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Influence of wind forcing on evolution and breaking of nonlinear wave groups.

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A numerical and experimental investigation of modulational instability and breaking of nonlinear wave groups in the presence of wind forcing is reported. A wave group is initially assigned by a superposition of two sinusoidal signals with close wave numbers: a carrier wave and a sideband. While propagating, such wave group experiences modulational instability, when new sidebands appear and develop. Wind forcing is added to the wave system. Evolution of the wave system is described in terms of distance to breaking and modulation depth. The wave modulation depth R is a height ratio of the highest H_h and the lowest H_l waves in the group: $R = H_h/H_l$. Numerical simulations are conducted by means of fully-nonlinear Chalikov Sheinin model (Chalikov and Sheinin, 2005).

In our previous research (Galchenko et al, 2010) distance to breaking and modulation depth were found to depend on initial primary wave steepness and ratio of initial primary wave steepness and steepness of sideband. In the same research it was experimentally proven that breaking severity (energy lost in a single breaking event) grows with modulation depth R. It was also shown that probability of breaking for wave groups with R <2.2 is very low.

The present research continues the investigation described in Galchenko et al (2010), now including wind effects. Wind influence on the wave groups described above appears to be defined by wind forcing U/c, where U is the wind speed (here it is wind speed on height of half of the wavelength) and c is the phase speed of the carrier wave. When wind forcing is increasing, it tends to suppress modulational instability and reduce modulation depth. Maximum suppression is found to be for U/c=6-8, when we can simultaneously observe low values of modulation depth (close to 1) and decreased distance to breaking. For such wind forcing modulation depth is independent of primary wave steepness. Further increase of wind forcing (to extreme winds) changes the situation: both modulation depth and distance to breaking begin to grow, the suppression of modulation depth becomes less significant.

A laboratory experiment has shown that severity of breaking in the presence of moderate wind forcing is significantly lower than without wind. That is, wind forcing reduces the severity of a single breaking event. However, wind increases the breaking probability. We can also note that in the presence of wind probability of breaking for waves with modulation depth R <2.2 noticeably grows. This means that the reasons for breaking in this case are other than modulational instability.

References

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