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Modeling of the convective patterns in the thermal boundary layer of the sea

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The paper is concerned with the problem of roll convection in a near-surface thermal boundary layer arising in the presence of the wind. Such convection that may be caused by water evaporation and the temperature jump between the atmosphere and the sea surface is widely encountered in the real sea and is also observed in experiments.

Development of the convective structures in à thin layer of liquid blown up by an air current in a wind tunnel was investigated theoretically and experimentally. The experiments were made with a well-evaporating liquid (alcohol), which allowed us to better visualize the convective structures. The evolution of the structures with increasing velocity of the air current was studied. The transition from the convective cells (arising in the absence of air current) to the convective rolls elongated in the wind direction was revealed. The velocity of the surface drift flow induced by tangential wind stresses and the surface temperature were measured.

The theoretical analysis is constructed within the framework of a two-dimensional model with a shear flow in a liquid layer. The onset and development of convective rolls are simulated numerically. It is found that at large Rayleigh numbers a quasi-stationary system of rolls occurs, which is characterized by slow modulation in space and time. Time dependence of mean roll scale and its dispersion is obtained. The temporal behavior of the individual vortex scale is investigated.

It is revealed that the system demonstrates the property of multistability, i.e., the scale of the selected rolls is sensitive to the choice of initial conditions. However, this occurs only when the initial disturbances of a certain scale are large enough. If the initial fluctuations are small and random, the result of the selection is determined by the dynamics of the system and does not depend on the initial conditions. In this case, the characteristic size of the rolls calculated for Ra=60140, Pr=16.6 coincides well with results of the experiments with alcohol. The preferable wave number decreases with the growth of the Rayleigh number that also agrees well with the experimental data. Thus, for the system considered a correct description of convective roll selection is obtained within the framework of the two-dimensional model.

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