can be of the order of 0.1.

We use the method of multiple scales for deriving the nonlinear Schrödinger (NLS) equation with wave growth rate of first order in the wave steepness. We find that a simple coordinate transformation reduces the wind-forced NLS equation into the standard NLS equation with constant coefficients. Thus, we show how the Peregrine, Akhmediev and Kuznetsov-Ma solutions are modified in the presence of this first-order wind. In particular, the lifetime of both the Peregrine and the Akhmediev solitons increases for large growth rates and the maximum amplitude of these solitons slightly increases for growth rates larger than a certain value. The enhancement of both lifetime and maximum amplitude of rogue waves under the action of wind has been observed in tank experiments and numerical simulations of dispersive focusing, thus confirming the relevance in this context of the case $\Gamma_M/f = O(\epsilon)$ considered in the present study.