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# Effect of sea sprays on air-sea momentum exchange at severe wind conditions

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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. The idea on saturation (and even reduction) of the coefficient of aerodynamic resistance of the sea surface at hurricane wind speed was first suggested in [1] on the basis of theoretical analysis of sensitivity of maximum wind speed in a hurricane to the ratio of the enthalpy and momentum exchange coefficients. Both field [2-4] and laboratory [5] experiments confirmed 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.

Two groups of possible theoretical mechanisms for explanation of the effect of the sea surface drag reduction can be specified. In the first group of models developed in [6,7], the sea surface drag reduction is explained by peculiarities of the air flow over breaking waves. Another approach more appropriate for the conditions of developed sea exploits the effect of sea drops and sprays on the wind-wave momentum exchange. Papers[8,9] focused on the effect of the sea drops on stratification of the air-sea boundary layer similar to the model of turbulent boundary layer with the suspended particles [10], while papers [11-13] estimated the momentum exchange of sea drops and air-flow. A mandatory element of the spray induced momentum flux is a parameterization of the momentum exchange between droplets and air flow, which determines the “source function” in the momentum balance equation.

In this paper a model describing the motion of a spume droplet, the wind tear away from the crest of a steep surface wave, and then falling into the water. We consider two models for the injection of droplets into the air flow. The first one assumes that the drop starts from the surface at the orbital velocity of the wave. In the second model we consider droplets from the water jet formed at the base of the collapsing cavity of the air bubbles in whitecaps of breaking waves. In both models, we calculate the momentum that acquires the droplet in the interaction with the air flow. Depending on the particular airflow velocity field, on the wave parameters and on the radius of the droplet, it can as receive and deliver momentum to the airflow during its life cycle from the separation from the surface of the water to fall into the water. Large droplets with a radius greater than 100 microns can as deliver momentum to the air flow and acquire it, but small droplets with a radius of less than 100 microns after detachment from the surface of water levitate in the air flow. However, they are accelerated (or decelerated) from the speed they had on the water surface (the orbital velocity of waves in the first model and the ejection velocity of the top jet droplet in the second model) to the air flow velocity, on average taking away its momentum. The experimental data, compilation of which is given in [14] show that the droplet generation function $\frac{dF}{da}$ exponentially decreases with increasing a $\frac{dF}{da} = be^{-a/a_0}$, where a0 = 38.5 mm. As a result, the main contribution to the momentum flux is due to small droplets, taking away the momentum from the air flow, and then spray formation slows down the airflow and, consequently, increase aerodynamic drag of the sea surface. It should be noted, however, that the effect of momentum transfer by spume droplets torn away from the crests of breaking waves, is small compared with the turbulent momentum flux in most realistic conditions, including hurricane winds, but it grows rapidly with increasing wind speed. The wave-induced momentum flux and can be compared in magnitude with the turbulent momentum flux, when the wind friction velocity $u_*$ is about 2.5 m / c.

Thus, the direct calculation of the momentum exchange between sea sprays and wind shows that this mechanism leads to an increase of aerodynamic resistance of the sea surface with increasing wind speed. To explain the effect of the sea surface drag reduction at high wind speed conditions, apparently, changing of the form drag, possibly associated with the influence of foam should be considered.

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