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Investigation of air-sea momentum transfer under hurricane wind conditions within laboratory modeling

D.A. Sergeev (1,2), Yu.I. Troitskaya (1,2), G.A. Baidakov (1,2), M.I. Vdovin (1,2), A.A. Kandaurov (1,2), V.I. Kazakov (1,2)

(1) Institute of Applied physics RAS, Nonlinear Geophysical Flows, Nizhny Novgorod, Russian Federation (daniil@hydro.appl.sci-nnov.ru), (2) Lobachevsky State University of Nizhni Novgorod ,Russian Federation

Wind-wave interaction at extreme wind speed is of special interest now in connection with the problem of explanation of the sea surface drag saturation at the wind speed exceeding 30 m/s. Now it is established that at hurricane wind speed the sea surface drag coefficient is significantly reduced in comparison with the parameterization obtained at moderate to strong wind conditions. However lack of experimental data prevents from specifying a definite mechanism of this effect.
We supposed that the peculiarities of surface drag coefficient can be explained by dependence of the form drag of surface waves at strong wind conditions. To verify the supposition we measured simultaneously aerodynamic resistance of the water surface and frequency-wave number spectra of wind waves in wide range of wind speeds in the laboratory tank of the Institute of Applied Physics. Aerodynamic resistance of the water surface was measured by the profile method with Pitot tube. A method for data processing taking into account the self-similarity of the air-flow velocity profile in the aerodynamic tube was applied for retrieving wind friction velocity and surface drag coefficients. Simultaneously with the airflow velocity measurements, the wind wave field parameters in the flume were investigated by system of wire gauges. Analysis of the wind wave spectra showed tendency to saturation for mean square slope for wind speed exceeding 25 m/s simultaneously with the surface drag coefficient and linear dependence between surface drag coefficient and mean square slope. Video filming indicates onset of wave breaking with white-capping and spray generation at wind speeds approximately equal to 25 m/s.
We compared the obtained experimental dependencies with the predictions of the quasi-linear model of the turbulent boundary layer over the waved water surface. Comparing shows that theoretical predictions give low estimates for the measured drag coefficient and wave fields. We took into account small scale (high frequency) part of the surface roughness (k >1 1/cm) adding the model short wave spectra suggested by Elfouhaily et al, 1997 to measured long wave part. New theoretical results are in better agreement with experiment.
Basing on the experimental data we can conclude that the drag saturation at severe wind conditions in the laboratory tank can be explained by saturation of the form drag of surface waves under these conditions. Tearing of the wave crests at severe wind conditions leads to the effective smoothing (decreasing wave slopes) of the water surface, which in turn reduces the aerodynamic roughness of the water surface. Quantitative agreement of the experimental data and theoretical estimations of the surface drag occurs if momentum flux associated with short wave part of the wind wave spectra is taken into account.
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