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Wind flow modulation due to variations of the water surface roughness

Olga Shomina, Stanislav Ermakov, Ivan Kapustin, and Tatiana Lazareva
Institute of Applied Physics RAS, Nizhny Novgorod, Russian Federation (seamka@yandex.ru)

Air-ocean interaction is a classical problem in atmosphere and ocean physics, which has important geophysical applications related to calculation of vertical and horizontal humidity, aerosol and gas fluxes, development of global climate models and weather forecasts. The structure of wind flow over fixed underlying surfaces, such as forestry, buildings, mountains, is well described, while the interaction between a rough water surface and turbulent wind is far more complicated because of the presence of wind waves with different wavelength and amplitudes and propagating with different velocities and directions.
The aim of this study was to investigate experimentally the variability of the wind profile structure due to variations of wave characteristics. The surface roughness variations were produced using a) surfactant films (oleic acid) spread on the water surface and b) mechanically generated waves superimposed on wind waves. The first case is related to oil slicks on sea surface, the second one - to the sea swell, which propagates into zones with lower wind velocities and interacts with wind flow.
Laboratory experiments were conducted in the Oval Wind Wave Tank (OWWT) at the Institute of Applied Physics, cross-section of the wind channel is 30 cm x30 cm. Wave amplitude and the spectrum of surface waves were measured by a wire wave gauge, the wind speed was measured using a hot-wire anemometer DISA and a Pitot tube.
In the experiments with surfactants, two frequencies of dripping of the oleic acid were studied, so that low concentration films with the elasticity parameters of about 19 mN/m and the high concentration (“thick”) films with the elasticity of 34 mN/m were formed. In the experiments with mechanically generated waves (MGW) different regimes were studied with MGW amplitude of 3.4 mm and of 4.4 mm, and with MGW frequencies of 3.3 Hz and 3.7 Hz.
It was shown, that:
a) the mean velocity of the wind flow in the presence of surfactant and MGW can be described by a logarithmic profile;
b) in the presence of a surfactant film an increase of wind speed was revealed; the more elastic films was deployed on the surface - the stronger wind acceleration was detected;
c) MGW result in deceleration of wind flow, the larger MGW amplitude the stronger wind flow reduction is;
d) the wind deceleration effect is more pronounced for MGW with higher frequency, i.e. for slower propagating MGW.
e) experimental dependencies of the logarithmic wind profile characteristics as functions of the rout mean square (RMS) wave height were obtained demonstrating the growth of the wind friction velocity and the roughness coefficient with RMS.
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