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On effect of wind surface waves on mass and momentum transfer in a stratified turbulent boundary layer

Yu. Troitskaya, E. Ezhova, D. Sergeev, A. Kandaurov, G. Baidakov, and M. Vdovin
Institute of Applied Physics, Nonlinear Oscillations and waves, Nizhny Novgorod, Russian Federation
(yuliya@hydro.appl.sci-nnov.ru)

The most important characteristics that determine the interaction between atmosphere and ocean are fluxes of momentum, heat and moisture. For their parameterization the dimensionless exchange coefficients (the surface drag coefficient CD and the heat transfer coefficient or the Stanton number CT) are used. Numerous field and laboratory experiments show that CD increases with increasing wind speed. This is due to the fact that the transfer of the momentum wave disturbances, or form drag, increases with increasing wind speed, which is accompanied by broadening the wind wave spectrum. The dependence of heat transfer coefficient CT on the wind speed is not well studieds and the role of the mechanism associated with the wave disturbances in the mass transfer is poorly understood. Observations and laboratory data show that this dependence is weaker than for the CD, and there are differences in the character of the dependence in different data sets. For example, the algorithm COARE 3.0 (see [1] indicates a slight increase in CT with increasing wind speed U10, a similar dependence was obtained in [2] and the laboratory experiment, [3], and in [4] a dependence of CT on the wind speed was not found. The weak dependence of the CT on U10 is confirmed by theoretical models [5], but the details of the dependence (growing or dropping) were sensitive to the choice of model.
The purpose of this paper is investigation of the effect of waves on the surface of the water on the exchange of momentum and mass to drive the boundary layer of air and from this point of view it largely follows [5]. The main difference is related to the used model of the marine atmospheric boundary layer, in which the perturbations induced by the waves on the water surface in the atmosphere are calculated. It is a generalization of the model developed for a homogeneous atmosphere in [6] to the case of a stratified marine atmospheric boundary layer. The model was recently verified by comparing with experimental results [7] and direct numerical modeling [8]. Two first-order closing models of turbulence are discussed. In the first model, wave-dependent eddy viscosity and heat conductivity are postulated by decreasing turbulent momentum flux near the wavy water surface due to wave momentum transfer. In the second model, the turbulent transfer coefficients are parameterized only by the constant wind friction velocity.
Special experiments were carried out in the wind-wave flume to investigate velocity and temperature distribution in the stratified air boundary layer above the water surface disturbed by paddle generated waves. Experiments showed that in accordance with the second closing model the air flow velocity decreases with the growth of the surface wave amplitude and the temperature profile was wave-independent within experimental errors.
Surface wave spectrum is an important element of the model. We investigated sensitivity of the model to spectral models, including spectra suggested by [9-12], which describe waves in wide range of wavelengths from energy-containing scales to centimeters and millimeters. Comparing of the theoretical calculations with the experimental algorithm TOGA-COARE [1] shows, that the best agreement takes place, when the Hwang spectrum [12] corrected at high wind conditions is used.

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